

t.

TRAUNER VERLAG

UNIVERSITÄT



Charles Bridge Prague (J. Chroust, 2018)

Schriftenreihe
Informatik

51

CHROUST GERHARD ■ DOUCEK PETR ■
OŠKRDAL VÁCLAV (EDITORS)

IDIMT-2022

Digitalization of Society, Business and Management in a Pandemic

30th Interdisciplinary Information
Management Talks
Sept. 7–9, 2022
Prague, Czech Republic



Impressum

Schriftenreihe Informatik

Chroust Gerhard ■ Doucek Petr ■
Oškrdal Václav (Editors)

IDIMT-2022

Digitalization of Society, Business and Management in a Pandemic

30th Interdisciplinary Information Management Talks

This publication was partially supported by the Česká
spořitelna, a.s. and the Prague University of Economics and
Business – project IGA 409021

The Conference IDIMT-2022
took place September 7–9, 2022
in Prague, Czech Republic

Programme Committee

Altmann Mattis, DE
Aumayr Georg, AT
Buchalcegová Alena, CZ
Chroust Gerhard, AT
Delina Radoslav, SK
Doležel Michal, CZ
Doucek Petr, CZ
Fischer Jakub, CZ
Helfert Markus, IR
Maryška Miloš, CZ
Neubauer Georg, AT
Novotný Ota, CZ
Oškrdal Václav, CZ
Pavlíček Antonín, CZ
Pitner Tomáš, CZ
Prinzellner Yvonne, AT
Pucihar Andreja, SI
Purcarea Anca Alexandra, RO
Rainer Karin, AT
Scheuer Sabrina, AT
Sonntag Michael, AT
Schoitsch Erwin, AT
Tkáč Michal, SK
Wagner Jaroslav, CZ
Yablotschnikov Sergej, RU
Zimmermann Hans-Dieter, CH



© 2022
The Author(s) 2022

Herausgeber:
Em.o.Univ.-Prof.
Dr. Gerhard Chroust
Johannes Kepler Universität Linz
Österreich/Austria
Tel. +43 664 28 29 978

Kommisionsverlag:
TRAUNER Verlag + Buchservice
GmbH
Köglstraße 14, 4020 Linz
Österreich/Austria

Herstellung: Kern:
Johannes-Kepler-Universität Linz,
4040 Linz, Österreich/Austria

Herstellung: Umschlag:
Kontext Druckerei GmbH,
4020 Linz, Österreich/Austria

DOI:10.35011/IDIMT-2022

ISBN 978-3-99113-758-0
www.trauner.at

Table of Contents

INVITED CONTRIBUTION

CORNERSTONE TECHNOLOGY: EXPOSURE, RISK AND FUTURE	19
Christian W. Loesch	

MANAGEMENT AND DIGITALIZATION

MANAGEMENT AND DIGITALIZATION	35
Petr Doucek, Jiří Hološka, Lea Nedomová	

MEASUREMENT OF DIGITAL MATURITY OF ENTERPRISES	43
Andreja Pucihar, Mirjana Kljajić Borštnar	

EVALUATION OF BUSINESS MATURITY CONCERNING ROBOTIC PROCESS AUTOMATION	51
Klára Antlová, Petra Rydvalová, Martin Zelenka	

A NOVEL APPROACH TO BUSINESS PROCESS ANALYSIS AND OPTIMIZATION BASED ON ENTERPRISE ARCHITECTURE: A CASE OF LOCAL PUBLIC ADMINISTRATION IN THE CZECH REPUBLIC	59
Martin Lukáš, Tereza Čížková, Miloš Ulman	

ANALYSIS OF SUITABLE FRAMEWORKS FOR ARTIFICIAL INTELLIGENCE ADOPTION IN THE PUBLIC SECTOR	67
Václav Pechtor, Josef Basl	

INNOVATIONS AND STRATEGIES IN A PANDEMIC ERA

PANDEMIC AS AN INNOVATION BOOSTER	77
Tomáš Pitner, Jan Ministr	

THE PREPARATION OF YOUNG PEOPLE FOR MANAGEMENT PROFESSIONS	85
Věra Radváková	

THE “SEE DANTE MODEL” FOR RESOURCE MANAGEMENT IN EDUCATIONAL AREA	93
Petr Rozehnal, Karel Hlaváček, Aleš Lokaj, João Samartinho	
AUDITING REMOTE WORKPLACE SECURITY	101
Ladislav Vaněk	
DECISION SUPPORT FOR THE CHOICE OF A METHODOLOGICAL FRAMEWORK FOR IT SERVICES	109
Blanka Bazsová, Jan Ministr	
HOW MANY CONFERENCE SUBMISSIONS SHOULD WE EXPECT IN TOTAL? AN EMPIRICAL MODEL PREDICTING THE TOTAL NUMBER OF SUBMISSIONS	117
Lubomír Štěpánek, Filip Habarta, Ivana Malá, Luboš Marek	
COMPLEX DIGITAL APPROACHES FOR CRISIS MANAGEMENT – BLACKOUT IN PANDEMIC TIMES	
REQUIREMENT FOCUSED INTERVENTION-MATCHING FOR PANDEMIC MANAGEMENT: NATIONAL PERSPECTIVES FOR INVOLVEMENT OF EVIDENCE BASED LESSONS LEARNED.....	127
Karin Rainer, Alois Leidwein, Markus Hoffmann, Nicole Kramreither, Georg Neubauer, Bernhard Bürger, Dražen Ignjatović, Georg Aumayr, Ruth Kutalek, Janika Saretzky	
PERSPECTIVES ON THE FUTURE CROSS-BORDER PANDEMIC MANAGEMENT	137
Georg Neubauer, Dražen Ignjatović, Gerald Schimak, Johannes Peham, Bernhard Bürger, Adam Widera, Michael Middelhoff, Florian Gehre, Muna Affara, Helena Blažun Vošner, Jernej Završnik, Aleksander Jus, Karin Rainer, Alois Leidwein, Peter Kokol	
TOWARDS DIGITALIZING RECONNAISSANCE PROCESSES WITH STAKEHOLDER REQUIREMENT ANALYSIS AND PERFORMANCE INDICATORS.....	145
Refiz Duro, Rainer Simon, Dražen Ignjatović, Jasmin Lampert, Christoph Singewald	

COMBINING SOCIAL MEDIA AND OPEN SOURCE DATA WITH RELEVANCE ANALYSIS AND EXPERT KNOWLEDGE TO IMPROVE SITUATIONAL AWARENESS IN CRISIS AND DISASTER MANAGEMENT – CONCEPT 153

Dražen Ignjatović, Daria Liakhovets, Rainer Simon, Georg Neubauer, Anita Graser, Mina Schütz, Siegfried Vössner, Wolfgang Vorraber, Clemens Gutschi, Bernd Resch

DISINFECTION WITH VAPORIZED HYDROGEN PEROXIDE FLUID IN DIFFERENT ENVIRONMENTS AND ITS APPLICATIONS AND ADVANTAGES IN CRISIS MANAGEMENT 161

Krista Rathammer, Lisa Winkelmayer, Alois Leidwein, Sarah Lindinger, Theres Requat, Hermann Schildorfer, Nikolaus Schmoll, Georg G. Duscher, Friedrich Bauer, Karl M. Hellemann, Philippe Jäger, Davul Ljuhar, Michael D. Mansfeld

SOCIAL MEDIA AUTHENTICITY AND TRANSPARENCY

CZECH MEDIA ACTIVITY ON FACEBOOK 173

Antonín Pavlíček

FAKE NEWS SUSCEPTIBILITY OF THE YOUNG GENERATION 185

Tomáš Sigmund, Jiří Korčák

SENTIMENT ANALYSIS ON SOCIAL NETWORKS IN CZECH AND SLOVAK (SYSTEMIC REVIEW)..... 193

Jana Syrovátková

TV CONTENT AUDIENCE PROFILE PREDICTION OPTIONS 201

Marie Kovářová, Miloš Maryška

SMART SUPPLY CHAIN

DEPENDENCY OF PUBLIC PROCURER ON SUPPLIER: DATA VIEW 211

Radoslav Delina, Gabriel Demeter, Anton Cornak

ANALYSIS OF PUBLIC PROCUREMENT SAVINGS IN V4 219

Michal Tkáč, Michal Tkáč

COMPARISON OF ELECTRONIC INVOICING ADOPTION BEFORE AND AFTER COVID-19 PANDEMICS IN EUROPEAN UNION	227
---	-----

Michal Tkáč, Jakub Sieber

SELECTED VIEWS ON EATING HABITS AND LIFESTYLE CHANGES OF CONSUMERS DURING THE COVID-19 PANDEMIC THROUGH THE OPTICS OF SUPPLY CHAINS	235
---	-----

František Pollák, Peter Markovič, Róbert Világi

IDENTIFYING THE CHALLENGES IN E-PROCUREMENT STANDARDIZATION	243
---	-----

Dana Pařová, Martin Vejačka

ONLINE REPUTATION OF BUSINESS ENTITIES FROM THE FIELD OF SUPPLY CHAIN: AN EMPIRICAL STUDY ON THE CZECH MARKET	251
---	-----

Michal Konečný, Yaroslava Kostiuik, Michal Ruschak

CYBER SECURITY IN A DIGITAL WORLD

LEGAL PITFALLS OF SW REPLACEMENT AND THEIR SECURITY IMPLICATIONS	259
--	-----

Michael Sonntag

EMPIRICAL EVALUATION OF PASSWORDS: INFLUENCE OF THE MODIFIED VERSION OF ZXCVCBN	269
---	-----

Jiři Sedláček

MULTI-LEVEL CYBERSECURITY GOVERNANCE FRAMEWORKS FOR PUBLIC ADMINISTRATION	277
---	-----

Františka Romanovská, Tomáš Pitner

LITERATURE REVIEW OF AUDIT OF DATABASE SECURITY	285
---	-----

Felix Espinoza, Miloš Maryška

SUSTAINABILITY AND PERFORMANCE MANAGEMENT AND BUSINESS REPORTING

A BIBLIOMETRIC ANALYSIS OF SUSTAINABILITY REPORTING IN HIGHER EDUCATION	295
---	-----

Petr Petera

THE MATURITY LEVEL ASSESSMENT OF INTERNAL CONTROL ASSURANCE.....	305
--	-----

Vlasta Svata

COMPETENCY MANAGER AS A VERY USEFUL COMPETENCY MANAGEMENT TOOL	313
--	-----

Jana Holá, Markéta Moravcová, Lukáš Čegan, Eva Hlaváčková

CARBON REPORTING: EVIDENCE FROM THE CZECH FINANCIAL SECTOR	323
--	-----

Ladislava Volková

CIRCULAR ECONOMY IN RELATION TO FINANCIAL DATA	331
--	-----

Miroslava Vlčková

ENVIRONMENTAL REPORTING OF MINING COMPANIES AS PART OF ENVIRONMENTAL POLICY.....	339
--	-----

Ladislava Míková, Petra Rydvalová

ANALYSIS OF THE RELATIONSHIP BETWEEN FINANCIAL INDICATORS AS A TOOL FOR OPTIMIZING FINANCIAL HEALTH OF BUSINESSES	345
---	-----

Jarmila Horváthová, Martina Mokrišová, Igor Petruška

SMART TECHNOLOGIES FOR A SUSTAINABLE GREEN WORLD

SMART TECHNOLOGY AND CIRCULAR ECONOMY FOR A GREENER WORLD AND RESILIENT SOCIETY.....	357
--	-----

Erwin Schoitsch

USAGE OF UNMANNED AERIAL VEHICLES FOR DETECTION OF PLANT ANOMALIES	367
--	-----

Ivana Čermáková, Roman Danel

BROWNFIELDS OPPORTUNITIES FOR SMART REGIONS	375
Ivana Čermáková, Roman Danel, Tereza Vašenková	
AUTONOMOUS VEHICLES AS A MANAGEMENT CHALLENGE - MEETING CONFLICTING INTERESTS	381
Richard Antonín Novák, Tomáš Sigmund, Lucie Böhmová	
A PROPOSED X.800-BASED SECURITY ARCHITECTURE FRAMEWORK FOR UNMANNED AIRCRAFT SYSTEM.....	389
Abdelkader Magdy Shaaban, Oliver Jung, Christoph Schmittner	
CHALLENGES AND TRENDS IN SOFTWARE DEVELOPMENT	
MIGRATION FROM MONOLITHIC TO MICROSERVICE ARCHITECTURE: RESEARCH OF IMPACTS ON AGILITY	401
Josef Doležal, Alena Buchalceková	
DOES AGILE MANAGEMENT CONTRIBUTE TO THE OVERALL SATISFACTION OF THE PROJECT?	413
František Hašek, Hana Mohelská	
A SINGLE CASE STUDY ON PRODUCT OWNER ACTIVITIES IN SAFE: PRELIMINARY RESULTS FROM FOCUS GROUP GATHERINGS	419
Daniel Remta, Matthew McLaughlin	
STRESS MITIGATION IN AGILE SOFTWARE DEVELOPMENT	429
Sergei Shcherbinin, Alena Buchalceková	
MOTIVATIONAL DIFFERENCES AMONG SOFTWARE PROFESSIONALS	437
Marcel Valový	

VIRTUAL COLLABORATION & EXCHANGE - CHALLENGES AND EMERGING APPROACHES

OPTIMIZING FORMATIVE FEEDBACK GUIDELINES IN COLLABORATIVE ONLINE INTERNATIONAL LEARNING.....	447
--	-----

Mattis Altmann

ATTITUDES AND PERCEPTIONS OF EMPLOYEES AND EMPLOYERS TOWARD REMOTE WORKING.....	459
---	-----

Galina Ostapenko, Martin Šikýř, Vincent Montenero

DYNAMIC EMERGENCE OF FEATURES IN COMPLEX SYSTEMS	467
--	-----

Gerhard Chroust

ANNEX

Statement of the Publication Ethics and Publication Malpractice	477
---	-----

List of Authors	479
-----------------------	-----



Praha, Charles Bridge (J. Chroust, 2018)

A Hearty Welcome to the 30th IDIMT Conference!

The world-wide challenges due to the COVID-19 virus have demonstrated the importance of interdisciplinary approaches and the need for management of information - two topics which have characterized the IDIMT conferences since their beginning in 1993. In this contribution we will provide a short view on the impressive history of the IDIMT conferences.

1. Looking back at 30 years of IDIMT Conferences

The IDIMT conferences were founded in 1993, soon after the fall of the Iron Curtain. This was one of the early scientific contacts which took place between Austria and the Czech Republic. A changed political situation, the a new professor of Informatics at the Kepler University Linz (Gerhard Chroust) and a young promising and ambitious student at the University of Economics Prague (Petr Doucek) were the ingredients for a successful start for this series of conferences.

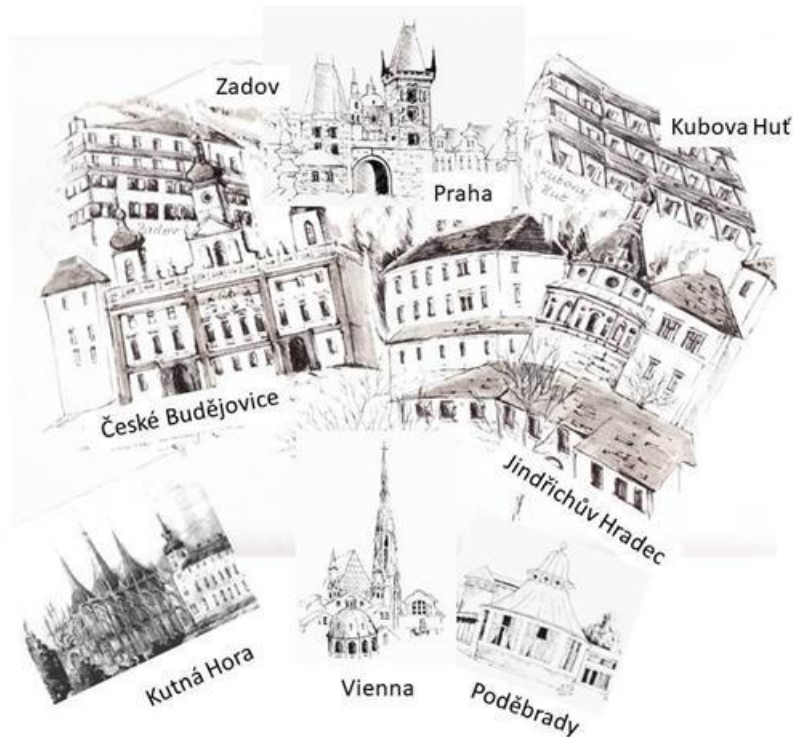
The IDIMT conferences have accompanied the world of Information Management, Software Technology and Systems Sciences throughout these 30 years. They have observed and commented the dramatic changes and advances which took place in these field and their applications. And IDIMT grew from a small 14 person meeting to a 50+ paper conference.

IDIMT has proved to be a mirror of interests and trends in Information Management related business and research in Central Europe. Numerous persons have 'walked with us in a part of this journey' and have contributed to our success. Factors which contributed were

- a loyal group of participants, who come year after year to present their findings and exchange information,
- the provision of ample discussion time after every session, taking into account all papers of the whole session and not just a single paper,
- a friendly informal atmosphere and a group of participants well known to one another.

This paper is a modest attempt to sketch the history of the IDIMT conferences. The impressive history of the IDIMT conferences has already been documented as a hard cover book plus its e-

book version (G. Chroust, P. Doucek, L. Nedomová: 25 Years of IDIMT: A History of Continuity and Change, Books on Demand, Norderstedt, Germany, 2017, ISBN 978-3-99062-119-6).



The eight locations of IDIMT Conferences - 1993-2022 (Janie Chroust)

Kubova Hut', 1993 - 1994 In the first two years the IDIMT conferences were held in Kubova Hut', a small South Bohemian village in Šumava Mountains (Böhmerwald) in hotel Arnika. Kubova Hut' is a delightful little village near Boubin's wild forest, but with very poor accessibility. In 1993 we started with a mere 13 papers, 14 participants and 150 pages of proceedings. But at the end of this meeting we decided to repeat this conference annually.

Zadov, 1995 - 2001 In 1995 we were forced to find a new location for the conference. We moved nearer to "civilization", to Hotel Olympia in Zadov - a famous tourist and skiing center in the Šumava Mountains. We stayed there for eight years. The combination of professional service of the hotel staff, especially concerning catering and other supplementary needs, beautiful scenery inspired the participants and influenced the spirit of the conference. During this time the session topics as well as the layout of the conference underwent considerable changes.

Praha and Zadov, 2002 In 2002, on the tenth anniversary of IDIMT, we made an interesting experiment. The conference was split into two parts. The first part (the 'PhD-Day') was held in Prague and was specifically organized for PhD students. It included sight-seeing with an impressive visit to Charles University - the oldest University in the Middle Europe. The second part, the IDIMT proper, was held in Zadov.

České Budějovice, 2003 - 2007 In 2003 an organizational problem in Hotel Zadov forced us to move the conference to České Budějovice, a historic city in South Bohemia (not to forget the famous beer!). Both the accommodation, the conference room and the ambience improved considerably.

Jindřichův Hradec, 2008 - 2012 The conference and accommodation facilities in České Budějovice limited the number of participant to 40 and thus blocked IDIMT's further development.

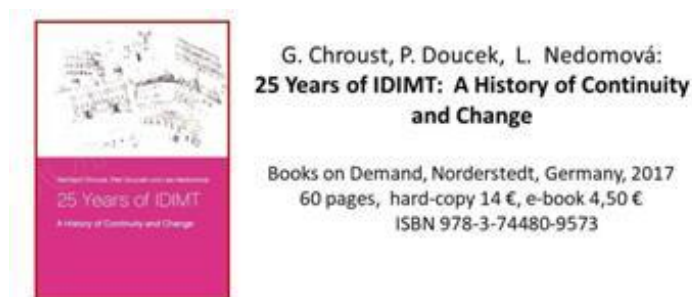
In 2008 we moved to a more impressive and spacious location: Jindřichův Hradec, a very important city in 1200 to 1700. It offers a historic district, a beautiful market square, and an impressive castle. 2008 we stayed in the Grand Hotel, and from 2009 onward in the larger Hotel Concertino, just across the market square.

Praha, 2013 In 2013 we cooperated with the CONFENIS-conference in a joint and parallel conference at the University of Economics in Praha. We achieved some synergetic effects by listening to several lectures of the parallel conference. We had also time to enjoy magnificent Praha, including a boat trip on the Vltava.

Poděbrady, 2014 - 2017 In the following year we moved to a smaller, quieter place, to Poděbrady, founded in the 13th century and having had a considerable political importance in the 14th to 16th century. It is now an important Czech spa town with stable weather and harmonious environment on the banks of the Labe (Elbe), but it still shows much of the atmosphere of the 1930's.

Kutná Hora, 2018 - 2021 Another change of location brought us to the historic jewel Kutná Hora, a strongly fortified city surrounding the marvelous Barbora Church. In the 14th century it was one of the two most influential town in Czechoslovakia due to the rich veins of silver ore beneath it. The conference facilities were even nicer than in previous locations. 2020 and 2021 the COVOD pandemic forced us to run a partially virtual conference with a satellite meeting room in Vienna at the AIT Research Institute. Many participants joined from their home-office.

Praha, 2022 This year brings us back to Praha, with the hope that we will celebrate our 30th anniversary with style. A definite improvement to the availability of the conference papers is that their distribution will be subjected to the Creative Common regulations ("BY-NC-ND"). Additionally all papers will receive a DOI-identifier for easy access.



A short history of IDIMT Conferences

2. IDIMT 2022

This year we received 49 submitted papers plus 11 keynote papers and one invited papers with a total of 135 co-authors. The submissions have been reviewed in a two-step double blind review process. The authors have received extensive comments and were required to improve their papers in order to re-submit them. The authors have come from 7 different countries: Austria, Czech Republic, Germany, Indonesia, Russia, Slovakia, and Slovenia. As usual the program will offer two parallel streams

For 2022 we have chosen the following topics:

- Management and Digitalization. (Petr Doucek)
- Innovations and Strategies in a Pandemic Era. (Tomáš Pitner)

- Complex digital approaches for Crisis Management - Blackout in pandemic times. (Georg Neubauer, Karin Rainer)
- Social media authenticity and transparency. (Antonín Pavlíček)
- Smart Supply Chains. (Radoslav Delina)
- Cyber Security in a Digital World. (Michael Sonntag)
- Sustainability in performance management and business reporting. (Jaroslav Wagner)
- Smart Technologies for a Sustainable Green World. (Erwin Schoitsch)
- Challenges and Trends in Software Development. (Alena Buchalceková)
- Virtual Collaboration and Exchange - challenges and emerging approaches. (Mattis Altmann)
- Invited Lecture: Cornerstone Technology: Exposure, Risk and Future. (Christian W. Loesch)

3. Acknowledgement

IDIMT 2022 would not have been possible without the support of many organizations and persons. We would like to express our thanks to:

- the Prague University of Economics and Business for the project IGA 409021,
- the Faculty of Informatics and Statistics of the Prague University of Economics and Business,
- the Johannes Kepler University Linz, Institute of Tele cooperation

Our further thanks go to:

- Petr Doucek for chairing the Organizing Committee, and for arranging the conference locations,
- Gerhard Chroust for chairing the Programme Committee,
- Antonin Pavlíček and Lea Nedomová, for organizing the program, the reviews, keeping contact with all involved speakers, and reminding forgetful authors and session chairs,
- Václav Oškrdal for arranging and assembling the accepted papers for the proceedings,
- Lea Nedomová, for her support in performing the necessary administrative tasks,
- all keynote speakers, speakers and contributors of papers,
- all members of the Programme Committee and the Session Chairpersons for soliciting contributors and creating an interesting and compact program,
- all reviewers providing critical remarks for improving the papers,
- the Johannes Kepler University Linz for providing the registry for the DOI-number of the papers,
- the Trauner Verlag as the publisher of our conference.

We want also to thank all the other unnamed persons contributing to the success of this conference.
We hope that their efforts will contribute to a good conference!

Looking forward to a successful and interesting conference!

Gerhard Chroust

Programme Chair

Johannes Kepler University Linz

gerhard.chroust@jku.at

Petr Doucek

General Chair

Prague University of Economics and Business

doucek@vse.cz

IDIMT Conferences 1993 – 2022

Year	Conference chair and editor	Location
1993 - 1994	G. Chroust, P. Doucek	Kubova Hut'
1995 - 1996	G. Chroust, P. Doucek	Zadov
1997	S. Hofer, P. Doucek	Zadov
1998 - 2000	S. Hofer, M. Beneder	Zadov
2001	C. Hofer, G. Chroust	Zadov
2002	C. Hofer, G. Chroust	Praha / Zadov
2003 - 2004	C. Hofer, G. Chroust	České Budějovice
2005 - 2006	Ch. Hoyer, G. Chroust	České Budějovice
2007	Ch. Hoyer, G. Chroust, P. Doucek	České Budějovice
2008	G. Chroust, P. Doucek, J. Klas	Jindřichův Hradec
2009 - 2012	P. Doucek, G. Chroust, V. Oškrdal	Jindřichův Hradec
2013	P. Doucek, G. Chroust, V. Oškrdal	Praha
2014 - 2017	P. Doucek, G. Chroust, V. Oškrdal	Poděbrady
2018 - 2021	P. Doucek, G. Chroust, V. Oškrdal	Kutná Hora
2022	G. Chroust, P. Doucek, V. Oškrdal	Praha

IDIMT Proceeding 1993 – 2022

Year	Authors	Papers	Pages	Date of conference
1993	14	13	151	6.- 8. Oct.
1994	27	23	233	9.-11. Nov.
1995	33	25	228	8.-10. Oct.
1996	30	21	215	16.-18. Oct.
1997	35	30	320	15.-17. Oct.
1998	39	27	390	21.-23. Oct.
1999	46	34	424	02.-03. Sept.
2000	48	32	440	20.-22. Sept.
2001	45	29	397	19.-21. Sept.
2002	38	24	350	11.-13. Sept.
2003	38	24	310	10.-12. Sept.
2004	31	23	304	15.-17. Sept.
2005	30	22	313	14.-16. Sept.
2006	45	29	364	13.-15. Sept.
2007	38	27	383	12.-14. Sept.
2008	53	33	455	10.-12. Sept.
2009	61	42	423	9.-11. Sept.
2010	62	42	397	8.-10. Sept.
2011	64	42	393	7.-9. Sept.
2012	57	37	400	12.-14. Sept.
2013	83	45	403	11.-13. Sept.
2014	84	40	413	10.-12. Sept.
2015	113	58	519	9.-11. Sept.
2016	94	41	463	7.-9. Sept.
2017	93	45	430	6.-8. Sept.
2018	115	57	509	5.-7. Sept.
2019	112	47	446	4.-6. Sept.
2020	116	54	497	2.-4. Sept.
2021	132	55	496	1.-3. Sept.
2022	128	51	479	7.-9. Sept.
	1904	1.072	11.026	

Sponsors of IDIMT 2022



General partner / Generální partner VŠE v Praze



INVITED CONTRIBUTION

CORNERSTONE TECHNOLOGY: EXPOSURE, RISK AND FUTURE

Christian W. Loesch

IBM ret.

CWL001@gmx.net

DOI: 10-35011/IDIMT-2022-19

Keywords

ICT Economy, successes and exposures, ICT future technologies, cornerstones of growth

Abstract

The recent events have impressively shown the interdependency of economy and ICT technology as cornerstone of our economy and our life. Thus a meaningful picture has to encompass both.

We will review the present situation of the ICT industry addressing both the extraordinary successes as well as the exposures and risks and lessons learned, the chip shortage, and the evolving challenges and in processing, the tsunami of data or other areas upcoming improvements of the present technology, new 2D materials, optical and other options. Special focus on areas as ICT Medicine, Automotive industry as well as by ML, promising research results at the technological horizon will complete the overview of a future scenario.

1. Introduction

The 30th anniversary of IDIMT in Prague is a special date at a special location and a special occasion. In the scenario for at the beginning of the '90s: no handy, no real laptop, no tablet, no WWW, no social networks, the “fastest telecom line was the line Vienna - Linz - CERN with 64k/sec, a special event for ICT in CS took place here in Prague.

The foundation of the first Supercomputer Center in Central and Eastern Europe, with computers previously embargoed, an online connection to the international networks and special education programs (of previously banned subjects), realized by a pioneering cooperation of four CS Universities, Prof. Ivan Havel and the Gen. Mgr. of the IBM Academic Initiative Chr. Loesch.

Our proposed agenda will attempt to present:

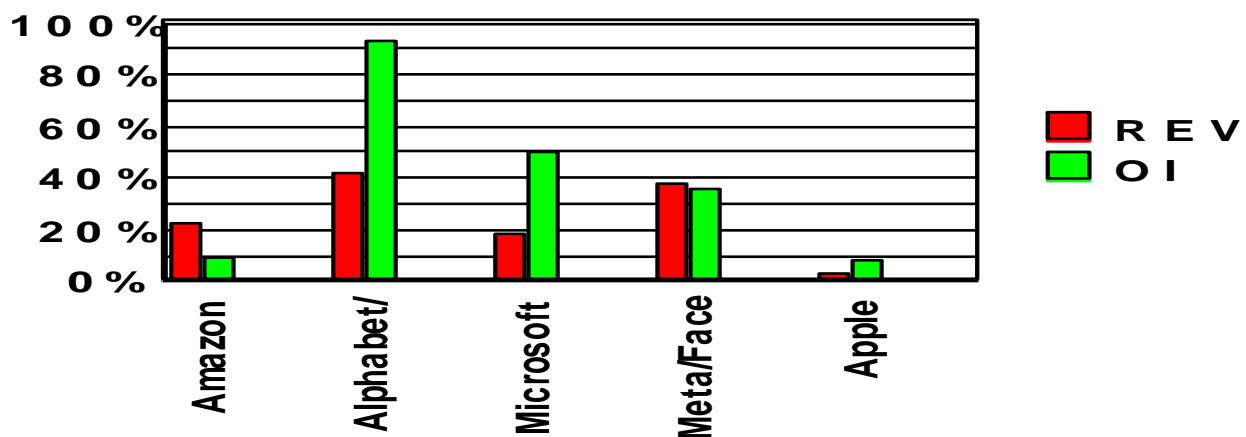
- Economic status and development of ICT
- Challenges and impact (chip shortage and more)
- Special features: Medicine and ICT in the automotive industry
- Extending technology (more Moore and to the 3rd dimension)
- Memory
- Data Tsunami and Storage
- Optical computing

- New 2D materials
- Biotechnology
- QC
- AI and ML concerns arising

2. Economy

The state of the ICT industry can be summarized by looking at the performance of the BIG FIVE - FAAAM (now due to Meta) MAAAM exemplified by growth of revenue and Operating Income.

How did the BIG FIVE fare in 2021



in figures:

	REVENUE	OI
AMAZON	21,50%	8,73%
ALPHABET	41,22%	90,93%
MICROSOFT	17,48%	49,66%
META/FACEBOOK	37,21%	35,52%
APPLE	35,00%	64,87%

The last years are a success story for the ICT industry. The Covid pandemic and the integration pervasion of all spheres of our live by ICT have accelerated in the past years. Semiconductor markets boomed with sales growing by more than 20 % to about \$600 billion in 2021. This is going to continue but in a more moderate scale resulting in an industry's aggregate annual growth to still reach 6-10% p.a. (some segments up to 15 %), a growth envied by many industries, resulting in a \$1 Trillion dollar industry by the end of the decade.

Top 15 Semiconductor Sales Leaders 3Q21 Forecast, \$M

3Q21F Rank	2Q21 Rank	Company	Headquarters	2Q21 Total Semi Actual	3Q21 Total Semi Forecast	3Q21/2Q21 % Change
1	1	Samsung	South Korea	20,297	22,320	10%
2	2	Intel	U.S.	19,304	18,785	-3%
3	3	TSMC	Taiwan	13,315	14,750	11%
4	4	SK Hynix	South Korea	9,213	10,135	10%
5	5	Micron	U.S.	7,681	8,465	10%
6	6	Qualcomm	U.S.	6,472	7,250	12%
7	7	Nvidia	U.S.	5,540	5,965	8%
8	8	Broadcom Inc.	U.S.	4,890	5,220	7%
9	9	MediaTek	Taiwan	4,496	4,600	2%
10	10	TI	U.S.	4,299	4,300	0%
11	11	AMD	U.S.	3,850	4,100	6%
12	13	Apple*	U.S.	3,100	3,500	13%
13	12	Infineon	Europe	3,280	3,495	7%
14	14	ST	Europe	2,983	3,200	7%
15	15	Kioxia	Japan	2,800	3,110	11%
Top-15 Total				111,520	119,195	7%

IC Source: Insights Strategic Reviews database

The table shows the effect of outsourcing and the moderate relevance of European companies.

Where will future growth come from? About 70 % of growth is expected from few industries:

- Automotive,
- Meditech/Healthcare,
- ICT (Computation, Data storage, and Communication).

Digitization will drive similar dynamics in retail, banking, travel and other fields with intense change and disruption.

2.1. Exposure and Risk

The global semiconductor shortage and, the case of Automotive Industry

Not all news were good news. But are chances as well.

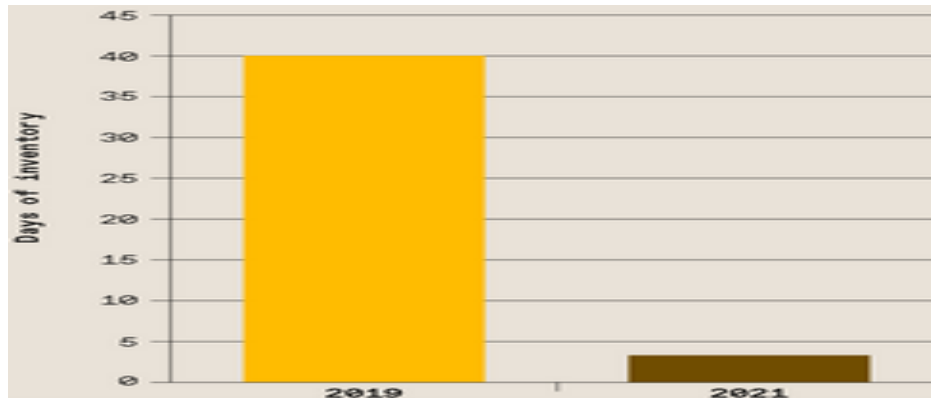
The global semiconductor shortage is affecting us not only by delivery problems and price increases economically and personally, it highlights the critical dependency on ICT in everything from computing, to appliances, to communication, transportation systems, critical infrastructure and thus the smooth functioning of the global economy.

The problem was looming long before the pandemic in manifold facets, and was foreseeable!

Semiconductor fabrication facilities typically run at about 80 % of their capacity, allowing thus maintenance, upgrades a.s.o. In summer of 2019, the utilization level was up to ~ 90 %, reflecting a growing demand reaching from home appliances to car production and pushed fabrication facility utilization rates above 90% with many of the semiconductor foundries operating at 100% load, making them extremely sensitive and vulnerable to disturbances.

The inventory backlog loss

Just as demand for semiconductors began outstripping supply, the median inventory of semiconductor products fell from 40 days in 2019 to less than 5 days in 2021, leaving companies vulnerable to the slightest setback.



US Congress Public statements by companies

Hoarding made it worse. Remember pictures of empty shelves for toilet paper, while there was actually plenty of toilet paper. The same happened with chips. Additionally contributing was the double-ordering by customers to bulk up on inventory, so never again a 12 -cent part will hold up a 4K television or car production.

Automotive industry and IC

The strongest-growing segment is likely to be the automotive industry. By the end of the decade, we expect semiconductor content in premium vehicles to increase by 500%.

There are few better opportunities to watch how technology is changing our economy than the automotive industry. The auto industry makes presently only less than 9 % of ICT industries revenue, but is expected to grow by exceptional ~10 % p.a. for the coming years. Employing more than 10 million people and more than one billions users gives it an importance the public and politicians are sensitive to. Automotive industry could attain as much as 20 % of industry expansion, compared to growth of 4 - 6 % in the computation and data-storage market.

The problems were not caused by the semiconductor industry but by the automotive industry itself. The semiconductor industry increased shipments to the automotive industry by 30% in 2021.

At the beginning of the COVID-19 pandemic, the auto industry cut back on production. With panic lockdowns, and general uncertainty, automakers cancelled orders. Simultaneously the Covid pandemic triggered a big shift of the workforce to the home office, purchasing computers, and other equipment, and the school systems switched to virtual learning with laptops and tablets. More time at home additionally resulted in more spending on home entertainment, TVs and game consoles.

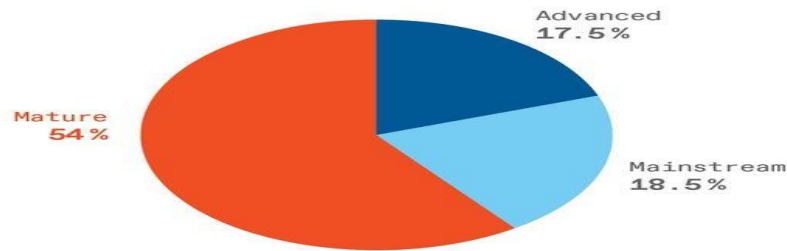
Additionally the 5G rollout, and growth in cloud computing quickly hoovered up the capacity automakers had freed. By the time car makers realized the situation they found themselves at the back of the waiting line for the chips needed.

2.2. Resilience and Relieve

The Legacy Node situation

As shown below a special exposure comes from Legacy Nodes i.e. non-cutting-edge hardware technology i.e. mature, older, less sophisticated chips, nevertheless critical for e.g. medical devices, broadband, and cars. These chips are not as profitable and prestigious, so companies are cautious investing in them. The common denominator is the 40 nm process technology, a technology being cutting edge more than 15 years ago but still dominating with 54 % of the installed capacity and is still on the 200-mm wafers of silicon.

CHIP PROCESS TECHNOLOGY



Source: IDC

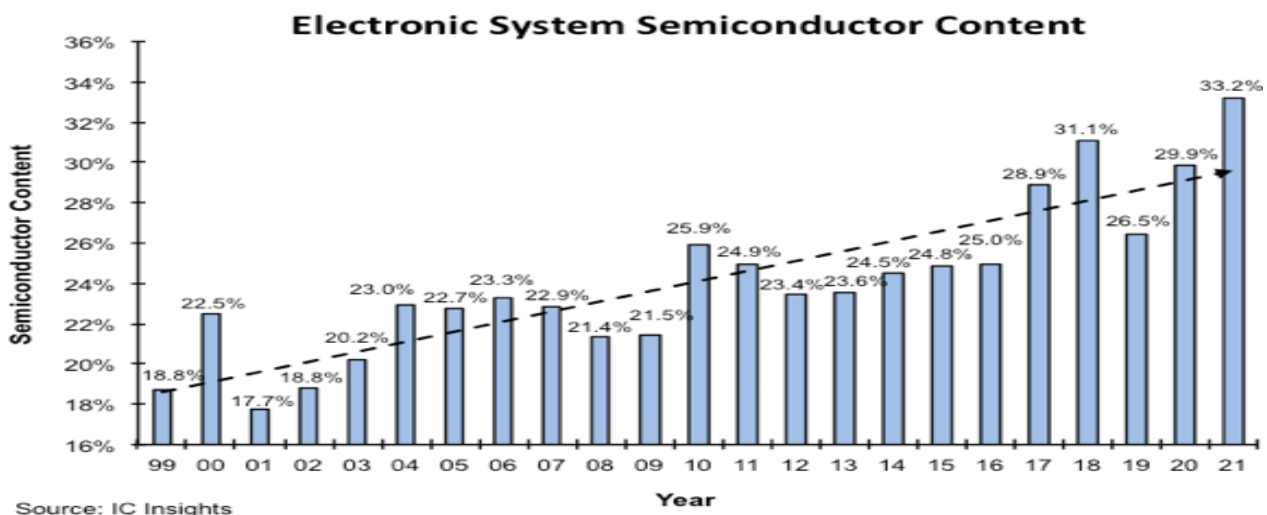
Despite the auto industry's desperation, there's no great rush to build new 200-mm fabs. The return on investment is comparable low and there are many legacy-node plants in China not operating efficiently right now, further reducing the incentive to build new fabs. Therefore the number of 200mm fabs is rising from 2020 to 2022 by only half of the expected increase of the more profitable 300-mm fabs.

Capital spending is an important indicator it represents the outlook, expectation and direction of the industry itself industry. Capital spending of the IC Industry is expected to raise again by 24% in 2022 after 36% in 2021, now the industries are on the move from its extreme dependence on lagging nodes, to more a technology where supply chain issues can be addressed through capacity expansions.

The chip shortage triggered national and governmental efforts to boost advanced logic chip manufacturing. Following the industry, South Korea announced \$450 billion program over ten years, United States are pushing legislation worth \$52 billion, and the EU \$160 billion. ICT Industry is starting to build 10 new 300-nm fabs in 2021 with 14 more in 2022. It is not just an eco-technological problem, it is logistics as well.

In the second half of the decade, the number of advanced lithography wafers produced every year is expected to double and continue to grow and by the end of the decade, over 40% of semiconductor revenue will come from these leading nodes. Nevertheless only few companies will be able to make the leap.

The ICT market surpassed \$500 billion for the first time in 2021 and is predicted to double to \$1 trillion by the end of this decade. The most advanced silicon process nodes, will grow five times faster. A once-in-a-generation opportunity for the semiconductor industry



A topic worth special attention is Medicine and ICT.

2.3. Medicine and ICT

Within the next years and health will merge further. These developments of ICT will affect us personally. ICT, Engineering Biology, AI and ML will establish a framework for a new medicine with decentralizing healthcare, moving more from institutions to the individual.

We can look forward to ease of use, low-cost higher quality diagnostic tests to individuals in every corner of the globe. Fewer infected people will have to leave their homes, altering disease epidemiology and decreasing the burden on the healthcare system, especially in the case of infectious diseases supported by the lessons hopefully learned within the Covid framework. Thus morbidity, mortality and costs should decrease, because this will allow to concentrate the resources on the severe cases which will need special care.

What can we expect?

- Wireless health monitoring and remote care extended, by the use of TVs in poorer areas
- Increase of “At-home lab tests”, Covid tests were advancing the acceptance
- A.I.-guided and portable US (ultrasound) systems, allowing use by less skilled personal.
- 3D printing of certain medications and medical supplies (esp. for remote areas)
- Digital health insurance and
- Digital twins

Nevertheless the economic justification is not yet fully proven, as example IBM sold Watson Health, as not sufficiently profitable business, in spite of its ~1 Billion\$ revenue p.a.

AI and ML will enable insights at an unprecedented level from all the medical Big Data. ICT-Medical industry is already very active, Google already made a cooperation agreement top clinics as Mayo Clinic for medical data.

Concerns arise as especially in data security, organization as in acceptance. The avalanche of data collected by Direct-to-consumer telehealth means patient data including CTs, MRs etc. will be integrated into all-encompassing electronic health records. Will patients accept this total transparency and the potential commercialization of medical data for e.g. health insurance business?

There might also come resistance from medical personnel to the inherent demystification and reduction of authority. The decentralization and the transfer of activities with the help of AI and ML to less costly medical personal as med.-techn. assistants will raise financial issues for the Med-Docs.

The development of medical technology will improve diagnosis and permit earlier detection since the quality of the equipment decides by its limits of detectability. If you detect a small tumor at an earlier stage or only after it has reached a potentially dangerous level can be decisive.

The Digital Twin is a development coming from the aerospace industry. There it is successfully used for analysis of the reaction to problems, disturbances and external actions on spacecraft or airplanes, extending to manufacturing, urban planning and others. Sensor technologies and the Internet of Things (IoT), and contributed to the rise of digital twin technology.

The human body is certainly more complex, but the advancement of technology and scientific knowledge especially simulation and sensor capabilities, make it possible to construct digital twins modeling functions, as bio-physical systems or protein structures or elements of the human body. This would make it possible to simulate and evaluate the effect of different drugs, therapies

effectiveness, procedure safety etc. with higher efficiency. Even a Pneumonic Digital-Twin is already under development.

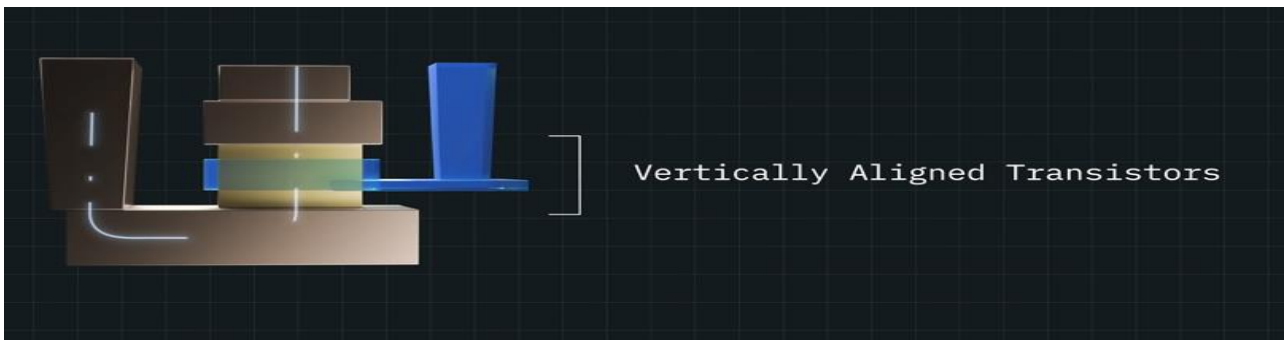
3. Technology and its Impact

Some pessimistic analysts are predicting the end of Moore's Law since years, the exponential growth slowing or reach a fundamental limits, but recent developments are extending the success story of Si-ICT technology.

In recent years, transistors have been miniaturized to almost unimaginably tiny sizes. The iPhone 12 features an ARM-based smartphone system-on-a-chip manufactured using a 5nm process node. (for comparison, the smallest viruses are 20nm in diameter or a DNA helix is 3nm long). Increasing transistor density brings significant advantages. Mastering this technology means shorter distances, more speed, reduced losses in connections and a significant economic advantage in production.

3.1. Extending Technology to the 3rd Dimension

Extending to the third dimension is a breakthrough in semiconductor architecture adding a vertical transistor architecture. This could reduce energy usage by 85% even compared to advanced FinFETs (Fin field-effect transistors). Manufacturing these vertical alignments at this scope of miniaturization needs an outstanding engineering ingenuity only few companies will master.



Source: Wikipedia

Top-of-the-range processors currently hold about 30 to 40 billion transistors. Intel expects its first chips with over a trillion transistors by in the next future and presented a roadmap for increasing the number of transistors on a chip by a factor of 50 until the end of the decade.

Another contribution are developments as:

IBM's 2nm chip.

IBM presented prototypes of chips based on a 2nm process, allowing 50 billion transistors to be crammed onto a chip potentially arriving in 2024 -2025 on the market. IBMs 2nm chip features ~ 333M transistors /mm², TSMC's most advanced ~173 MTr /mm² and Samsung's ~ 127 MTr/mm²

The potential benefits of 2nm chips are a 45 % higher performance, 75 % lower energy use resulting in quadrupling cell phone battery life, drastically speeding up a laptop's functions or contributing to faster object detection and reaction time (autonomous vehicles).

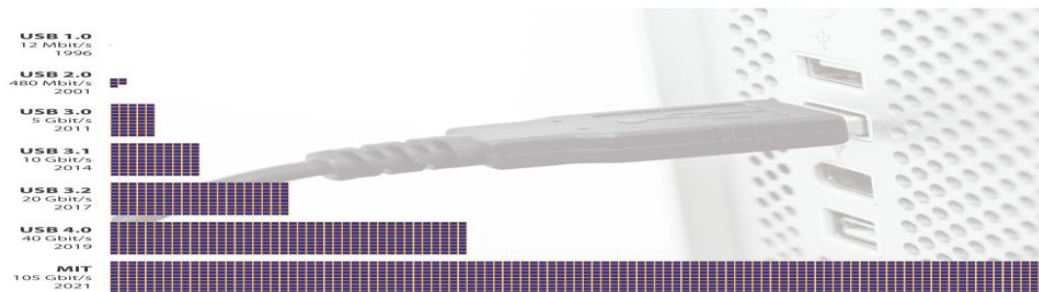
3.2. Interconnection – the antagonist of miniaturization

While size reduction benefits transistor performance, the opposite is true of interconnect wiring. Smaller wires have greater electrical resistance, which means reduced performance and higher power consumption .i.e., interconnect resistance would increase by a factor of 10 from the 7nm to the 3nm node, negating the benefits of transistor scaling.

A smartphone chip has tens of billions of copper interconnects, and wiring already consumes a third of the chip's power. The U.S. Company Applied Materials, revealed a new process to engineer the wiring of advanced logic chips that can scale down to 3nm. This is not the end, the company published a roadmap including plans for 1,4nm wiring in 2029.

3.3. Data transfer

Producing data is not good enough, you have to be able to transfer them fast and economically. Therefore a data transfer system exceeding 100 Gbit/s is highly desirable. Currently there is no economic feasible way to efficiently generate, amplify, or detect photons in silicon. An economic solution perspective has been developed, a data transfer system 20 times faster than USB 3.0, a new link that combines the benefits of both copper and fiber-optic. The conduit is made of plastic polymer, which is lighter and potentially cheaper to manufacture than traditional copper cables. Additionally for sub-THz signals this polymer link is far more energy-efficient than copper and has the advantage of being directly compatible with silicon chips, without any special manufacturing.

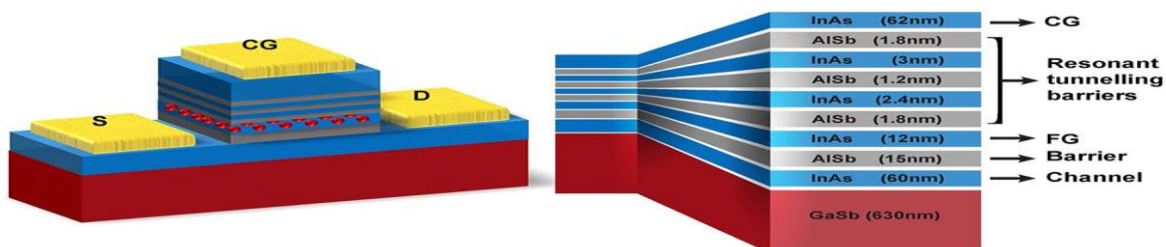


Data cable speed (each square ~100 Mb/sec); Source: FutureTimeline Net

3.4. Memory for the future

In view of the data tsunami threatening to consume up to 20% of global electricity by the end of this decennium a new DRAM computer memory device to meet the need for improvement of storage devices is of special importance.

Researchers at Lancaster University described a new electronic memory device able to record/delete data using 100 times less energy than DRAM or 1,000 times less than flash.



Lancaster University UK

Schematic of the device with control gate (CG), source (S) and drain (D) contacts (gold).

Nano-lamella storage device

The Data related problems are not only energy consumption but as well volume and long term storage. Under development is a fast and energy-efficient laser-writing method for producing high-density nanostructures in silica glass, using a femtosecond laser with a high repetition rate to create tiny pits containing a single “nano-lamella”-like structure measuring just 500 by 50 nm each. High-speed laser could thus write 500 TB of data into glass. These tiny structures can be used for long-term optical data storage, (more than 10,000 times denser than Blu-Ray optical disc storage.)

3.5. Advanced Tooling Technologies a “Conditio sine qua non”

All this would not be possible without very special prerequisites.

In the shadow of technologically advances there are developments of indispensable essential prerequisites which normally do not make it to the headlines. Here two European companies as world leaders:

ASML and Zeiss.

ASML is a world's leader in lithography for the semiconductor industry and supplier to the worldwide semiconductor industry. It is their lithography equipment which makes the downsizing to the above mentioned dimensions possible.



ASML Lithograph; Source: ASML

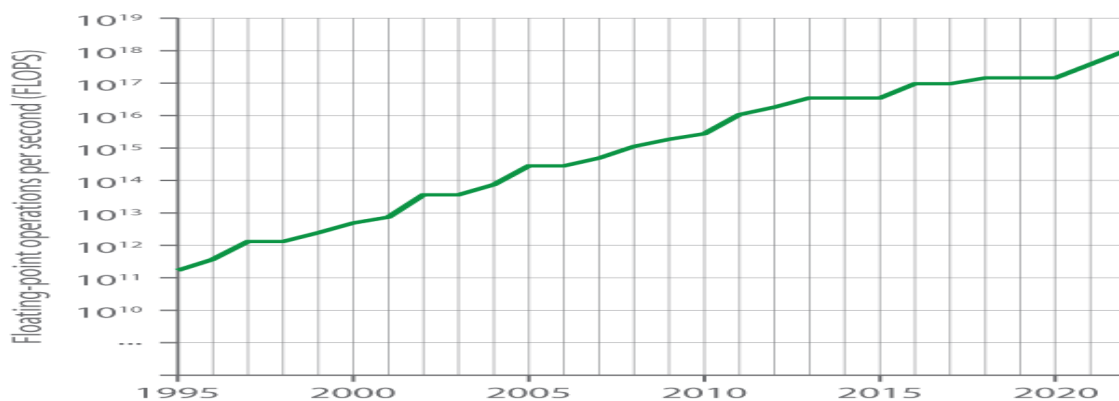
Since for EUV-light glass is not anymore penetrable and mirrors have to be used instead of glass lenses. Zeiss’s engineers had already made the special mirrors for space telescopes. The mirrors for ASML have to be even orders of magnitude smoother.

To give a sense of scale, if you blew the mirror in your bathroom up to the size of Germany, it would have bumps about five meters high. The special mirrors of Zeiss for ASML blown up to the same size of Germany, their biggest imperfections could be less than a millimeter high. These are the most precise mirrors in the world.

3.6. Petascale and Exascale computing

Permanent but effective improvement is ongoing silently. Many low visibility improvements are adding up to exponential computing power improvements. An Intel i5- chip of 2022 has a tremendous increase of performance of its equally named i5- chip of 2018.

In the last decennium performance is increasing from Petascale computing (quadrillions or 10^{15} FLOPS) to Exascale (10^{18} FLOPS). Leading companies aims even to achieve the next leap in half the time, setting a goal of delivering Zettascale computing (10^{21} FLOPS) by 2027.

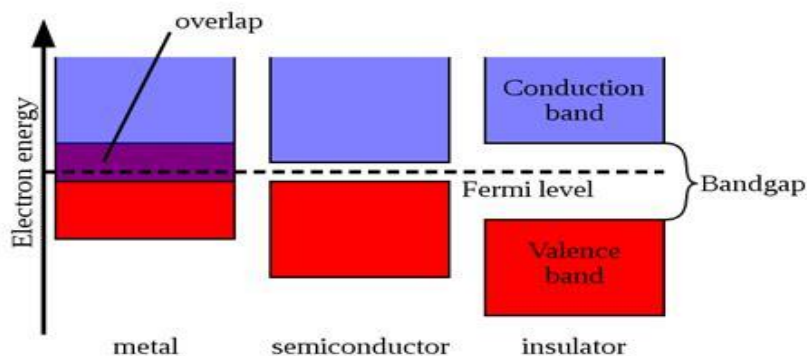


Top 500 Supercomputer database

3.7. Next Generation Materials

Graphenes are famous for their exceptional physical, optical and mechanical properties, but they have a significant shortcoming, the lack of a natural bandgap limiting its use in electronics. A material with the combination of the impressive properties of mono-layer atom sheets (therefore 2D) and a large enough bandgap could revolutionize electronics and opto-electronics. This initiated intensive research on 2D materials validated by an explosive growth of patents 2008 - 2018 for next generation materials.

For a better understanding let us recap the basics of the band model



Source: Wikipedia

A joint team from ETH Zurich and EPFL Lausanne made an remarkable research effort. They modelled the principles of potential 2D materials on a supercomputer, then sifted through 100,000 candidate materials, out of which they identified 1,825 were from which 2-D layers could be obtained. A further selection from 1,800 to 100 was based on which mono-layers of atoms were most likely to build into Fets. Limiting the selection from these 100 candidates to those having a large enough band gap between the valence band and conduction band they identified 13 showing promise exceeding the expectations for the presently leading Si FinFets.

3.8. Ultra-wide bandgap semiconductor (UWBGs)

A group of materials are UWBGs materials, defining materials with a bandgap $> \text{GaN}$ which is 3.4 eV e.g. materials as diamond, gallium oxide (Ga_2O_3), AlGaN , and AlN with the potential to realize devices with higher levels of performance than devices based on Si, GaAs, SiC, or GaN. Extending implemented WBGS, UWBGs have the potential to reinvent the electricity grid through new materials, devices, and architectures to improve the manner in which electrical power is generated, transmitted and consumed. Potential applications a wide range of applications are ranging from solid-state power conversion and control (i.e. power electronics), transportation, renewable energy generation, energy storage, grid modernization (solid-state transformers and DC distribution loads).

3.9. Optical computing

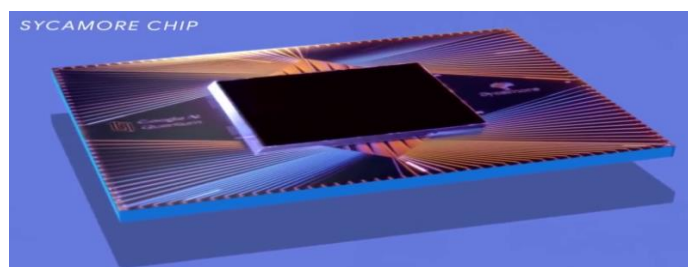
Extending optical technologies from communication (glass fiber cables) to optical computing would initiate a new area of computing.

Replacing electronic transistors in a new generation of computers using photons instead of electrons, which move faster and can be packed into a tighter space, would allow orders of magnitude improvements in processing speed, while giving off little or no heat since it takes only a few photons to switch.

A key prerequisite is an efficient optical switch. IBM and Skoltech (Skolkovo Institute of Science and Technology), Russia, announced an extremely energy-efficient optical switch. In addition to direct power saving, the switch requires no cooling, and works at room temperature. It would have the potential of 1 trillion operations/sec that is 1,000 times faster than today's top-of-the-range transistors.

3.10. Quantum Computing: Where does QC stand?

Google recently demonstrated its Sycamore quantum processor. It took 200 secs to solve a special problem that would take the biggest supercomputers 10,000 years to complete. Due to this and many other encouraging announcements, the quantum computing ecosystem is booming.



Source: Google

Tech giants and small start-ups alike jumped on the bandwagon. IBM had already been investing for years promptly joined by Microsoft and Amazon, and many other smaller companies started in this field. Instigated by potential unique advances in fields as biochemistry, material science, organic chemistry, logistics optimization or decrypting.

Governments in the EU, the UK, the USA and China are launching large-scale quantum programs, with billion dollar budgets. But this is no guarantee that QCs will open a fully all-encompassing new era of computing. A QC working on problems of real-world relevance, is anticipated to need one million or more qubits contrasting the hundreds of qubits of today's QCs.

Decryption of secret files may become one of the earliest and very attracting application. Think of all the encrypted documents collected by different agencies up to now becoming suddenly readable. Nevertheless future new QC-proof encryption codes will solve or at least contain this problem.

The experts are divided between the skeptical, blaming the tendency to over-hype a technology that is yet to prove itself and point at the plethora of unsolved problems as e.g. error correction.

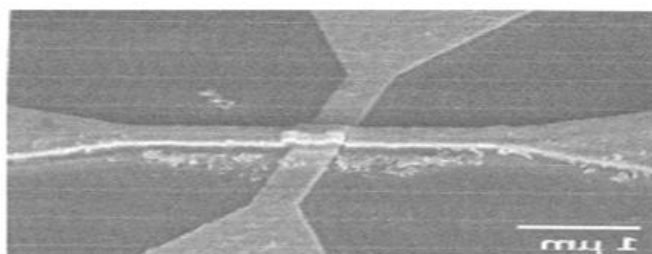
The optimistic view is that in the coming years quantum computing will have outgrown its infancy, and first devices will be able tackle meaningful, real-world problems with this decennium.

3.11. Biotechnology and Neuromorphic computing

Neuromorphic computing uses of electronic analogue circuits to mimic neurological architectures of the biologic brain and nervous system and to learn from their superior properties. In contrast to digital electronics analogue circuits work with continuously variable signals. This could also provide a tool to understand better the dynamic processes of learning, thinking, and development in the brain, its much greater energy efficiency, speed, and robustness against local failures.

Biosensor chip

The recently as first of its kind published biochip can observe direct electrical measurements of single-molecule interactions integrating single molecules into circuits. The chip uses individual molecules as universal sensor elements in a circuit, thus creating a biosensor with real-time, single-molecule sensitivity and scalability in sensor pixel density.

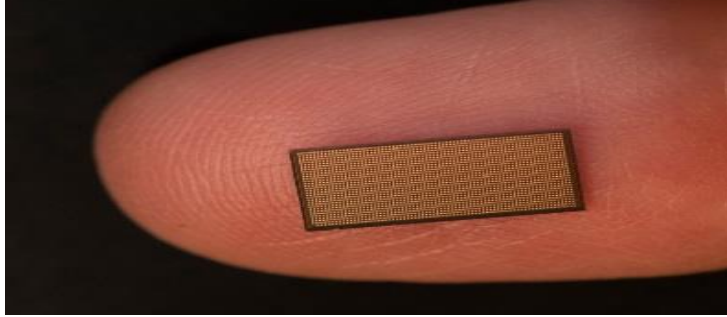


Fuller et al., PNAS 2021

This will support advances in fields based on observing molecular interactions, including drug discovery, diagnostics, DNA sequencing, and the large-scale study of proteomes surveillance, and precision medicine on portable devices. The sensor is programmed by attaching the desired probe molecule to the molecular wire and provides a direct, real-time electronic read-out of molecular interactions of the probe.

Picoamp-scale measurements are read out from the sensor array in digital form, at a rate of 1,000 frames/sec, and allow to capture molecular interactions data with high resolution, precision, and throughput.

Intel introduced, its second-generation neuromorphic research chip Loihi 2 containing a million artificial spiking neurons together with a new software framework, called Lava.



Intel Loihi 2

4. Concerns arising AI and ML - Deep fakes and post-theory science

AI and ML will be covered in special sessions, therefore only few remarks.

The National Academy of Sciences USA recently published their deep fakes study, providing a measure of how far the technology has progressed. The results suggest that real humans easily fall for machine-generated faces, and even interpret them as more trustworthy than the genuine. The result raises concerns that these faces could be highly effective when used for nefarious purposes, political manipulations, and novel forms of abuse and fraud.

ML programs predict your preferences better than any psychologist. AlphaFold, built by DeepMind, has produced the most accurate predictions yet of protein structures based on the amino acids they contain.

ML results do not offer an explanation, no set of rules for converting this into a theory. They just work well. Many expect programs of this type to change medicine and science and are starting to feel worried that Deep Learnings has impressive results could mean the classic methodology of hypothesize, predict and test has had its day, making many uncomfortable with a theory-free science contrasting to how science is done today.

Is this leading to a science nobody understands but everybody uses, the dawn of post theory science?

5. Summary

We tried to give a short overview of ICT from an economic, technological and application perspective. Reviewing the status and future developments as well as chances, challenges and risks.

We are living in a period of an unequalled boom of ICT due to the accelerated growth and integration into our life, as result of the accelerated increase of the ICT content in all products and additionally accelerated by Covid.

The end of the era doubling the performance every two years at the same cost has ended, but this instigated a multipronged R&D effort looking into many directions resulting in a plethora of new opportunities emerging to continue the success of ICT. We complemented this by view on subjects of special interest as chip shortage and automotive industry, or the upcoming new area in medicine. To complete the overview we made a short glance on the pipeline of new technologies on and over the horizon.

We can look forward to a future of a continued advancement of ICT putting Petaflop compute power and Petabytes of data within a millisecond for every human on the planet is within reach.

6. References and further reading

Alphabet (Google), annual report 2021
Alpine Quantum Technologies
Amazon, annual report 2021
Apple, annual report 2021
Applied Materials, Press release
Dhanda, R., Sherlock Biosciences
Dyakonov, M. The case against quantum computing, Univ. Montpellier
Facebook (Meta), annual report 2021
Farid, H., University of Cal, Berkeley, Feldhan, J., Semico Research
Fleming S., McKinsey
Gartner Data space and div. publications 2021/22
Gelsinger P., Intel CES 2022
Holloway, Data Transfer
IBM 2nm node chip, IBM Research Blog, 2021
IC Insights Strategic reviews data base, Semiconductor Industry Capex forecast and Flash Report 2022
Kürz, P., Zeiss AG
Lei et alii, Optica Journal ,
Loesch, C.W., IDIMT 2021
Meskó, B., Qortex and Dhunnoo, P., MedSign
McClean Report 2022
Microsoft, annual report 2021/22
Morales, M., Enabling technologies and semiconductors, IDC.
Raja, Koduri, Intel, Loihi 2,
National Academy of Sciences. USA. Proceedings
Saemoon Y., WEFT 2021
SciAm Journal 5/2022
SEMI's 3 June 2021 World Fab Forecast
SIA Publications 2021/22
Skoltech Institute of Science and Technology,
Tizno O., et al., a new electronic memory device, Lancaster Univ., Nature
Univ. Grenoble, 2D Materials, 2021
Wikipedia, Vertically aligned Transistors

MANAGEMENT AND DIGITALIZATION

MANAGEMENT AND DIGITALIZATION

Digitization takes an analog process and changes it to a digital form without any different-in-kind changes to the process itself. (Gartners, 2022)

Petr Doucek, Jiří Hološka, Lea Nedomová

Faculty of Informatics and Statistics
Prague University of Economics and Business
doucek@vse.cz, jiri.holoska@vse.cz, nedomova@vse.cz

DOI: 10-35011/IDIMT-2022-35

Keywords

Digitalization, ICT penetration into business, ransomware, human resources, digital public services, connectivity, information security threats

Abstract

The digitization of society and thus of business activities is a clear trend set by the European Union for its Member States. This article compares data on the digitization of the economies of the V4 countries and other select countries – Austria, Germany and Slovenia – with the EU-28 average during the years 2016-2021. The basic source of data is the Digital Economy and Society Index (DESI). The data are analyzed both based on the individual dimensions of the DESI and the overall calculated DESI. The analysis includes the following components Human Resources, Digital Public Services, Integration of Digital Technology, Digital Infrastructure – Connection. By analyzing the time series starting in 2016, we have concluded that Austria, Germany and Slovenia have the best conditions for digitization since their aggregate DESI is at the EU-28 average. The V4 countries are below the EU-28 average, in the following order: the Czech Republic, Slovakia, Hungary and Poland. The open task and focus of our follow-up analyses is to compare the identified values with those of the EU Baltic Member States.

1. Introduction

Digitalization is one of the processes that are to improve, speed up and enhance services in the information society. We can hardly disagree with the definition of digitalization (Gartners, 2022) as stated in the header of the article. Specifically, we can picture, for example, the introduction of new methods and technologies in cybersecurity, artificial intelligence, robotics, connectivity, including 5G networks, and other innovations of information technologies (European Commission, 2022). Nowadays, we can see the declared priority of this process ever so often not only in private corporations, but also in the state and public sectors. Using various methodologies, we try to adapt common work processes to processes supported by computer technology (information and communication technologies – ICT) and we create ever larger and larger volumes of digital data (Kotova et al., 2020). We then store them in data lakes, warehouses, databases or files, convinced that we would go back to them later on to finally analyze them (Potancok et al., 2021). As a result, our well-intentioned efforts to increase the efficiency of processes can actually make them more complex and more difficult to manage.

We can see an optimistic declaration on the website of the EU that measures the current degree of digitization of economies using the Digital Economy and Society Index: “All EU Member States have made progress in the area of digitalisation, but the overall picture across Member States is mixed, and despite some convergence, the gap between the EU's frontrunners (Sezer et al., 2021) and those with the lowest DESI scores remains large” (DESI, 2021a). As the EU declaration shows, we must expect an increased pressure on digitization, and not only a competitive pressure in business organizations, but also in the state and public administration. And which areas show the biggest digitalization efforts? Out of the traditional industries that we have recently analyzed, it is, for example, Industry 4.0 (Basl, & Doucek, 2019; Schaupp et al., 2017). Healthcare is another industry undergoing rapid digitalization (Konttila, 2019; Cerný et al., 2019). This is very much needed in the Czech Republic since there are in fact no standards for transmitting data between the groups of healthcare facilities or even between individual healthcare facilities within one group. Data transmission and processing in the public and state administration is also a problem. Despite the more than 20 years of efforts of different Czech governments, the situation in this area is the most critical because of the considerable resistance of both officials and entire organizational units and structures against change (Bokša et al., 2019).

The aim of this article is to present the progress of digitization in select EU Member States (V4 countries, i.e. the Czech Republic, Slovakia, Poland and Hungary, Austria, Germany, Slovenia and finally the EU-28 average) based on the indicators aggregated in the Digital Economy and Society Index. It concerns the following areas Human Resources, Digital Public Services, Integration of Digital Technology, Digital Infrastructure – Connection. We provide a comparison for the years 2016–2021. In the end, we emphasize two areas on which the digitization process has an immediate impact – IS security and management in a digital society.

2. Methodology

The methodology was based on the data available at (DESI, 2021a). The Digital Economy and Society Index is one of the economy digitalization indicators that the EU monitors on an annual basis. For the purposes of this article, we used this database to analyze data for the years 2016–2021 and for EU-28 to compare the position of the analyzed EU Member States. We mainly focused on the Visegrad Four countries, i.e. the Czech Republic, Slovakia, Poland and Hungary, compared them with two neighboring countries – Austria and Germany – and added Slovenia that shows a very similar development during the last centuries.

The Digital Economy and Society Index consists of four basic components Human Resources, Digital Public Services, Integration of Digital Technology, Digital Infrastructure – Connection. The results presented in this article are structured based on these components.

3. Results

The results that we obtained by analyzing Digital Economy and Society Index data are divided based on DESI individual components. We will present the situation in Human Resources, Digital Public Services, Integration of Digital Technology, Digital Infrastructure – Connection.

3.1. Human Resources – Internet Users Skills

The human capital dimension of the DESI has two sub-dimensions covering ‘internet user skills’ and ‘advanced skills and development’. The former draws on the European Commission’s Digital Skills Indicator, calculated based on the number and complexity of activities involving the use of

digital devices and the internet. The latter includes indicators on ICT specialists, ICT graduates and enterprises providing dedicated ICT training. According to the latest data, Finland is leading in Human capital, followed by Sweden, the Netherlands and Denmark. Italy, Romania and Bulgaria rank the lowest. In comparison to last year, the largest increases in Human capital were observed in Finland (+2.6 percentage points), Estonia (+1.7 percentage points) and Greece (+1.6 percentage points) (DESI, 2021b).

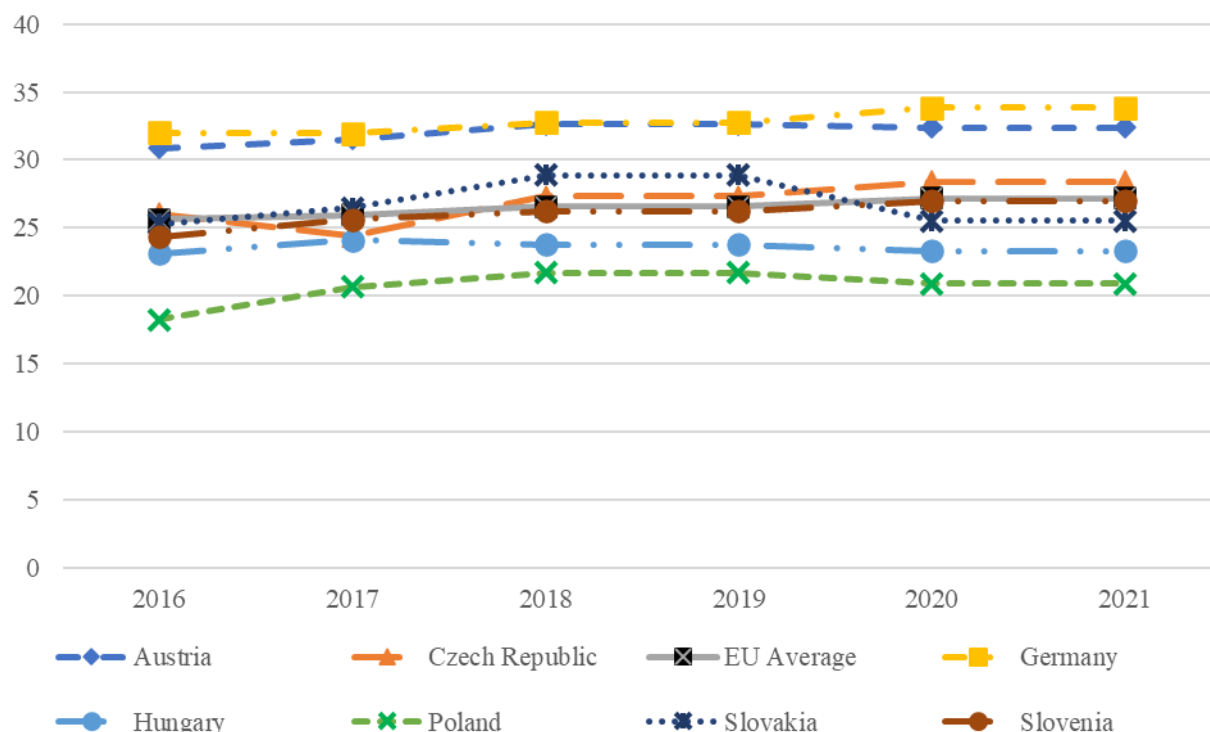


Figure 1 Human Resources – Internet Users Skills

In terms of human capital, it is noteworthy that the improvement of internet user skills during the last six years was minimal. We can see that the progress of advanced skills conditions for digitization is slower, which is closely related to the education system and its effectiveness and efficiency. We can divide the analyzed countries into three clusters. The first cluster includes Austria and Germany, where Internet user skills are on a significantly higher level than in other countries. The middle cluster includes all V4 countries as well as Slovenia and the EU-28 average. It is very interesting that the level of Internet user skills in Slovakia dropped in the last year. The third cluster of the least advanced countries includes Hungary and Poland, where this analyzed indicator is the lowest.

3.2. Digital Public Services

Digital technologies increasingly place new demands and expectations on the public sector. Realising the full potential of these technologies is a key challenge for governmental organisations. Effective e-government can provide a wide variety of benefits including more efficiency and savings for both governments and businesses. It can also increase transparency and openness. This dimension measures both the demand and supply sides of digital public services as well as open data (DESI, 2021c).

Denmark, Finland, and the Netherlands performed very well on this measure, with more than 90% of internet users (aged 16-74) interacting with the public administration choosing governmental

portals. Romania, Bulgaria and Italy were less strong in this measure, and were the only three countries where the percentage of citizens interacting with public administrations was less than 40% (DESI, 2021c).

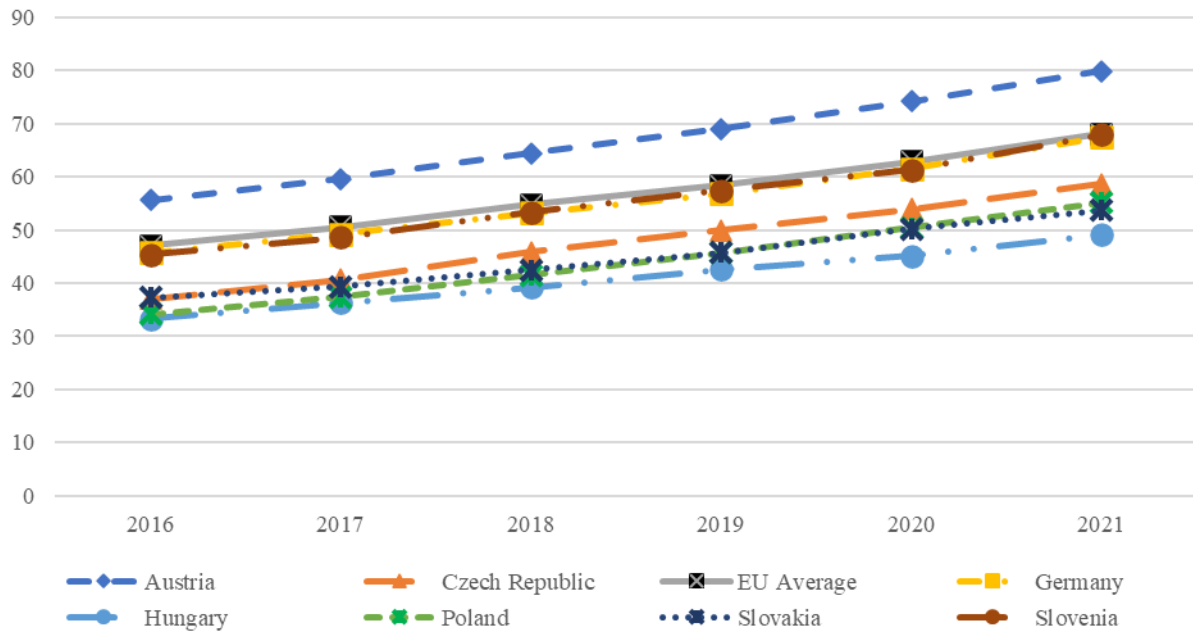


Figure 2 Digital Public Services

The digital public services indicator shows a significantly higher growth rate than the human capital indicator. We can again divide the identified values into three clusters. Austria as the most advanced country in terms of public digital services is the only one in the first cluster. The second cluster includes Slovenia and Germany. The values in these countries are very similar to the EU-28 average, which is also included in this cluster. The V4 countries form the last cluster. Out of these countries the Czech Republic is the best, while Hungary is the worst.

3.3. Integration of digital technology

Digital technologies enable businesses to gain competitive advantage, improve their services and products and expand their markets. Digital transformation of businesses opens up new opportunities and boosts the development of new and trustworthy technologies. The EU's digital sovereignty will depend on the capacity to store, extract and process data while satisfying the requirement of trust, security and fundamental rights¹. This dimension measures the digitalisation of businesses and e-commerce.

The top performers in the integration of digital technologies are Finland, Denmark and Sweden. Bulgaria, Hungary and Romania have the weakest performance (DESI, 2021d).

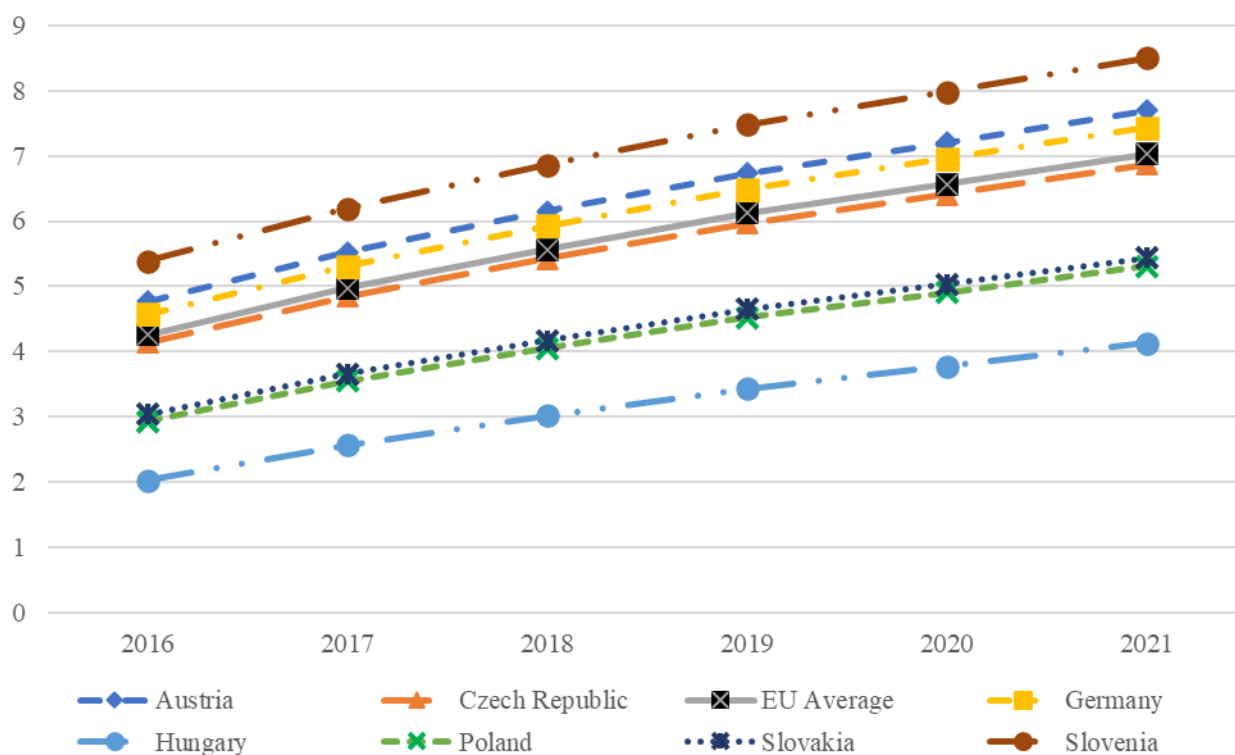


Figure 3 Integration of digital technology

The use of information technologies supporting business digitalization is another dimension of the DESI. The identified values divide the analyzed countries into four clusters. Slovenia shows the best results by far. Austria and Germany form the second cluster. The indicator for all these countries is significantly above the EU-28 average. The indicator for the Czech Republic is just below the EU-28 average, which puts the CR in the second cluster. The third cluster includes Poland and Slovakia. The difference between these two countries is minimal. The fourth cluster includes Hungary, where the integration of digital technology in business activities is the lowest out of all analyzed countries.

3.4. Digital Infrastructure – Broadband Connectivity

The Digital Decade defines two targets in the area of broadband connectivity for 2030: gigabit coverage for all households and 5G in all populated areas. The connectivity dimension of the Digital Economy and Society Index (DESI) looks at both the demand and the supply side of fixed and mobile broadband. Under fixed broadband, it assesses the take-up of overall, at least 100 Mbps and at least 1 Gbps broadband, the availability of fast broadband (next generation access of at least 30 Mbps) and of fixed very high capacity networks (VHCNs)¹. Under mobile broadband, it includes the population coverage of 4G and 5G² networks, the assignment of radio spectrum for 5G (5G readiness) as well as the take-up of mobile broadband³. In addition, it captures the retail prices of fixed and mobile offers and also those of converged bundles (consisting of fixed and mobile service components).

In connectivity, Denmark has the highest score, followed by the Netherlands and Spain. Greece and Bulgaria have the weakest performance on this dimension of the DESI (DESI, 2021e).

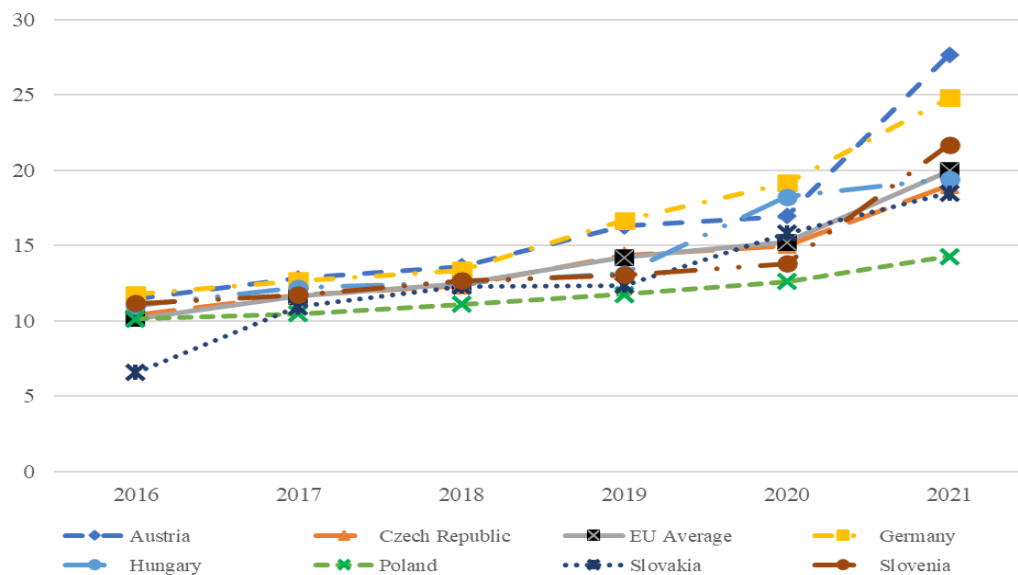


Figure 4 Digital Infrastructure – Broadband Connectivity

The broadband connectivity indicator shows an extraordinary increase in the last year, especially in Austria and Slovenia. The first cluster of the most advanced countries in terms of this indicator includes Austria and Germany. The second cluster includes all other countries except for Poland, which considerably lags behind other countries in terms of building a communication infrastructure. This is why, Poland is included in the third cluster.

3.5. Security

What nowadays fundamentally affects the development of an information society, and thus also the digitization of today's society, is the fear of further development, especially in foreign political relations, which at first glance have nothing to do with digital public services and their implementation into everyday life. However, the opposite is true. The war in Ukraine has significantly decreased the effectiveness of network security services and increased the number of cyberattacks on various targets. As is usual in war conflicts, both sides attack each other in cyberspace (Holoska et al., 2021). This has also been confirmed by the National Cyber and Information Security Agency, which especially provides information about cyberattacks with Wiper malware on the Baltic countries (Lithuania, Latvia and Estonia). In connection with the crisis in Ukraine, there is a threat of a Russian cyberattack on the banking systems of the European Union and the USA. The National Cyber and Information Security Agency also issued a warning about a threat of cyberattacks on strategic organizations in the Czech Republic. So, there are a lot of threats in cyberspace. The only way to prevent them is to strengthen the protection and security of information systems (Doucek et al., 2020), including those of relatively small companies, through which the information systems of large companies could be hacked.

3.6. Management

The digitization of services is a great opportunity for management. The advantages of digitization from the management's point of view undoubtedly include the acceleration of provided services and the improvement of their transparency, as data are collected and their volumes keep increasing, it will be necessary to delegate decision-making powers and thus to distribute responsibilities and powers in the entire system of state and public administration (Jeske et al., 2020). The processing of

large data volumes and the implementation of artificial intelligence features to evaluate data will become a major trend (Möller et al., 2020).

Digitization also has its downside; it fundamentally changes existing competencies and powers, while strengthening the tasks and roles of employees who use information and communication technologies and are able to obtain added value by analyzing data. We can also expect that the number of employees able to use information technology will go up. However, as the growth rate in Figure 1 shows, this process will take a very long time and will require major changes in the education system. We can expect that digitization will have an impact on individual ecosystems and on the environment as a whole.

4. Conclusions

All sub-indicators show a positive trend as well as better conditions for digitalizing economies and societies. As apparent from Figure 5, the year-on-year increase has rather accelerated in most countries. However, this trend also has a negative impact, which is the fact that the gap between countries keeps widening, as the least advanced countries do not show the fastest positive growth of the analyzed indicators.

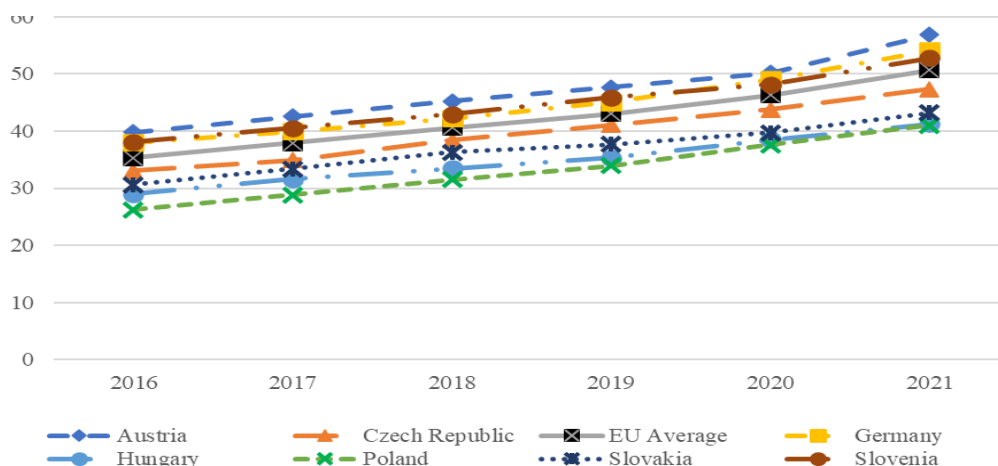


Figure 5 Overall evaluation of the DESI for analyzed countries

In terms of the overall DESI, we can say that out of all analyzed countries, three countries – Austria, Germany and Slovenia – are best prepared for digitalization and are also above the EU-28 average. The V4 countries are below the EU-28 average. Out of the V4 countries, the Czech Republic shows the highest digitization rate; Slovakia ranks second, Hungary third and Poland fourth. Poland and Hungary show the lowest aggregate DESI.

Our follow-up research will focus on comparing the data presented in this article with data concerning the Baltic countries (Lithuania, Latvia and Estonia), which are comparable especially to Slovenia and Slovakia in terms of size.

5. Acknowledgement

Paper was processed with support from institutional-support fund for long-term conceptual development of science and research at the Faculty of Informatics and Statistics of the Prague University of Economics and Business (IP400040) and the project IG 409022.

6. References

- Basl, J., & Doucek, P. (2019). A Metamodel for Evaluating Enterprise Readiness in the Context of Industry 4.0. *Information*. 10(3), DOI: 10.3390/info10030089. Available at: <https://www.mdpi.com/2078-2489/10/3/89>
- Bokša, M., Bokšová, J., Horák, J., Pavlica, K., Strouhal, J., & Šároch, S. (2019). Digitální Česko v digitální Evropě. ŠKODA AUTO VYSOKÁ ŠKOLA o.p.s., ISBN 978-80-87042-75-5
- Cerný, J., Potancok, M., & Molnár, Z. (2019). Open Human Medicine Data in Competitive Intelligence. In: *Vision 2020: Sustainable Economic Development and Application of Innovation Management from Regional Expansion to Global Growth*. IBIMA 2019, 1963–1974. Available at: https://vse-my.sharepoint.com/:b:/g/personal/xpotm03_vse_cz/EW6Xl0m0HZPsU37N5P3oL4B_VpxScQfPQWEg0VbQs2eSA?e=eCpBi9
- DESI. (2021a). Digital Economy and Society Index 2021: overall progress in digital transition but need for new EU-wide efforts. Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_21_5481
- DESI. (2021b). Digital Economy and Society Index (DESI) 2021, Human Capital. Available at: <https://digital-strategy.ec.europa.eu/en/policies/desi-human-capital>
- DESI. (2021c). Digital Economy and Society Index (DESI) 2021, Digital Public Services. Available at: <https://digital-strategy.ec.europa.eu/en/policies/desi-digital-public-services>
- DESI. (2021d). Digital Economy and Society Index (DESI) 2021, Integration of digital technology. Available at: <https://digital-strategy.ec.europa.eu/en/policies/desi-integration-technology-enterprises>
- DESI. (2021e). Digital Economy and Society Index (DESI) 2021, Digital infrastructures. Available at: <https://digital-strategy.ec.europa.eu/en/policies/desi-connectivity>
- Doucek, P., Pavlíček, L., Sedláček, J. & Nedomova, L. (2020). Adaptation of Password Strength Estimators to a Non-English Environment – the Czech Experience. *Computers & Security*. 95(2020), DOI: <http://dx.doi.org/10.1016/j.cose.2020.101757>
- European Commission. (2022). Shaping Europe's digital future. The Digital Europe Programme. Available at: <https://digital-strategy.ec.europa.eu/en/activities/digital-programme>
- Gartners, (2022). Information Technology – Gartner Glossary. Available at: <https://www.gartner.com/en/information-technology/glossary/digitization>
- Holoska, J., Doucek, P., & Nedomova, L. (2021). Industry 4.0 – Selected trends in digital transformation. In: *IDIMT-2021 Pandemics: Impacts, Strategies and Responses*. Linz: Trauner Verlag Universität, 35–46.
- Jeske, T., Weber, M.A., Lennings, F., & Stowasser, S. (2020). Holistic Productivity Management Using Digitalization. 10th International Conference on Applied Human Factors and Ergonomics (AHFE)/International Conference on Human Factors and Systems Interaction. *Advances in Human Factors and Systems Interaction*. Springer International Publishing Aggwerbestrasse 11, 104-115, DOI: http://dx.doi.org/10.1007/978-3-030-20040-4_10
- Konttila, J., Siira, H., Kyngas, H., Lahtinen, M., Elo, S., Kaariainen, M., Kaakinen, P., Oikarinen, A., Yamakawa, & M., Fukui, S. (2019). Healthcare professionals' competence in digitalisation: A systematic review. *Journal of Clinical Nursing*. 28(5-6), 748-761, DOI: <http://dx.doi.org/10.1111/jocn.14710>
- Kotova, O.V., Popova, N.I., & Vorotilova, O.A., (2020). Digitalization" is a Modern Tendency in the Management of Economic Systems in the Russian Economy. 2nd International Scientific and Practical Conference - Modern Management Trends and The Digital Economy. Atlantis Press, 29 Avenue Lavmiere, Paris, 1109-1114.
- Möller, K., Schaffer, U., & Verbeeten, F. (2020). Digitalization in management accounting and control. *Journal of Management Control*. 1(1-2), 1-8. DOI: <http://dx.doi.org/10.1007/s00187-020-00300-5>
- Potancok, M., Pour, J., & Wui, I. (2021). Factors Influencing Business Analytics Solutions and Views on Business Problems. *Data*. 6(8), DOI: <http://dx.doi.org/10.3390/data6080082>
- Sezer, A.A., Thunberg, M., & Wernicke, B. (2021). Digitalization Index: Developing a Model for Assessing the Degree of Digitalization of Construction Projects. *Journal of Construction Engineering and Management*. 147(10), DOI: [http://dx.doi.org/10.1061/\(ASCE\)CO.1943-7862.0002145](http://dx.doi.org/10.1061/(ASCE)CO.1943-7862.0002145)
- Schaupp, E., Abele, E., & Metternich, J. (2017). Potentials of digitalization in tool management. *Manufacturing Systems 4.0*, 63, 144-149, 50th CIRP Conference on Manufacturing Systems, DOI: <http://dx.doi.org/10.1016/j.procir.2017.03.172>

MEASUREMENT OF DIGITAL MATURITY OF ENTERPRISES

Andreja Pucihar, Mirjana Kljajić Borštnar

Faculty of Organizational Sciences

University of Maribor, Slovenia

andreja.pucihar@um.si, mirjana.kljajic@um.si

DOI: 10-35011/IDIMT-2022-43

Keywords

Digital transformation, digital capability, organizational capability, digital maturity assessment

Abstract

Digital maturity indicates the degree of ability to take advantage of the opportunities offered by digital technologies. By measuring digital maturity, we can gain insight into the state of an individual company, as well as insight into the state of a number of companies, which allows companies and support institutions to take more appropriate actions in the digital transformation process. In this paper, we present a model for assessing the digital maturity level of small and medium-sized enterprises in Slovenia. We focus on the application of the model in practice and analyse the results of the assessment of the digital maturity level of 613 small and medium-sized enterprises. The results of the application have shown that the digital maturity assessment model has a high utility value in assessing an individual company, in gaining insight into the state of digitalization of a group of companies and in assessing the impact of measures to promote digitalization of small and medium enterprises.

1. Introduction

The development of digital technologies in recent decades dictates the evolution of organizations, society and also affects individuals (Pucihar, 2020). Organizations must adapt to changes in their environment if they want to remain competitive, evolve and grow. Organizational change is not a new phenomenon ((Nolan & Croson, 1995), but in the last two decades these changes have become more pronounced due to the emergence of digital technologies SMACIT (social, mobile, analytics, cloud, internet of things) (Pucihar et al., 2021). Therefore, today's changes in organizations and society are called digital transformation. This is reflected in radical changes in business that are felt at all levels of the organization and in all elements of business models (Wade, 2015). It is an ongoing process in which digital capabilities are redefining business processes, business models, employee connectivity, and the organization's connection with external stakeholders (Dehning et al., 2003; (Lucas et al., 2013). All of this brings new opportunities for creating new value (Pucihar, 2020; Jeansson & Bredmar, 2019), product and service innovation (Matt et al., 2015), changing relationships with customers and business partners, and the digitization of business models. Over the past two years, as the global economy has faced the Covid-19 epidemic, making it challenging to reach customers, deliver services, and producing products, digital technologies have also emerged as a solution for business continuity. It has also been shown that more digitally mature

companies were able to more easily overcome the challenges of the epidemic (Gourinchas et al., 2020).

Although today we know the benefits of digital technologies, many companies still face many challenges in building digital capacity and making the necessary organizational changes (Pucihar, 2020; European Commission, 2021). This is confirmed by various reports, such as the Digital Economy and Society Index Report (DESI index), which measures the digital competitiveness of European Union countries (European Commission, 2021a). A similar picture emerges from the European Commission and OECD reports, which find that small and medium-sized enterprises (SMEs) are struggling with digital transformation and lagging behind large enterprises (OECD, 2021). We have known about the problems SMEs face for decades. They date back to a time when information technology became an important resource to gain a competitive advantage (Buonanno et al., 2005; Ramdani et al., 2009). In the past, SMEs have also reported practical difficulties in implementing information technology (IT), lack of knowledge and skills in using technology, and lack of financial resources (Marolt et al., 2010; (Pucihar et al., 2016; Kartiwi & MacGregor, 2007; Macgregor & Vrazalic, 2005; Cragg & King, 1993). Data from the digital entrepreneurship report produced by SURS (SURS, 2021) show that the barriers to digital transformation are primarily in the following areas: Lack of knowledge and skills, lack of financial resources, lack of management flexibility, and lack of opportunities to experiment and innovate with digital technologies. Most companies still do not have a formally defined digitalization strategy. The problems also manifest themselves in management's lack of understanding of the opportunities presented by digital transformation. At the same time, large companies are somewhat more advanced and successful in digital transformation because they have more resources at their disposal (OECD, 2021). Although large companies are considered less flexible than SMEs, data show that even during the epidemic, large companies showed more resilience than SMEs (Gourinchas et al., 2020; OECD, 2021). It is therefore clear that we need to give more attention and support to SMEs on the digital transformation journey, which we also discuss in the paper.

In this article, we discuss the problem of measuring the digital maturity of SMEs to identify the areas where they need support. The problem of measuring digital maturity can be viewed as a multi-criteria problem of evaluating variants, where the variant is represented by a single company. To this end, we developed a hierarchical multicriteria model (Borštnar & Pucihar, 2021), which we linked to a web-based interface for data collection and an automatic feedback generator for SMEs that performs the evaluation. We also present aggregated data on the achieved digital maturity level of 613 companies that completed the assessment in the period from December 2020 to April 2021.

2. Digital maturity assessment methodology

The success of a company's digital transformation depends on a number of factors and not just on the use of digital technologies. Digitally mature organizations are more successful in this regard. However, in order for companies to choose appropriate approaches and activities on the path to digital transformation, it is important to understand the current state of digital maturity. Monitoring the digital maturity and transformation of companies is also of greater economic and social importance. Effective strategies and incentives for the digital transformation of the economy can only be developed by countries that have a good understanding of market realities.

2.1. Digital maturity assessment model

In collaboration with the Digital Innovation Hub (DIH Slovenia) and the company Arctur, we developed a multi-criteria model for assessing the digital maturity of Slovenian SMEs. The goal of DIH Slovenia is to help SMEs recognize the added value of digital technologies and help them with

digital transformation, thus increasing their competitive advantage. Although there are several assessment models and tools, they are either vendor-focused, address specific areas of digitalization or are targeted at large companies (Felch et al., 2019; Virkkala et al., 2020; Leino et al., 2017). The proposed model addresses different areas of digitalization (from technological and organizational perspective) and also some specifics and needs of domestic companies, which are generally also characteristic of the broader region and can therefore be used in a wider geographical area with minor adjustments. It is based on previous theoretical findings, but also considers existing models and strategic documents of the EU and Slovenia.

The development of the model followed the design science research approach (Hevner et al., 2004), with the qualitative multi-criteria decision method DEX (Bohanec & Rajkovič, 1999) in its core. A group of experts collaborated in the identification of the criteria, the definition of the measurement scales and criteria importance, and finally validation. The model was then tested (and refined) on 10 selected SMEs and implemented as a web tool. The model consisted of 34 basic and 17 aggregate attributes, arranged in a hierarchical tree structure. A discrete qualitative scale was defined for each attribute. Options are evaluated using utility functions defined for each aggregated attribute and used to transform the basic attribute values all the way to the final value – the digital maturity level. The utility functions are presented in the form of simple “if-then” rules, which provide transparent evaluation and explanation of the evaluation results (Bohanec & Rajkovič, 1999). The model is described in detail in (Borštnar & Pucihar, 2021).

2.2. SMEs assessment methodology

The model enables a transparent assessment of individual SMEs and also provides companies with comprehensive feedback on the situation in individual areas of digital transformation. By assessing a large number of companies, it also provides transparent insight into the situation of SMEs in Slovenia. By conducting continuous assessments, we can also track the evolution of the situation over time for an individual company or a group of companies, depending on the type of company and industry. This type of solution enables effective selection and monitoring of activities on the company's digital transformation path. The company receives an assessment of the current situation on the path of digital transformation, which allows it to prepare short- and long-term goals, as well as effective strategies and activities to achieve them.

The evaluation process is described in Figure 1. It begins with the company's registration in the web application, which is mandatory due to the application for funds from the DIHS Voucher Programme (<https://dihslovenia.si/vavcerji>). Registration in the system allows the company to interrupt the assessment process at any time and continue it later. In the first part, the company enters basic demographic data (size, region, activity according to the standard sector classification), and in the second part, it answers questions derived from the basic attributes of the model (34 questions). For each question there are defined answer options (scales), corresponding to the set of values of the respective attribute of the model. The companies answer the questions posed in relation to the current situation and the situation they would like to achieve in the next five years.

As shown in Figure 1, the digital maturity assessment consists of “digital capability” part, where the use of digital technologies, role of informatics, digital business model and strategy are assessed by 21 attributes, and “organizational capability” part, where human resources, organizational culture and management are assessed by 13 attributes.

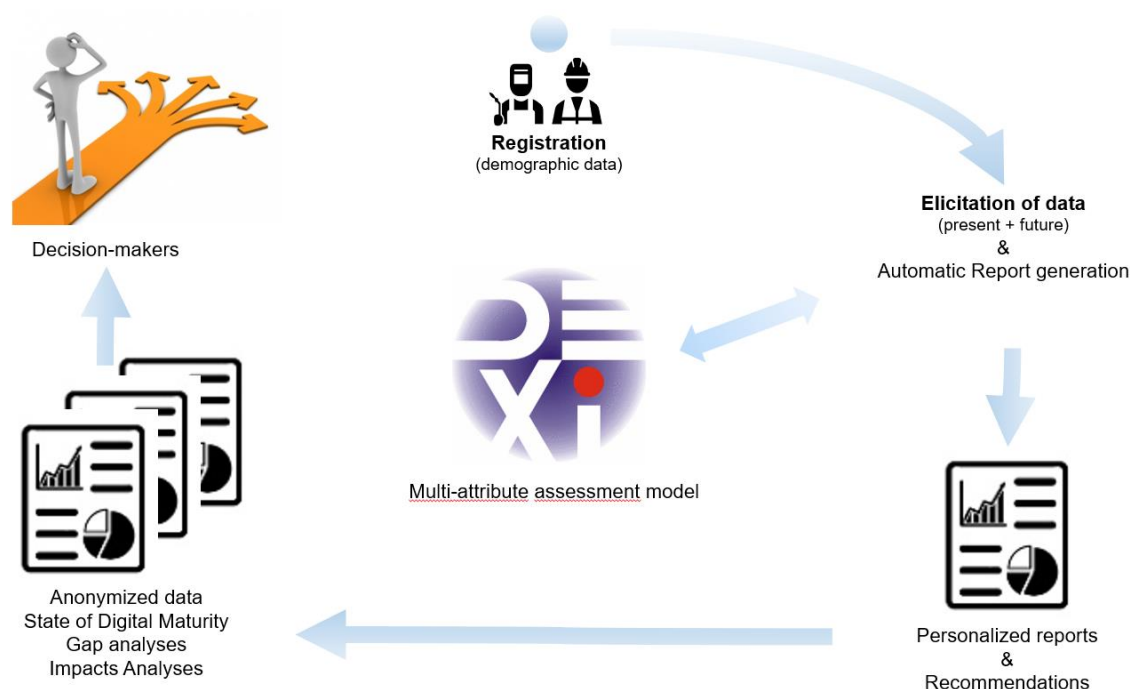


Figure 1: The automated digital maturity self-assessment process

The answers to the questions are automatically transferred to the model, which performs the final digital maturity assessment and returns to the user (company) an evaluation of the digital maturity level as well as a detailed analysis of the current state of digitalization and an assessment of the desired state. The Digital Maturity Assessment Model is implemented as an automated online digital maturity assessment tool (AAT) that transforms qualitative data into condensed information supported by visualizations for the user. It automatically generates transparent and clear reports with visualizations of the results and additional explanations and recommendations for further activities on the path to digital transformation in relation to the company's set goals.

3. Analysis of the results

The companies assessed between December 2020 and April 2021 have applied for the tender of digitization funds, which are announced by DIHS in conjunction with the Public Fund for Entrepreneurship to accelerate the digitization of SMEs. This means that the sample of companies is not randomly selected from the population. However, the basic demographic data shows that the target sample is similar to the population of Slovenian SMEs in terms of the share of SKD (standard sector classification), regions and size. Nevertheless, it is necessary to be careful when generalizing the results based on the analysed sample and it must be considered that those companies that are already aware of the importance of digitalization applied for the DIHS tender. The digital maturity assessment was carried out by 613 SMEs, of which 253 were micro (41%), 274 small (45%) and 86 (14%) medium-sized enterprises. Of all 613 companies, 396 companies received the rating "lagging behind", 214 received the rating "initial stage of digitalization" rating, and 3 companies received a "digital winner" rating. Figure 2 shows a more detailed insight into the assessment of the degree of digitalization by company size.

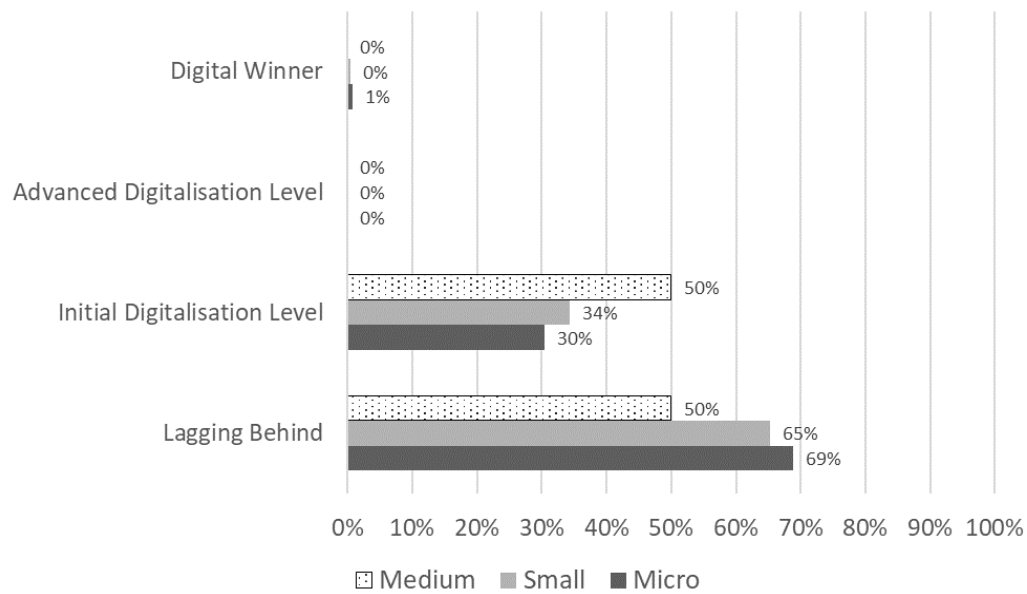


Figure 2: Assessment of the degree of digital maturity according to the size of companies

Of the three companies that received the "digital winner" rating, two have fewer than 10 employees, and the third is a small business. All three companies are in the "provision of other business-related services" industry. Most of the small and medium-sized enterprises are rated with the lowest rate (lagging behind), 179 smalls (65%), 174 micro (69%) and 43 medium-sized (50%). Among the companies assessed with an initial level of maturity, there are 94 smalls (34%), 77 micro (30%) and 43 (50%) medium-sized enterprises.

Further analysis of the assessment of the organizational and digital capabilities show that companies mostly perceive their digital readiness worse than the company's organizational capability, as shown in Figures 3 and 4.

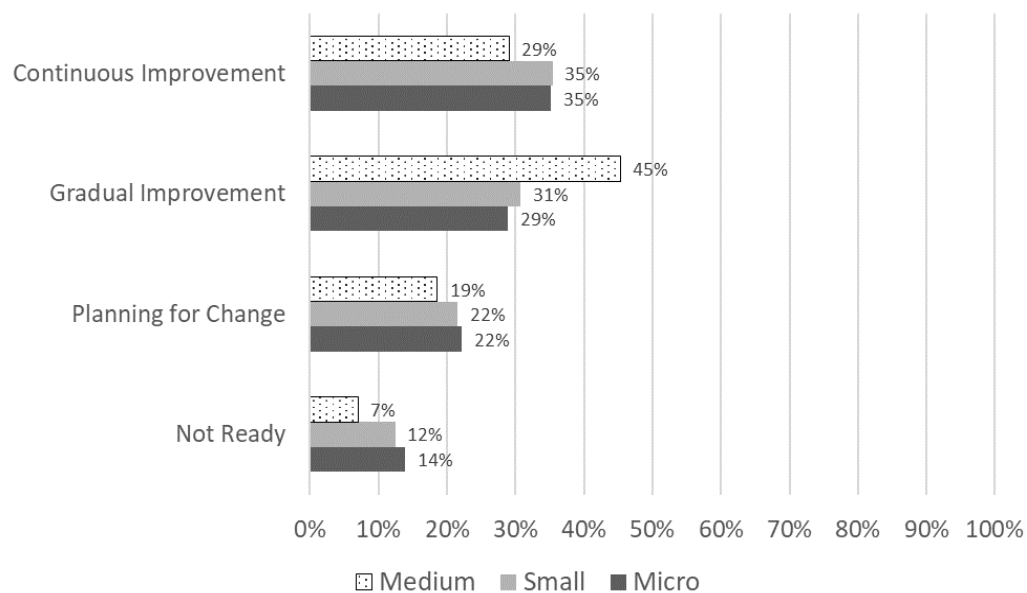


Figure 3: Organizational capability level according to the size of the company

The highest score, continuous improvement, was achieved by 211 (34%) of all SMEs, second highest, gradual improvement, was achieved by 196 (32%), planning for change achieved by 131 (31%) and only 75 SMEs were assessed as not ready (Figure 3).

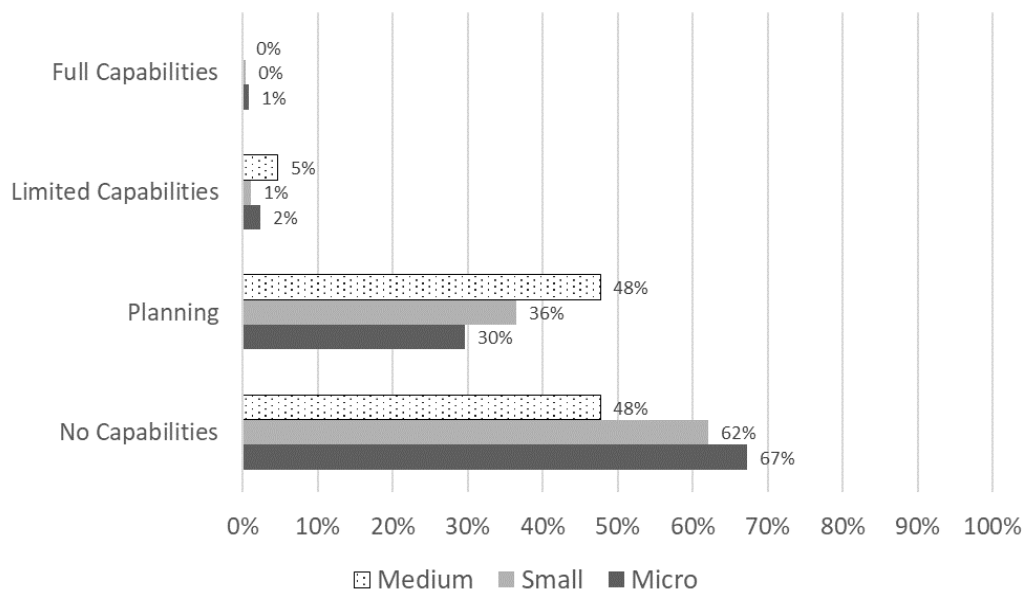


Figure 4: Digital capability level according to the size of the company

Figure 4 shows digital capability, measured on a four-level scale (no capability, planning, limited capabilities, and the highest - full capability) by company size. In general, most SMEs do not yet have digital capability (381 SMEs, up 62%) or are currently planning digital capabilities (216 SMEs, up 35%). Limited and full digital capabilities are achieved by only 16 SMEs. In detail, however, we see that as many as 170 micro and small enterprises and only 41 medium-sized enterprises fall into the "no capability" level. In addition, 100 small, 75 micro and 41 medium-sized companies landed in the "planning" capability level.

4. Discussion and Conclusions

In this paper, we present a methodology for assessing the digital maturity of SMEs, which is used as an automated self-assessment tool to obtain funding to accelerate the digital transformation of the company. The core of assessment methodology is the hierarchical multi-criteria model (Borštnar & Pucihar, 2021). After completing the questionnaire, SMEs received feedback on their digital maturity level and recommendations to help them plan further activities in the area of digitization and digital transformation. This represents added value and a comprehensive service in the area of digital maturity assessment.

Data from 613 companies that completed the assessment between December 2020 and April 2021 were analysed in this paper. We found that most of the assessed SMEs, 65%, achieved the “lagging behind” in digital transformation level, and 35% of them “early stages of digitalization”. The data is consistent with the data from the Statistical Office of the Republic of Slovenia, which shows that in 2021 most companies with at least 10 employees have a very low digital index (44%), 31% of them achieve a low digital index, a high digital index is achieved by 20% of companies and only 5% achieve a very high digital index. Most companies with a very low and low digital index are SMEs (SURS, 2021).

The indicators used to assess digital maturity using a multi-criteria hierarchical model and the digital index produced by SURS (in collaboration with Eurostat), which is based on several questions, are largely different and in some cases identical. However, both assessments suggest that the level of digitalization among SMEs is poor. Therefore, the various incentives, projects and resources that SMEs can invest in the area of digitalization and digital transformation in cooperation with the supporting environment are still very welcome.

In terms of further use and development of a digital maturity assessment model, the next step would be to revisit the criteria and their set of values based on a detailed analysis of SME assessment data and address any shortcomings. It would also be useful to check whether new criteria have emerged in the last two years that should be included in the model. The development of digital technologies and, in particular, the combination of the use of different technologies always brings new opportunities for change and innovation that should be considered. It would also be possible to adapt the model to assess the digital maturity of large companies.

In practice, it has become apparent that various models have been developed for assessing digital maturity. Some are generic and aimed at all companies, while others focus on specific areas of digital transformation or target organizations of different sizes. Recently, digital maturity assessment guidelines for eDIH (Network of Digital Innovation Hubs) were issued by the European Commission. Perhaps this is also an opportunity to develop a unified model at the EU level that allows for comparability of in-depth digital maturity assessment across regions, countries, industries, and company sizes, in addition to the SME assessment itself.

5. Acknowledgement

This research was supported by the Slovenian Research Agency: Program No. P5-0018— Decision Support Systems in Digital Business and Digital Innovation Hub Slovenia.

6. References

- Bohanec', M., & Rajkovič ', V. (1999). Multi-Attribute Decision Modeling: Industrial Applications of DEX. *Infoimatica*, 23, 487.
- Borštnar, M. K., & Pucihar, A. (2021). Multi-attribute assessment of digital maturity of smes. *Electronics* (Switzerland), 10(8). <https://doi.org/10.3390/electronics10080885>
- Buonanno, G., Faverio, P., Pigni, F., Ravarini, A., Sciuto, D., & Tagliavini, M. (2005). Factors affecting ERP system adoption: A comparative analysis between SMEs and large companies. *Journal of Enterprise Information Management*, 18(4), 384–426. <https://doi.org/10.1108/17410390510609572>
- Cragg, P. B., & King, M. (1993). Small-Firm Computing: Motivators and Inhibitors. *MIS Quarterly*, 17(1), 47. <https://doi.org/10.2307/249509>
- Dehning, B., Richardson, V. J., & Zmud, R. W. (2003). The value relevance of announcements of transformational information technology investments. *MIS Quarterly: Management Information Systems*, 27(4), 637–656. <https://doi.org/10.2307/30036551>
- Digital for SMEs - OECD Digital for SMEs Global Initiative. (n.d.). Retrieved January 28, 2022, from <https://www.oecd.org/digital/sme/>
- European Commission. (2021a). Digital Economy and Society Index – DESI. Clinical Epigenetics. <https://digital-strategy.ec.europa.eu/en/library/digital-economy-and-society-index-desi-2021>
- European Commission. (2021b). Shaping Europe's Digital Future Policy. Digital Innovation Hubs (DIHs) in Europe. <https://digital-strategy.ec.europa.eu/en/activities/edihs>

- Felch, V., Asdecker, B., & Sucky, E. (2019). Maturity Models in the Age of Industry 4.0 – Do the Available Models Correspond to the Needs of Business Practice? Proceedings of the 52nd Hawaii International Conference on System Sciences. <https://doi.org/10.24251/hicss.2019.620>
- Gourinchas, P.-O., Kalemli-Özcan, Şebnem, Penciakova, V., Sander, N., Decker, R., Martin, P., Neiman, B., Ragot, X., Sraer, D., Thesmar, D., & Wang, J. (2020). COVID-19 AND SME FAILURES. <http://www.nber.org/papers/w27877>
- Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly*, 28(1), 75–105. <https://doi.org/10.2307/25148625>
- Jeansson, J., & Bredmar, K. (2019). Digital Transformation of SMEs : capturing complexity. 32nd Bled EConference Humanizing Technology for a Sustainable Society : June 16 – 19, 2019, Bled, Slovenia: Conference Proceedings, 523–541. <https://doi.org/10.18690/978-961-286-280-0>
- Kartiwi, M., & MacGregor, R. C. (2007). Electronic Commerce Adoption Barriers in Small to Medium-Sized Enterprises (SMEs) in Developed and Developing Countries: A Cross-Country Comparison. *Faculty of Informatics - Papers (Archive)*, 5(3), 35–51. <https://doi.org/10.4018/jeco.2007070103>
- Leino, S.-P., Kuusisto, O., Paasi, J., & Tihinen, M. (2017). VTT Model of Digimaturity. Towards a New Era in Manufacturing.
- Lucas, H., Jr., Agarwal, R., Clemons, E. K., El Sawy, O. A., & Weber, B. (2013). Impactful Research on Transformational Information Technology: An Opportunity to Inform New Audiences. *MIS Quarterly*, 37(2), 371–382. <https://www.jstor.org/stable/43825914>
- Macgregor, R. C., & Vrazalic, L. (n.d.). A basic model of electronic commerce adoption barriers A study of regional small businesses in Sweden and Australia. <https://doi.org/10.1108/14626000510628199>
- Marolt, Marjeta, University of Maribor, F. of O. S., Andreja Pucihar, University of Maribor, F. of O. S., & Lenart, Gregor, University of Maribor, F. of O. S. (2010). Uporaba IKT in trendi e-poslovanja med malimi in srednje velikimi podjetji v Sloveniji = ICT usage and e-business trends among small and medium-sized enterprises in Slovenia. In T. KERN (Ed.), Človek in organizacija: zbornik 29. mednarodne konference o razvoju organizacijskih znanosti = People and organization: proceedings of the 29th International Conference on Organizational Science Development. Moderna organizacija.
- Matt, C., Hess, T., & Benlian, A. (2015). Digital Transformation Strategies. *Business & Information Systems Engineering*, 57(5), 339–343. <https://doi.org/10.1007/s12599-015-0401-5>
- Nolan, R. L., & D. C. Croson. (1995). Creative Destruction: A Six-Step Process for Transforming the Organization. Harvard Business School. <https://www.hbs.edu/faculty/Pages/item.aspx?num=243>
- Pucihar, A. (2020). The digital transformation journey: content analysis of Electronic Markets articles and Bled eConference proceedings from 2012 to 2019. *Electronic Markets*, 30(1), 29–37. <https://doi.org/10.1007/s12525-020-00406-7>
- Pucihar, A., Lenart, G., Marolt, M., Borštnar, M. K., & Maletič, D. (2016). Role of ICT in business model innovation in SMEs - Case of Slovenia. IDIMT 2016 - Information Technology, Society and Economy Strategic Cross-Influences - 24th Interdisciplinary Information Management Talks.
- Pucihar, A., Marolt, M., Lenart, G., & Vidmar, D. (2021). Digitalna preobrazba in njeno stanje v organizacijah v (U. Rajković & A. Baggia (Eds.)). University of Maribor Press. <https://doi.org/https://doi.org/10.18690/978-961-286-509-2.1>
- Ramdani, B., Kawalek, P., & Lorenzo, O. (2009). Predicting SMEs' adoption of enterprise systems. *Journal of Enterprise Information Management*, 22, 10–24. <https://doi.org/10.1108/17410390910922796>
- SURS. (2021). Digitalno podjetništvo, podrobni podatki, Slovenija, 2021 Podjetja v vzhodni Sloveniji izkazujejo nižji digitalni indeks.
- Virkkala, P., Saarela, M., Hänninen, K., & Simunaniemi, A.-M. (2020). Business Maturity Models for Small and Medium-Sized Enterprises: A Systematic Literature Review.
- Wade, M. (2015). Digital Business Transformation A Conceptual Framework.

EVALUATION OF BUSINESS MATURITY CONCERNING ROBOTIC PROCESS AUTOMATION

Klára Antlová, Petra Rydvalová, Martin Zelenka

Faculty of Economics
Technical University of Liberec

klara.antlova@tul.cz, petra.rydvalova@tul.cz, martin.zelenka@tul.cz

DOI: 10-35011/IDIMT-2022-51

Keywords

Business Process Management, Robotic Process Automation, Return on Investment, Maturity of the process

Abstract

This paper aims to evaluate the state of the company's processes in terms of maturity for implementing robotic process automation (RPA). The goal is to formalize the degree of maturity of the company concerning RPA. In connection with a brief insight into the development of the company's process management, the authors deal with the impact of RPA on the company's operation and its impacts caused by changes in human resources management, measuring the return on investment in RPA and RPA process life cycle. Based on these findings, the authors developed a model which evaluates the state of automation of automated processes in the company. The model was subsequently verified in selected economic entities from various sectors of the economy (manufacturing and services).

1. Introduction

The process management of the company was developed in several stages. The forerunner of procedural control was a functional approach to business management by Adam Smith (2014). Its essence lies in dividing production processes into smaller and simpler tasks. Around 1920, Frederick W. Taylor came up with running the business based on analyses, methods, and procedures. According to M. Hammer and J. Champy (1999), the next stage is the concept of business reengineering processes in the 1990s (BPR). The following stage is the creation of processes during and across the business, where a process map helps their modeling and optimization. We speak about business process management (BPM). Its goal is to ensure the company in all its ties and the dynamics of change using the possibilities of information technology. A way how-to expand process control opportunities is robotic process automation (RPA). The issue addressed in this text is to assess the stage of the company's processes in terms of maturity for the implementation of RPA. Digitization is nothing new, so robots are already a well-known phenomenon. Automation comes from manufacturing companies (Baranauskas, 2018) and penetrates even those of a non-manufacturing nature, focusing on the client service process. Process automation using software bots attracted attention (Hofmann et al., 2020). The term bot is further used for a software robot to distinguish it from general robots. Company Gartner (2022) defines robotic process automation as a tool that allows you to execute if-then-else statements on structured data, typically using a combination of user environments or by connecting via API or HTML code.

RPA tools are controlled by mapping the process to be followed into the RPA language. The process script is executed in allocated computational time (Kedziora et al., 2021). RPA automates processes where human costs are higher (and not required) and where another type of automation is too expensive or simply not appropriate (Hofmann et al., 2020). Activities or even individual tasks are performed as humans would do. A person's behaviour may be imitated, so other systems may not know that someone has been replaced. The most typical for automation are standardized, rule-based processes (i. e., no creative thinking, evaluation or decision-making required), are performed frequently and manually by people, and direct access to multiple environments/systems (Hofmann et al., 2020). RPA is far from the first of the 'initiatives' to change the company's process map. One of them is Business Process Management (BPM). At first glance, the relationship between RPA and BPM may seem like they have a similar goal - to make processes work better. BPM is about changing the process through its redesign which leads to process efficiency. BPM focuses on building the foundation of the process, its orchestration, systems and data integration. RPA goes the way of automating the existing process and its tasks. RPA is not invasive towards the environment and preserves the original infrastructure and ecosystem (Doguc, 2022).

Specifically in the financial sector, the term Straight Through Processing (STP) appears, which, similar to RPA, refers to the omission of the human element from processes. Classic STP requires intervention in systems or replacement of systems by others and therefore is suitable for some of the operations. RPA can work in almost any environment (van der Aalst et al., 2018). BPM and RPA can coexist successfully (Doguc, 2022). RPA is a very young technology. Except for the first few suppliers (namely UiPath, Blue Prism and Automation Anywhere), most suppliers appeared after 2016 (van der Aalst et al., 2018). It isn't easy to look for some universal best practices after such a short time. Academic and professional studies are delayed, and some questions are not answered (van der Aalst et al., 2018). The literature review brings some questions connected to the state of affairs in the implementation of RPA. Whether it is a novelty for companies or an established technology, degrees of maturity should be formed from the view of the RPA, which will make it possible to measure the market situation and also provide guidance to individual companies on how to proceed in the case of the implementation of the RPA. This paper aims to formalise RPA maturity at the company level. To achieve this goal, the authors designed the research sub-objectives:

S-O1: A survey of current literature concerning the maturity of the implementation of RPA and the definition of critical factors for the evaluation of process maturity.

S-O2: Qualitative interviews in companies using RPA as a pilot study.

2. Literature review

RPA tools can effectively replace some of the sub-activities in the company. Based on the functionalities of RPA tools, they are divided into three areas: data, integration and process. In the data area, these are mainly activities related to data transmission (e.g. encryption or file upload), file processing (e.g. format change) and data analysis (e.g. report creation or transcription of speech into text). In the integration area, the activities are related to controlling and other applications (e.g. writing to a cell in Excel), invoking available (cloud) services (e.g. creating a post on a social network) or controlling (imitating control) input devices (e.g. clicking, 'drag and drop', closing the application). In the process area, the activities are dependent on a specific trigger (e.g. uploading a new file) or controlling the sequence of activities itself (e.g. order processing cycle) (Hofmann et al., 2020).

2.1. Positive effects of RPA

RPA brings primary (direct) and secondary (indirect) benefits. Primary ones are easier to measure. They include, for example: increasing efficiency, reducing errors and reducing the number of employees (or eliminating the need to hire new ones). Secondary benefits cannot be accurately measured but may be more crucial for a company with a long-term market position. Secondary benefits include asset flexibility, improved customer experience, faster scalability, and increased job attractiveness (Doguc, 2022).

Primary impacts are often measured by saving staff costs per year (Kedziora et al., 2021). A more flexible environment, thanks to RPA, is not limited only to existing processes but can enable the emergence of new ones (Doguc, 2022). For example, the dependence and limitations resulting from so-called 'legacy systems' persist in the banking sector. These secure systems from the 1980s and 1990s cannot be easily replaced. These systems can be a barrier to new products or sales channels. RPA will make it possible to operate from the point of view of these 'old age' systems without system integration, thanks to the fact that the existing interface will be used in these systems. In addition, the risk of failure can be reduced. The risk of failure can be high for legacy systems in the event of systematic intervention, as a generation of their creators has already retired (Gregusova, 2021).

2.2. Changes for employees

Due to its nature, RPA is not an isolated activity. It can affect many positions in the company - IT, audit, risk management, compliance, legal, human resources management, etc. (Hofmann et al., 2020). When starting with an RPA, you need to understand its principles and technologies. The dissemination of information and knowledge about RPA across the company must be at least transparent where the employee will get answers to their questions about RPA. Ignorance and concern are the main obstacles to the successful implementation of RPA (Zelenka & Vokoun, 2021). In particular, the collaboration between IT and business units is key to successful RPA (Hofmann et al., 2020).

2.3. RPA return measurement

The classic approach to measuring RPA return on investment is to compare invested costs to profits, defined as the difference between benefits and costs, see (1), (Doguc, 2022):

$$\text{Return on Investment(ROI)} = (\text{yield on investment} - \text{investment costs}) / \text{investment costs} \quad (1)$$

In business practice, investments in RPA is as an optimization problem of maximizing the economic value of individual automated processes in conditions of budgetary and investment constraints (Wanner et al., 2019). Process automation is a one-time investment, but it has no defined end, as it can run for years. In the long run, additional costs may occur. One can even imagine a situation where RPA is an obstacle to further development, see chapter 3. For this reason, it makes sense to evaluate the return in a low number of years. A project with a return on investment more than three years is not recommended for RPA (Wanner et al., 2019). The literature brings cases with a one-year ROI, ranging between 30 and 200%, depending on the type of process (Willcocks et al., 2018). The return on investment in RPA must be assessed at the level of individual processes before selecting automation. Disappointment from RPA projects stems from the fact that the estimates of benefits are determined based on the subjective opinions of the employees involved in the actual process (Wanner et al., 2019). Prevention is the definition of the objective indicators, which may not be accessible at the beginning of RPA projects due to the company's inexperience (Vokoun & Zelenka, 2019). In principle, measuring returns using ROI

makes sense, but it is necessary to think about costs and benefits, as both are not so easy to determine (Leno et al., 2021).

2.4. RPA cost

The total cost of ownership (TCO) of the process owners can be used to estimate the costs. This principle is either already applied in companies or has been introduced in the context of RPA, as it makes more sense than a direct cost approach (Willcocks et al., 2018). By TCO, we mean technical costs, labour costs, costs associated with organizational change, operating costs and costs related to replacement/upgrade at the end of the life cycle. It is necessary to assess fixed and variable costs - and differentiate them for decision-making (Wanner et al., 2019). There are guidelines for minimizing the costs associated with RPA, which typically recommend best practices for each phase of the life cycle (Noppen et al., 2020).

2.5. Life Cycle of the RPA process

Deployment of RPA bots is not immediate, but the implementation is by using multiple phases (Enríquez et al., 2020). We can distinguish between these phases:

1. The analytical part means more candidates for processes for automation.
2. Process description/design means the detailed description of the process for selected processes, including the environment and the decision of the actions assigned to the bot.
3. Bot design means that the bot implementation is based on the process described in parts suitable for automation.
4. Deployment of the bot means creating an environment in which the bot can work (e.g. user rights, placement on the server), including creating contact points with the environment/person.
5. Control phase and monitoring (babysitting) - deployment is typically not one-time but has a transition period where the bot's functionality is tested and possible errors are sought.
6. Functioning itself + evaluation of performance - even in full deployment of the bot, it is necessary to monitor its performance and evaluate the success of the deployment.

Measuring the entire life cycle of RPA bots (and automated processes) is essential for further direction so as not to focus only on 'cherry-picking' of the process (choosing only high ROI). The strategic advantage of RPA can give the company a real competitive advantage or ensure that it keeps pace with the competition.

3. RPA maturity in the company

The inspiration for finding a business maturity model from the point of view of RPA are maturity models of business processes (e.g. Tarhan et al., 2016) and business readiness models for Industry 4.0 (e.g. Zoubek et al., 2021). RPA is strongly tied to the maturity of processes (Costin, 2020) and allows the implementation of Industry 4.0 technologies (Ribeiro et al., 2021). With its position on the edge of approaches based on process optimisation and the performance of intelligent systems, it deserves a different reflection on the maturity approach in the company. RPA is based on the practical needs of companies; theoretical support in connection with the models of process maturity is waiting for a more detailed examination (Baranauskas, 2018).

Balasundaram & Venkatagiri (2020) distinguish 3 phases concerning the maturity of RPA in business: Initiation, industrialisation and institutionalisation. The initialisation phase can be divided into two depending on whether it is the level of the entire company or a specific department. It must occur in both, so the result is the automation of a particular process. At the enterprise level, there must be a technical (e.g. from an IT point of view), organisational (e.g. roles and decision-making) and competent environment (e.g. RPA and business analysts) that RPA will enable. At the level of a specific department, it is necessary to name the required roles, set up decision-making, provide training to employees and try automation on the first processes. The business case does not play a crucial role here; it is a matter of learning to work with RPA. The industrialisation phase mainly expands RPA, repeats a functioning model, and seeks best-practice. In this phase, opportunities for automation are actively sought, the leading work team is decided on, and the architecture is gradually changing. Business cases of the individual processes play a role. The institutionalisation phase (at the strategic) level leads to deciding which activities will be entrusted to the people and the bots. It is no longer a question of finding specific processes but instead of changing the entire company, including building the necessary architecture. This phase is also about increasing the efficiency of automated processes, including minimising the risks associated with a possible failure of the RPA infrastructure.

Willcocks et al. distinguish four stages of company maturity by using RPA (2018). Their division depends mainly on how the benefits of RPA are perceived. In the first phase, there is an 'intoxication of returns on investment' - it does not have to be a company-wide initiative but automation of those 'glaring' places where it makes sense. The second phase is about reducing costs. The focus is already on engaging on a broader and common platform in the company. The risks of RPA appear, and the company recognises examples of good and bad practices. Between the second and third phases, the steepest learning takes place. The company has examples of automated processes; learning takes place through training. The company must find its way and its position towards RPA that fits into its strategy. The third phase comes to the search for compliance for the main parties involved, i.e. moving towards a so-called 'triple-win' situation, where customers, employees and shareholders benefit from RPA (Willcocks et al., 2018). Customers get new, better and faster services. Employees work in an environment where they gain more experience, flexibility, and less routine. Shareholders can achieve a controlled regulatory environment and scalability, as mentioned earlier. The fourth phase represents blending with the overall strategy of the company. And to do this, everyone must find their way through their understanding of the benefits and risks of RPA. Automation is no longer a separate area in terms of innovation but fits into the overall innovation strategy. According to the authors, the transition from the first two phases to phases three and four takes about three years (Willcocks et al., 2018).

Wewerka et al. (2020) pay attention to an important area in the RPA maturity model, user acceptance. According to their modification of the General Technology Acceptance Model (TAM), they see the main factors in useability: results, a good sense of innovation, and social influence. A company with a high maturity will have a well-described, documented and pleasant environment that users will trust. There will be measurable results, including quality reports of automated processes. Users will be highly trained. Management will ensure quality and human communication, including personal involvement, so bots do not become "enemies". Process maturity is one of the critical success factors of RPA in the company (Leshob et al., 2018). In addition to inspiration from process maturity models, it is necessary to include the maturity of processes as one of the critical dimensions. When the company moves towards creating an RPA Center of Excellence, the following changes representing maturity should be gradually achieved. (Juntunen, 2021):

1. Extension of robust methods, techniques, and tools to support RPA projects.
2. Unification of RPA management procedures (governance), unification of RPA-related services (design, development, operation and maintenance) and introduction of central ownership of RPA.
3. Linking RPA with business strategy. Establishing the RPA project portfolio management (business units then manage individual projects). A proactive approach to project selection (no proposals expected).

4. Methodology and research results

Based on the above findings, a model was developed to evaluate the state of robotic automation of automated processes in the company. The RPA maturity level determination model is based on four areas and four maturity levels matrix according to Wilcocks et al. (2018): 1. Initiating and Proving, 2. RPA is establishing and part of processes, 3. Scaling and 4. Establishing – part of the strategy. These factors with the degree of statements were defined for each area to make a clear self-evaluation possible. This model allows the company to get feedback on the state of implementation of RPA when the most valuable phase is the search for fulfilment of given factors. The authors deeply interviewed two managers with a long experience responsible for the RPA implementation at the end of 2021. Both managers are from companies operating in the Czech Republic. These companies are significant in terms of the number of employees and economic indicators (banking and manufacturing in the automotive industry). Table 1 provides the evaluations carried out in the interviews by the experts in charge of the development and implementation of RPA in the institutions examined. The status level was assessed based on statements from interviews (based on the factors in table 1) that describe the stage of RPA maturity level in a given economic entity.

Table 1: RPA - Evaluation of respondents (A=automotive, B=bank)

Area	Factor	Maturity level			
		1	2	3	4
Strategy / Management	Measuring success			A, B	
	Management method		A		B
	Internal goals of the RPA process		A		B
Technology / Processes	RPA technology			A, B	
	IT governance	A			
	Level of RPA implementation process			A	B
Users	People/roles		A		B
	Knowledge of RPA		A		B
	Technology acceptance		A	B	
RPA deployment areas	Process selection method		A	B	
	Task types for RPA		A		B
	Data			A	B

Respondents were also asked:

- To confirm/not confirm that for each factor, if they followed previous steps (or solved challenges they represent)
- To confirm/not confirm that for each factor, the higher maturity level represents the further direction of RPA

Both respondents confirmed that the suggested maturity step represents their experience, style of management, relationship with the IT and business strategy, and the aims for the future. They offer slight changes in the wording but not structural changes in the suggested levels. There was an important suggestion for the Internal goals of the RPA process. For higher maturity levels, the development and operation of RPA must be separated, which is necessary for scalability. The RPA may work in desktop mode for higher maturity levels, but only if these desktops are virtual – the bot „owns“ its desktop. The authors asked respondents to suggest areas not covered by the factors in the model. Both respondents indicated that the model does not cover the Quality of RPA operation in their wording. Therefore this factor the authors added to the model. The highest level of this factor expects the RPA to operate with a few exceptions and in an optimal way (this should be added to the monitoring component helping to optimize the RPA services).

5. Conclusion

The implementation of the RPA is more and more often in the companies, and the authors of the article intended to search for the quality of performance. They used the maturity models of business processes. After the pilot study in two companies with long experience, they designed and verified the proposed model with four maturity levels. This model differs from the General Technology Acceptance Model in understanding and emphasising quality. The authors see the limit of the pilot model in the weights of uniform factors which were not determined at this stage of the research. In addition to the weighting of factors, further research should focus on the maturity of companies in this area in terms of different industry sectors. It would be helpful to supplement the research with international comparisons. RPA, which works in conjunction with Artificial Intelligence (IPA), has the potential to completely change the job market and the expectations of 'white-collar' jobs. Therefore, these technologies should not be overlooked in business support programs. In this context, some verification of the maturity of RPA in the company makes sense. The authors expect to develop and improve this pilot model in future.

6. Acknowledgement

The article was supported by Internal Grant Project (26_KA) EF TUL.

7. References

- Balasundaram, S., & Venkatagiri, S. (2020). A structured approach to implementing Robotic Process Automation in HR. *Journal of Physics: Conference Series*, 1427(1), 012008.
- Baranauskas, G. (2018). Changing patterns in process management and improvement: Using RPA and RDA in non-manufacturing organisations. *European Scientific Journal*, 14(26), 251–264.
- Costin, B. V. (2020). Sap And RPA Implementation In Production Area-Risks During The Pandemic Periode. A Case Study. *Annals-Economy Series*, 6, 118–123.
- Doguc, O. (2022). Robot process automation (RPA) and it's future. In *Research Anthology on Cross-Disciplinary Designs and Applications of Automation* (pp. 35–58). IGI Global.
- Enríquez, J. G., Jiménez-Ramírez, A., Domínguez-Mayo, F. J., & García-García, J. A. (2020). Robotic process automation: A scientific and industrial systematic mapping study. *IEEE Access*, 8, 39113–39129.
- Gartner. (2022). Robotic Process Automation (RPA) – Glossary. Available from: <https://www.gartner.com/en/information-technology/glossary/robotic-process-automation-rpa>.
- Gregusova, J. (2021). 5 Ways Process Mining and Robotic Process Automation Complement Each Other. <https://www.minit.io/blog/5-ways-process-mining-and-robotic-process-automation-complement-each-other>

- Hammer, M & Champy, J. (1999). *Reengineering the Corporation*, Allen & Unwin Pty., Limited, 1999, ISBN-13 978-1863737067
- Hofmann, P., Samp, C., & Urbach, N. (2020). Robotic process automation. *Electronic Markets*, 30(1), 99–106.
- Juntunen, A. J. (2021). *Scaling Up Robotic Process Automation Capabilities Organisation-Wide*.
- Kedziora, D., Leivonen, A., Piotrowicz, W., & Öörni, A. (2021). Robotic Process Automation (RPA) Implementation Drivers: Evidence. *Information Systems*. Tornbohm, C., & Dunie, R. (2017). *Gartner market guide for robotic process automation software*. Report G00319864. Gartner.
- Leno, V., Polyvyanyy, A., Dumas, M., La Rosa, M., & Maggi, F. (2021). Robotic process mining: Vision and challenges. *Business & Information Systems Engineering*, 63(3), 301–314.
- Leshob, A., Bourgouin, A., & Renard, L. (2018). Towards a process analysis approach to adopt robotic process automation. 2018 IEEE 15th International Conference on E-Business Engineering (ICEBE), 46–53.
- Noppen, P., Beerepoot, I., Weerd, I., Jonker, M. & Hajo R. (2020). How to Keep RPA Maintainable? 18th International Conference, BPM Seville, Spain, September 13–18, 2020.
- Smith, A. (2014) *The Wealth of Nations*, Shine Classics, ISBN 978-1505577129
- Tarhan, A., Turetken, O., & Reijers, H. A. (2016). Business process maturity models: A systematic literature review. *Information and Software Technology*, 75, 122–134.
- Taylor, F.W. (1997) *Principles of Scientific Management*, Dover Publications Inc., ISBN: 9780486299884
- Van der Aalst, W. M. P., Bichler, M., & Heinzl, A. (2018). Robotic Process Automation. *Business & Information Systems Engineering*, 60(4), 269–272. <https://doi.org/10.1007/s12599-018-0542-4>
- Vokoun, M., & Zelenka, M. (2019). Robotic process automation in the Czech financial sector. 14th International Conference on Liberec Economic Forum.
- Wanner, J., Hofmann, A., Fischer, M., Imgrund, F., Janiesch, C., & Geyer-Klingenberg, J. (2019). Process selection in RPA projects—towards a quantifiable method of decision making.
- Wewerka, J., Dax, S., & Reichert, M. (2020). A user acceptance model for robotic process automation.
- Willcocks, L., Hindle, J., & Lacity, M. (2018). Keys to RPA success. Executive Res. Rep., Knowl. Capital Partners, USA, Tech. Rep.
- Zelenka, M., & Vokoun, M. (2021). Information and Communication Technology Capabilities and Business Performance: The Case of Differences in the Czech Financial Sector and Lessons from RPA. *Review of Innovation and Competitiveness: A Journal of Economic and Social Research*, 7(1), 99–116.
- Zoubek, M., Poor, P., Broum, T., Basl, J., & Simon, M. (2021). Industry 4.0 maturity model assessing environmental attributes of manufacturing company. *Applied Sciences*, 11(11), 5151.

A NOVEL APPROACH TO BUSINESS PROCESS ANALYSIS AND OPTIMIZATION BASED ON ENTERPRISE ARCHITECTURE: A CASE OF LOCAL PUBLIC ADMINISTRATION IN THE CZECH REPUBLIC

Martin Lukáš, Tereza Čížková, Miloš Ulman

Department of Information Technologies
Faculty of Economics and Management
Czech University of Life Sciences Prague
lukas@pef.czu.cz, cizkovat@pef.czu.cz, ulman@pef.czu.cz

DOI: 10-35011/IDIMT-2022-59

Keywords

Digital transformation, enterprise architecture, public administration, business architecture, business process.

Abstract

Digital transformation projects in public administration are inherently complex and prone to failure. Stakeholders who do not understand information system analysis and software engineering methods need to put significant effort into reading and understanding the business process models created during the initial analysis. The paper presents a novel method of business process analysis and optimization in public administration based on enterprise architecture methods. We developed and pilot-tested the method within two local public administration digital transformation projects in the Czech Republic. We interviewed 21 respondents and devised process cards in a simple tabular format. Substituting detailed process maps in BPMN, decision trees, and state and transition diagrams with process cards, tables, and high-level diagrams in ArchiMate was very well comprehensible for stakeholders in both cases. The paper contributes to the theoretical understanding of the impacts of business process modeling methods on communication and understanding between various stakeholders of digitalization projects. The practitioners such as managers and subject matter experts in public administration may benefit from reduced time spent on the project specification and analysis of business processes.

1. Introduction

According to a 2020 PwC survey of 2,380 executives, only 5 % of them were seeing some tangible benefits of digital transformation projects (PwC, 2020). Failure in digital transformation projects is one of the major issues (Kozak-Holland & Procter, 2020). The reasons of failure are numerous – starting from a digital strategy formulation and implementation (Correani et al., 2020), lack of digital culture (Hemerling et al., 2018), omitting a broader socio-technical scope of the project (Datta, 2020), various forms of organizational inertia (Hur et al., 2019), or having a large number of systems supporting organizations operations (Kozak-Holland & Procter, 2020).

The Czech Republic has average to below-average results in digitization within Europe. According to the Digital Economy and Society Index (DESI), the Czech Republic ranked 18th out of 27 EU Member States in 2021, down one place from 2020 (EC, 2021). Since the Czech Republic accession to the EU, many central eGovernment projects have been implemented, such as the Basic Registers Information System, eGON ServiceBUS, CzechPoint, Electronic Law Collection, and Electronic Legislation, Redesign of the Statistical Information System, Central Service Point, eGovernment Cloud, Data Box Information System, Citizen Portal, eNeschopenka, eRecept, a digital wallet covid-19 certificate and verification apps (Tečka, čTečka), National Identity Authority / eGovernment Key, Public Administration Communication Infrastructure, and National Catalogue of Open Data. However, the success rate of the projects has been often disputed (e.g., Horák et al., 2020; Špaček, Csótó and Urs, 2020). Although the central eGovernment projects have been essential for building solid foundations for a deeper digitalization of public administration, the main challenges that have been remaining unaddressed are more on the client side of the digital services. Creating secure, simple, and connected services for public administration clients is yet to be done. Co-financing by the European structural Funds aimed at the digitalization of public and private sector projects is an opportunity (Lukáč & Ganobčík, 2021).

Public organizations increasingly more often devise enterprise architecture (EA), a well-established framework describing various aspects of an organization both from business and IT perspectives. EA provides instruments facilitating communication, cooperation, and better understanding between various stakeholders (Kotusev, 2017). Therefore, EA is seen as an approach to contain organizational complexity by creating a clear overview of the business functions, processes, and information systems. (Niemi & Pekkola, 2020). Further, EA should contribute to a more efficient implementation of e-Government projects and help to achieve benefits (Kristin et al., 2018; Tamm et al., 2011). The benefits that EA delivers to individual projects and whole organizations have been extensively researched in numerous meta-reviews (e.g., Foorthuis et al., 2016; Lumor, Pulkkinen and Hirvonen, 2019)

A particular area of interest in digital transformation projects is the phase of project scoping and analysis of current business processes and functions of the organizations. This is when an analytical team interviews stakeholders and process owners and develops process maps and models by using information system analysis methods and tools such as BPMN diagrams. However, stakeholders usually do not understand these methods, and reading and understanding the business process models require from them significant cognitive and mental effort (Figl & Laue, 2011; Wang et al., 2016). This results in erroneous and reluctant communication between subject matter experts and analysts, which may, in the final turn, result in misspecification and delay of a digital transformation project.

The paper presents a novel method of business process analysis and optimization in public administration. The method draws on the methods of EA. We developed and pilot-tested the method within two local public administration digital transformation projects in the Czech Republic. The paper is structured as follows. Section 2 offers a literature review on enterprise architecture and business process analysis and modeling. In Section 3, we present a sample of respondents that we surveyed during two digital transformation projects in the Czech Republic and EA methods used for the business process analysis. Section 3 summarizes the results of two surveys and interprets the findings. Section 4 summarizes the implications and proposes further research directions.

2. Literature review

2.1. Enterprise architecture

EA involves a structured top-down approach to understanding and designing areas such as motivations and goals of the organization, how to meet those goals through processes and agendas, and how to support the processes and agendas with ICT (Kotusev, 2017). The creation of the EA aims to develop a clear and transparent model of the organization covering all the above areas that the organization provides (so-called as-is, or current state model) and should provide (so-called to-be, or future state model) (Foorthuis et al., 2016). ArchiMate, a graphical modeling language, is used to represent EA. It is primarily used to represent, describe, and analyze the organization and its architecture. The language allows visualizing different views (aspects) of the organization. The graphical symbols and terminology of ArchiMate are very close to the TOGAF framework created by The Open Group. ArchiMate answers the question "how", while TOGAF answers the question "what" (Lankhorst, 2017).

Among the benefits delivered by EA are the support of compliance, support to achieve key business goals, management of organizational complexity, facilitating standardization, deduplication and integration of processes and systems, and increased agility of the organization. Working with EA should reduce project costs and duration, reduce project risk, and improve project success (Foorthuis et al., 2016). Although EA benefits are well researched in the literature, some of them rather amount to unsubstantiated claims. Therefore, future research should focus more on evidence of EA benefits but also EA process and principles (Lumor et al., 2019).

2.2. Business process modeling

Business Process Model and Notation (BPMN) is a globally recognized standard for process modeling (OMG, 2010). Process modeling is one of the most important components of successful business and IT alignment, which is why more and more organizations, including the public administration, are using it. BPMN is quite simple for logical and structure-minded people, which is why they can work with BPMN notation very quickly and describe exactly how the process works (Figl & Laue, 2011). However, this is more difficult than just a rough and not-so-exact description of the process (Wang et al., 2016). It is clear from the BPMN language that it was developed primarily to support the technical implementation of processes ("process automation"). The more important IT is in a company, the more useful the use of BPMN. On the other hand, the narrowness of BPMN discourages non-IT users (Alotaibi, 2016).

3. Methodology and data collection

Based on the literature review, we formulated the following research question: "Can the EA approach sufficiently support the preparation phase of digitalization projects in local public administration projects?" We conducted a survey with 21 key process owners at two public institutions. The first public institution was the City Hall of Bílina, located in the northwest of the Czech Republic. Ten organizational units of the city hall serve 15 thousand inhabitants; the IT department consists of three members. A process specialist was not employed by the city and was outsourced to an external consultant. The second institution was the City Hall of Králíky, which is in the northeast of the Czech Republic and has nine organizational units serving 5 thousand inhabitants. Its IT department consists of two members and with no internal process specialist.

In collaboration with the city hall representatives, we identified relevant and essential processes for analysis. The processes were classified from two perspectives: 1) type of the agenda, i.e., independent agendas, the exercise of state administration agendas in delegated competence, or a combination of both, and 2) type of the process, i.e., key processes, management processes, supporting processes. Table 1 shows the overview of the selected processes in both cities.

Table 1. An overview of the selected processes

City	Agenda Type			Process Type		
	Independent	Delegated Competence	Combination	Key Process	Management	Supporting
Bílina	9	0	6	8	0	7
Králíky	13	0	7	8	2	10

In the next step, we constructed the survey instrument for detailed process analysis. The purpose of the survey was to describe the AS-IS status of the business architecture, which is part of EA, and identify opportunities for improvements of selected processes as a prerequisite for digital transformation. After that, we outlined the theoretical and practical context of using ArchiMate, an EA modeling language that aids EA development. Finally, we scrutinized respondents' answers to identify opportunities for process digitalization and created a structured representation of the identified processes both as process cards and simple visual diagrams using ArchiMate elements that can be easily read by stakeholders without any background knowledge. The paper presents implications of our findings both for the theory and practice of digitalization projects in public administration, especially in the preparation phase of the project.

4. Results and Discussion

We interviewed 21 respondents in two Czech local public administration bodies. We devised process cards with a simple tabular format indicating the number of process inputs and outputs, metrics, number of manual steps needed in a process, number of risks, and number of opportunities for optimization (Table 2). The identified processes were then visualized as ArchiMate diagrams that hid unnecessary technical details and proved to be comprehensible for the subject matter experts. Substituting detailed process maps in BPMN, decision trees, and state and transition diagrams with process cards, tables, and high-level diagrams in ArchiMate was very well comprehensible for stakeholders in both cases.

Table 2. An overview of the identified processes at two local administration bodies; Source: Own elaboration

Process	No. of process inputs	No. of process outputs	No. of metrics	No. of identified manual actions	No. of risks	No. of opportunities for optimization
Submission	1	1	3	2	12	3
Electronic submission	4	2	3	6	11	3
Provision of information (Act no. 106/1990 Coll.)	7	5	7	2	4	1
City official notice board and website	1	2	4	8	8	1
Communication with citizens	2	3	3	2	4	2
Internal documents elaboration	5	5	3	8	7	3
Internal review of documents	5	5	3	6	4	3
Handling of petitions	3	2	2	3	4	2

Process	No. of process inputs	No. of process outputs	No. of metrics	No. of identified manual actions	No. of risks	No. of opportunities for optimization
and complaints						
Accounting documents workflow	2	1	5	7	4	3
Tax and fee collection	4	4	6	5	1	2
Fine collection	1	2	2	4	11	3
Contract approvals	1	1	2	10	12	2
Submission to the Registry of Contracts	1	1	1	9	2	2
Administrative proceedings	1	1	2	8	15	4
Implementation of the city council meetings	9	3	2	3	6	3
City council meetings	10	2	2	7	4	3
City council voting	6	5	4	5	3	3
City council meeting - document workflow	3	2	4	8	3	4
City council meeting – information disclosure	2	10	4	6	6	3
City council meeting – storage and archiving	4	4	4	6	1	2
Total	72	61	66	115	122	52

By using high-level diagrams, process cards, and tables, we managed to close the gap between IT specialists and subject matter experts in both projects. We used only main elements from the business and application layers, e.g., business actor, role, process, and several more (Figure 1). Although the processes might be analyzed without the EA and visualized in, e.g., BPMN, this would not help to close the gap and would require more time and resources for the preparation phase of the projects.

The presented approach brings several benefits. First, it enables to effectively describe processes without losing necessary information and obtain knowledge about processes that is adequate to the needs of the respondents without overburdening them. Second, it allows finding bottlenecks that can be optimized without drawing extensive process maps. The key differentiator of bottlenecks was how the part of the process (or activity) proceeds (e.g., manually, lacking IT support) and if they are repetitive in cycles. The processes that involve manual and repetitive activities were prioritized as the candidates for the automation (e.g., using RPA or AI) and influenced the impact on the business architecture of local administration organizations. Third, the approach fosters the formulation of process risks and using them to plan the projects needed to obtain EU funding. Fourth, analysts can propose a relevant software solution to eliminate repetitive, routine manual work, e.g., by introducing RPA, central eGovernment services, collaboration platforms, or connecting to the National Identity Authorization and Authentication. Further advantages are the description of how data can be extracted from documents and other artifacts that are part of processes, finding links between processes (continuities or even overlaps), and a better understanding of the structure and key elements for subject matter experts than with detailed BPMN diagrams of the process.

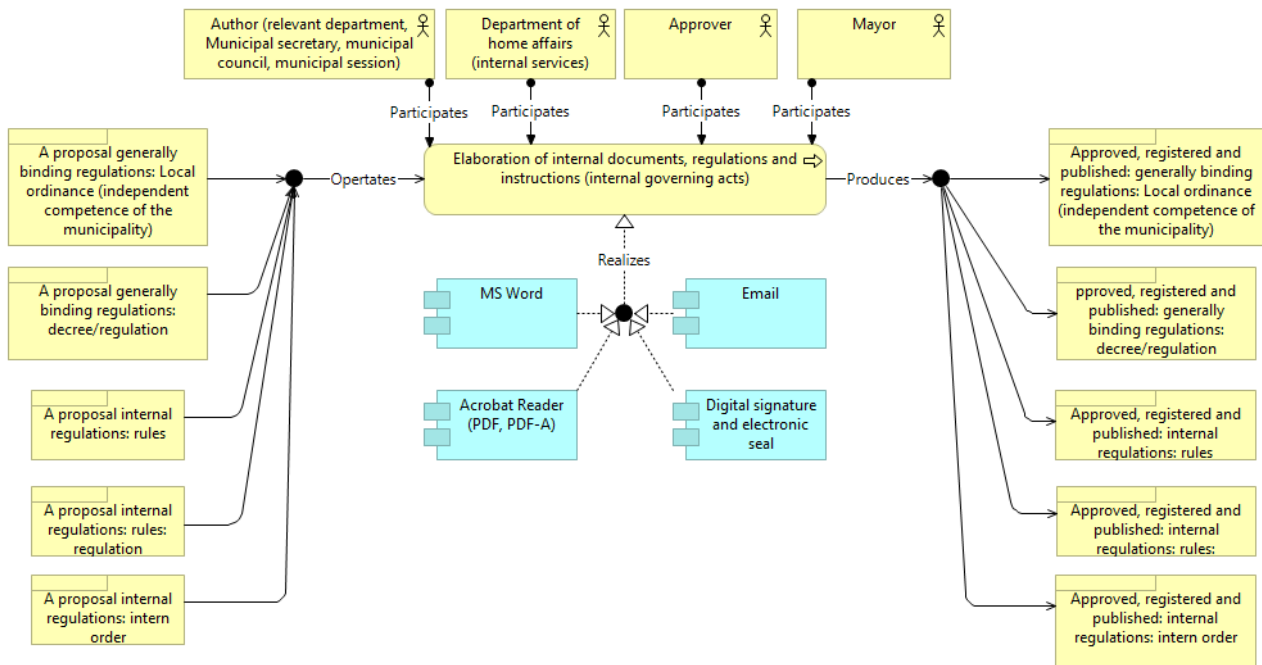


Figure 1. Drafting of internal documents, regulations, and instructions (internal management acts)

Drawing from the interviews, we created structured process cards and ArchiMate schemes using a combination of a basic set of ArchiMate elements. This allowed us to present and share information with clients, including various domain information, and especially promote the perception of complexity to find a compromise between breadth and depth of coverage, i.e., between detailed/expert and organizational/managerial approaches.

After several rounds of feedback from the representatives of the client organization, in total, 52 opportunities for process optimization were identified. For example, manual work needed for administration and archiving of submissions to the office can be eliminated by scanning barcodes used by the post services and devising RPA and OCR. The same technology can be utilized for conversions of information for publishing on the municipality website, storing on shared drives, and other internal document workflow steps.

Using the EA approach is well compliant with risk analysis, including risk description, classification, estimation of probability, and severity. Typical risks identified in both organizations were, for example, absence of rules for online meetings, outdated technology, lack of a higher degree of automation, redundant and excessive costs for printing, paper document workflow between organizations, or failure to comply with regulations on publishing official information online. We argue that the EA approach is sufficient in the preparation phase of digitalization projects. However, other methods such as UML and BPMN modeling languages are more suitable and effective for a detailed technical analysis.

5. Conclusion

The paper deals with specific issues related to the preparation phase of digital transformation projects in public administration and addresses the question of whether EA can aid this phase. Problems encountered in the initial stage of the project often stem from the complexity of tools used for modeling and describing the current state of the organization. EA offers tools to capture all relevant relationships and avoid technical details that are incomprehensible to the non-IT

stakeholders. This is the benefit of EA usage in business process analysis in the preparation phase of the digitalization project. By describing two cases of Czech local public administration bodies, the paper shows how EA practice and process improve communication and understanding between various stakeholders in digitalization projects adds. This adds to the growing body of literature on EA practice, benefits, and principles. At the same time, practitioners such as managers and subject matter experts in public administration, IT analysts, enterprise architects, and solution architects can benefit from the proposed method since the evidence shows that it can reduce time spent on the project specification and analysis of business processes.

6. Acknowledgement

This paper was supported by the Internal Grant Agency of the Faculty of Economics and Management CZU Prague, grant no. 2022A0014.

7. References

- Alotaibi, Y. (2016). Business process modelling challenges and solutions: a literature review. *Journal of Intelligent Manufacturing*, 27(4), 701–723.
- Correani, A., de Massis, A., Frattini, F., Petruzzelli, A. M., & Natalicchio, A. (2020). Implementing a Digital Strategy: Learning from the Experience of Three Digital Transformation Projects: *California Management Review*, 62(4), 37–56. <https://doi.org/10.1177/0008125620934864>
- Datta, P. (2020). Digital transformation of the Italian public administration: A case study. *Communications of the Association for Information Systems*, 46(1), 11.
- EC. (2021). The Digital Economy and Society Index (DESI) | Shaping Europe’s digital future. <https://digital-strategy.ec.europa.eu/en/policies/desi>
- Figl, K., & Laue, R. (2011). Cognitive Complexity in Business Process Modeling. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 6741 LNCS, 452–466. https://doi.org/10.1007/978-3-642-21640-4_34
- Foorthuis, R., van Steenberghe, M., Brinkkemper, S., & Bruls, W. A. G. (2016). A theory building study of enterprise architecture practices and benefits. *Information Systems Frontiers*, 18(3), 541–564. <https://doi.org/10.1007/S10796-014-9542-1/TABLES/12>
- Hemerling, J., Kilmann, J., Danoesastro, M., Stutts, L., & Ahern, C. (2018). It’s not a digital transformation without a digital culture. Boston Consulting Group, 1–11.
- Horák, J., Bokšová, J., Strouhal, J., Bokša, M., & Pavlica, K. (2020). Barriers Influencing the Development of e-Government Services in the Czech Republic from the Perspective of Municipal Authorities. *International Scientific Conference*, 43.
- Hur, J. Y., Cho, W., Lee, G., & Bickerton, S. H. (2019). The “Smart Work” Myth: How Bureaucratic Inertia and Workplace Culture Stymied Digital Transformation in the Relocation of South Korea’s Capital. *Asian Studies Review*, 43(4), 691–709. <https://doi.org/10.1080/10357823.2019.1663786>
- Kotusev, S. (2017). Conceptual model of enterprise architecture management. *International Journal of Cooperative Information Systems*, 26(03), 1730001.
- Kozak-Holland, M., & Procter, C. (2020). The Challenge of Digital Transformation. *Managing Transformation Projects*, 1–11. https://doi.org/10.1007/978-3-030-33035-4_1
- Kristin, A., Ajer, S., & Olsen, D. H. (2018). ENTERPRISE ARCHITECTURE CHALLENGES: A CASE STUDY OF THREE NORWEGIAN PUBLIC SECTORS VOIL-Virtual Open Innovation Lab View project Realizing Benefits from Enterprise Systems View project. <https://www.researchgate.net/publication/326736246>
- Lankhorst, M. (2017). Enterprise Architecture at Work: Modelling, Communication and Analysis (The Enterprise Engineering Series) (J. L. G. Dietz, E. Proper, & J. Tribolet, Eds.; Fourth Edi). Springer-Verlag GmbH Germany.

- Lukáč, M., & Ganobčík, J. (2021). Influence of public policy actors on the development of eGovernment in the Slovak Republic and other European countries. *Political Preferences*, 29, 77–97.
- Lumor, T., Pulkkinen, M., & Hirvonen, A. (2019). Enterprise Architecture: A Perspective on How Far We Have Come, and Directions for the Future. *IRIS*, 10.
- Niemi, E., & Pekkola, S. (2020). The Benefits of Enterprise Architecture in Organizational Transformation. *Business and Information Systems Engineering*, 62(6), 585–597. <https://doi.org/10.1007/S12599-019-00605-3/TABLES/6>
- OMG. (2010). About the Business Process Model And Notation Specification Version 2.0. <https://www.omg.org/spec/BPMN/2.0/>
- PwC. (2020). 2020 GLOBAL DIGITAL IQ. Buckle up. Uncertainty is back.
- Špaček, D., Csótó, M., & Urs, N. (2020). Questioning the real citizen-centricity of e-government development: Digitalization of G2C services in selected CEE countries. *Network of Institutes and Schools of Public Administration in Central and Eastern Europe. The NISPAcee Journal of Public Administration and Policy*, 13(1), 213–243.
- Tamm, T., Seddon, P. B., Shanks, G., & Reynolds, P. (2011). How does enterprise architecture add value to organisations? *Communications of the Association for Information Systems*, 28(1), 10.
- Wang, W., Indulska, M., & Sadiq, S. W. (2016). Cognitive Efforts in Using Integrated Models of Business Processes and Rules. *CAiSE Forum*, 33–40.

ANALYSIS OF SUITABLE FRAMEWORKS FOR ARTIFICIAL INTELLIGENCE ADOPTION IN THE PUBLIC SECTOR

Václav Pechtor, Josef Basl

Faculty of Informatics and Statistics
Prague University of Economics and Business
pecv06@vse.cz, josef.basl@vse.cz

DOI: 10-35011/IDIMT-2022-67

Keywords

Artificial intelligence, machine learning, framework, digitalization, literature review, public sector

Abstract

Modern management and digitalization are gaining momentum in the public sector. Governments and municipalities are trying to catch up to the private sector, where the adoption of Artificial Intelligence (AI) is further advanced. Research about AI in the public field is still in the early stages, but publications have increased in the last few years. This paper analyzes the current literature regarding the adoption of AI in the public sector. The goal is to evaluate if there are suitable frameworks that help public institutions introduce, build, and run AI applications. To this goal, articles are evaluated how much the existing frameworks support the adoption AI process.

1. Introduction

The adoption of artificial intelligence (AI) applications is moving fast in the public sector and seems to be very beneficial for creating public value (Misuraca et al., 2020). However, the research about AI's adoption, use, and impacts is heavily skewed towards the private sector. A recent literature review showed that from 1142 articles, only 59 cover the specific application of AI in the public sector (van Noordt & Misuraca, 2020a). Nevertheless, the uptake of AI in public administration is now an essential topic in states' political agendas worldwide and especially in the EU (van Noordt et al., 2020). The challenges for the authorities are manifold and consist of the topics like the need for governance, transparency, data collection, and prevention of discrimination (van Noordt & Misuraca, 2020b). The introduction and adoption of AI bring various challenges that fall into the following groups: social, economic, ethical, political, legal, organizational, data-related, and technological (Sun & Medaglia, 2019). While the social, ethical, and political challenges belong to the broad field of AI governance, organizational and technical aspects can be covered by frameworks that help organizations tackle these issues.

There are many different definitions of AI, based primarily on what is regarded as intelligence. Due to the constant development of new capabilities that AI can achieve, those definitions continue to develop further (Misra et al., 2020). Also, the expectations toward AI are often still unclear (Nordström, 2021). For this article, we choose the definition of (Wirtz et al., 2019), which is based on a literature review and unifies several other definitions: "AI refers to the capability of a computer system to show humanlike intelligent behavior characterized by certain core

competencies, including perception, understanding, action, and learning". Going further, the term AI application is defined as "the integration of AI technology into a computer application field with human-computer interaction and data interaction". However, this is still just a snapshot of what is currently viewed as AI or AI applications; this might change over time. This change in the perception of AI is referred to as the so-called "AI effect" (McCorduck, 2004). This effect describes technologies described as AI in the past that are not called AI today because society got used to them – so the current classification might be invalid in 5 – 10 years (Misuraca et al., 2020).

While AI is now regarded as general-purpose technology (European Commission. Joint Research Centre., 2020), few researchers concentrate on concrete frameworks that help adopt artificial intelligence (Alsheibani et al., 2020). This paper aims to research the literature about AI in the public sector for existing frameworks. Secondly, these frameworks should be assessed if and how they can be used or modified to support agile AI adoption in the public sector. This leads to two following questions:

Q1: Can suitable frameworks be found in the literature, especially in the area of AI in the public sector

Q2: How can the existing framework contribute to the agile adoption of AI in the public sector with concrete guidelines and fields of action

The goal is to examine which frameworks, or at least artifacts, can be used to develop an agile adoption approach. The available articles are graded from this point of view; the grade is not meant to measure quality.

This paper should help give guidance regarding AI adoption in the public sector, particularly about the current state of available frameworks. It should also identify further research needs to develop an agile approach for adopting AI in the public sector.

2. Research Method and Evaluation

Critical factors for the adoption of AI in the public sector are subject matter knowledge, organizational structures, and a methodical approach (Wirtz et al., 2019). Unfortunately, limited resources and know-how are, together with budget restrictions, the common barriers to adopting new technologies in public institutions (van Noordt & Misuraca, 2020b). Therefore, a framework should offer structured guidance for introducing artificial intelligence to help institutions overcome these barriers (Bauer, 2020). Guidelines might include assessing the AI readiness, recommendations for different levels of the institution's hierarchy, and concrete directions to navigate the adoption process. In practice, it is also essential to maintain the AI application throughout the whole lifecycle, which means that the framework should cover more than only the introduction of a prototype (Sorgenfrei et al., 2014). Therefore, this paper suggests a list of requirements used to assess the existing frameworks in the literature (Table 1).

The search was conducted through Scopus and WOS with the search terms "ai AND public sector" and "artificial intelligence AND public sector" in the time range of 2018 to 2022. Due to the small number of results, the search was also extended to Google Scholar. Other keyword combinations were tried but led mostly to irrelevant results, e.g. including the health sector or AI solutions for Covid-19-related challenges. The titles and abstracts were screened if the papers were eligible for further analysis. One criterion was that only academic papers were included, and the time range was set to the past five years. As the next step, the papers were reviewed for frameworks.

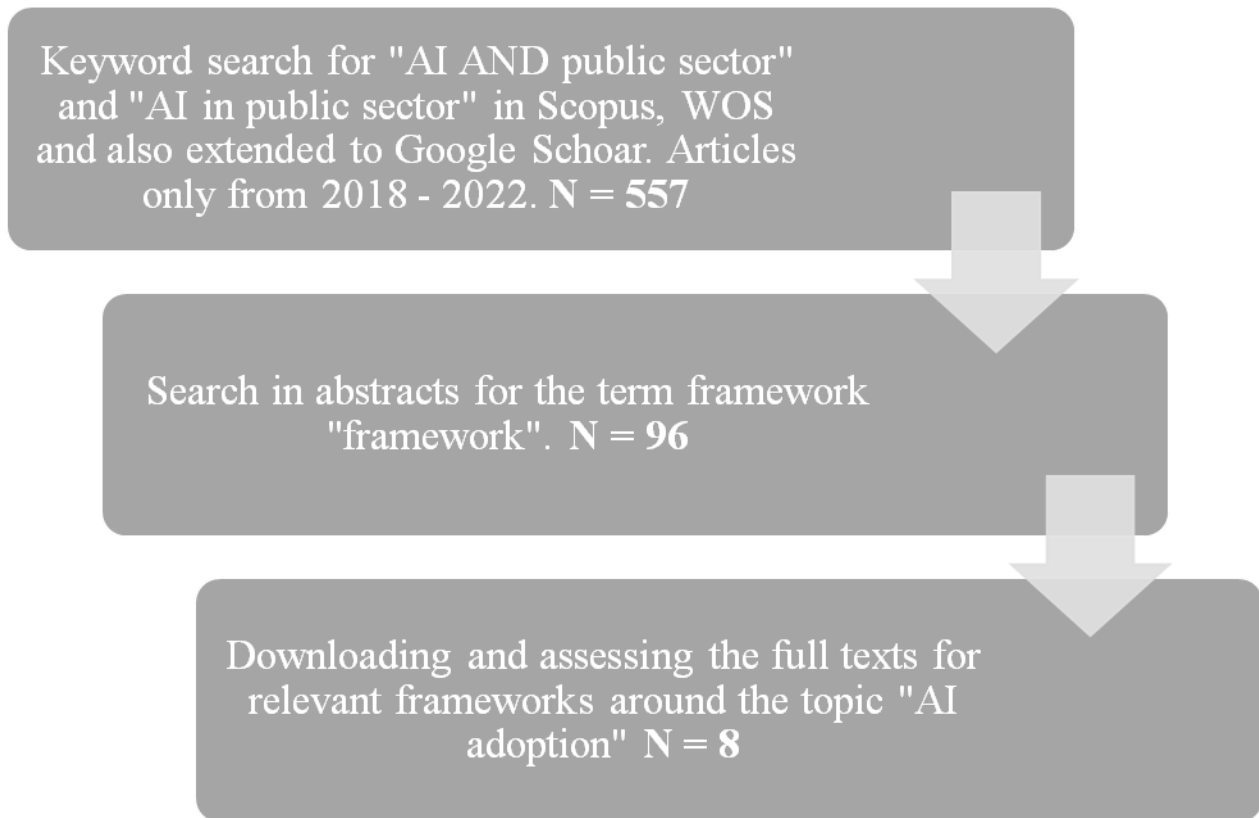


Figure 1 - Selection process of the relevant articles. Source: authors

Eight papers presented different kinds of frameworks related to AI in the public sector and were further examined. The frameworks were assessed by using several attributes. First was the coverage of the AI application lifecycle in the public sector (Levy et al., 2021) to check how broad the method is. The lifecycle describes six steps from idea through the production stage to dismantlement. Because this cycle focuses mainly on purchased third-party solutions, the "procurement" step was extended by "build the solution" to consider if AI applications are built in-house.

A framework for AI adoption should cover as much of the lifecycle as possible to ensure that the focus is not only on rapid prototyping but also on productive deployment and evaluation.

Another interesting aspect is whether the proposed approach is very general or offers concrete steps and fields of action. Frameworks can then facilitate access to AI solutions and reduce the need for technical knowledge (Bauer, 2020). It is also essential that the framework addresses different layers of abstraction (Sun & Medaglia, 2019). An example of a multi-level structure is the macro, meso, and micro model of Veale and Brass (Veale & Brass, 2019). Studies from other sectors showed that agile approaches might be a better fit for developing and adopting AI (Kruse et al., 2019). The trend towards agile development and management is now increasing in the public sector, following the agile movement in the private sector (Mergel et al., 2018). Agility should not be limited only to the development phase but should also be extended to deployment and maintenance (Ruf et al., 2021). These methods are derived from the DevOps movement and are now the focus of research as MLOps (Mäkinen et al., 2021). Another evaluation metric is whether the frameworks assess the different grades of AI readiness (Peretz-Andersson et al., 2021). Lastly, technology adoption and technological-organizational aspects should be considered because this might be a crucial aspect of AI's successful, productive usage. Also, the acceptance and confidence in the decision made by AI should be regarded (Chong et al., 2022). Therefore, an user acceptance model like UTAUT2 (Unified Theory of Acceptance and Use of Technology) (Cabrera-Sánchez et al., 2021) for user

acceptance and TOE (Technology–Organization–Environment Framework) or DOI (Diffusion of Innovation) for adoption in organizations (Schaefer et al., 2021) should be somehow incorporated into the framework.

Table 1 - Weighted requirements for AI adoption frameworks; Source: author

Requirement	Weight	Description
R1: Coverage of the AI lifecycle	10%	Is the AI lifecycle considered in the framework?
R2: Concrete steps and fields of action	20%	Does the framework offer concrete steps in fields of action on how to adopt AI? Can the framework be used as a guideline?
R3: Granularity on multiple levels	20%	Is there a multi-level model (macro, meso, micro) that offers various forms of granularity?
R4: Agile aspects (e.g., MLOps)	25%	Were agile development principles considered in the framework, for example, MLOps?
R5: Consider AI maturity	10%	Is the framework adaptive to different levels of AI maturity?
R6: Incorporation of other methods (e.g., UTAUT2, DOI, TOM)	15%	Does the framework incorporate standard models for technology adoption like TOE or user acceptance models, e.g., UTAUT2?

The attributes were accordingly weighted to emphasize the aspects of agility, granularity, and field of action. In total, these weights sum up to 100%, the most emphasis is on the requirements R2 – R4. Because there are already several frameworks to determine the AI readiness of organizations, its weight is relatively low.

3. Findings and evaluation results

In total, eight articles were identified suggesting frameworks in the realm of AI in the public sector. The presented frameworks cover different aspects of artificial intelligence in the public sector. The variety ranges from prevention of discrimination, assessing the impact of AI, or even multi-layer conceptual frameworks.

Each framework was evaluated according to the given requirements. The fulfillment of each requirement was rated on a scale from one to five, with a score of five being the highest grade for fulfilling the requirement ultimately or delivering additional aspects in that area. A score of one means that the aspect is not covered at all. The emphasis was on agile aspects, concrete steps, and multi-level usage to ensure that the framework is oriented towards practical use.

Table 2 - Results of the assessment; Source: authors

Name	R1	R2	R3	R4	R5	R6	Weighted Scale
(Makasi et al. 2021)	4	5	4	1	1	1	2.7
(Misuraca and Viscusi 2020)	3	3	5	1	4	1	2.7
(van Noordt and Misuraca 2020a)	4	3	4	1	4	1	2.6
(Wirtz and Müller 2019)	4	2	5	1	3	1	2.5
(Buhmann and Fieseler 2022)	5	3	4	1	1	1	2.4
(Kankanhalli et al. 2019)	2	2	2	1	1	1	1.5
(Yfantis and Ntalianis 2020)	2	4	1	1	1	1	1.5
(C. Weyerer and F. Langer 2019)	2	1	2	1	1	1	1.3

Requirement R1 evaluated how much the AI application lifecycle is considered. Learnings from other sectors like healthcare show, that the attention to the whole lifecycle is currently underrated (Jackson et al., 2019). Several frameworks use parts of the AI lifecycle like design, development, and deployment (Buhmann and Fieseler 2022), whereas Van Noordt and Misuraca focus on the

adoption steps in general. Wirtz and Müller presented cycles and adoption processes at different organizational and technical layers. The other papers are more specialized on distinct aspects and less oriented towards a specific AI application lifecycle. Thus, their framework concentrates mainly on the factors influencing AI adoption and the resulting outcomes.

The second requirement, R2, was derived from Q2, highlighting the need for practical advice. Almost all articles tend to be conceptual, whereas (Yfantis & Ntalianis, 2020) offer a more tangible solution based on game theory. This approach is not very common in practice and might be challenging to apply in public sector institutions. The most concrete steps are presented by Makasi et al. because the fields of action are tightly coupled to the ITIL (Information Technology Infrastructure Library) framework.

In hierarchical organizations like they can be found in the public sector (Pūraitė et al., 2020), it might be helpful to cover different levels of abstraction. The grade for requirement R3 reflects if the framework supports this or not. Two articles (Wirtz and Müller 2019 and Misuraca and Viscusi 2020) introduce this multi-level approach that can be used or extended for a future agile framework. Misuraca and Viscusi use macro, meso, and micro as system levels, while Wirtz and Müller introduced policy, application, functional and technical layers. Depending on the perspective, both models are suitable as a base for another framework.

In order to foster trust in AI applications, openness is a crucial aspect (Bostrom, 2017). Openness can be achieved using an agile approach combined with transparency principles (Zieni et al., 2021). The idea of MLOps (Machine Learning Development and Operations or ML DevOps) or other agile practices was not mentioned in any framework. Because the implementation of AI applications is heavily data-driven, AI projects could similarly benefit from using agile methods like Big Data Analytics (BDA) projects. There the use of agile is already partially established and recognized as beneficial (Grady et al., 2017). Several newer papers show, that the use of agile methods in Machine Learning (ML) projects can improve the project outcomes in terms of failure rate and duration (Ranawana & Karunananda, 2021; Uysal, 2022). The lack of presence of agile methodologies in the existing frameworks can indicate that further research is needed in that field and was covered by requirement R4.

Public sector institutions often show low AI readiness (Mutawa & Rashid, 2020), which should also be considered in an adoption framework. This is indicated by requirement R5. Since there are already existing methods to assess readiness (Holmstrom, 2021), this requirement has the lowest weight. The papers from Misuraca et al. and van Noordt discuss the necessary prerequisites to adopt AI, which implies that they presume a minimum level of readiness.

Frameworks like TOE or DOI help better understand the technology adoption process (Alsheibani et al., 2018). Also, user acceptance plays an important role and can be recognized with models like UTAUT2 (Gansser & Reich, 2021). Requirement R6 evaluates whether one of these existing methods was considered in the frameworks. None of these models were mentioned, which might be another field for future research regarding the public sector.

4. Conclusion and future work

This paper aims to answer research questions Q1 and Q2 about the availability of frameworks for AI adoption in the public sector. First, the literature was scanned for articles about AI in public institutions. The resulting 96 papers were analyzed to whether they present a framework that might support the adoption process. The relatively small number of articles and the recent publication dates indicate that the research about AI in the public sector, especially the adoption, is still in the early stages.

Q1: Even if the total number of eight identified frameworks is small, Q1 can be answered with yes.
Q2: Regarding Q2, some frameworks contribute to the adoption of AI in the public sector, but the top scores (2.7) indicate that the existing frameworks still lack essential support for certain aspects. Primarily requirements R4 and R6 are not supported at all, whereas R5 is at least supported by three out of four of the best-rated frameworks. This shows that agile aspects and existing models for technology adoption need to be incorporated with the already existing work. This would then result in a higher score (four and above), representing an improved framework for AI adoption in the public sector with some practical relevance.

The number of existing frameworks for the public sector is relatively small, and they differ in focus and field of application. Those covering the AI adoption process are more on the conceptual side of the spectrum; frameworks helping to identify concrete fields of action are still scarce. Another conclusion could be that the review process should be repeated to see how the research develops in that area

Newer approaches like MLOps are not yet covered in the public sector research. These models may be going to be included within the following years. Also, models covering technology adoption on organizational levels like TOE or DOI are not represented in the AI research of the public sector. The same is true for user acceptance models like UTAUT2. Another underrepresented area is the coverage of the AI application lifecycle. Only two papers describe such a lifecycle so far (De Silva & Alahakoon, 2021; Levy et al., 2021).

Because applications are typically purchased for 5+ years in the public sector, the maintenance and life cycle play an essential role. This is an area that should be researched further to help the public IT have a long-term perspective on the adoption of AI. The research about AI in the private sector is already more advanced, and there these trends started to emerge in the last two years. Therefore, it is also a finding that there is still much potential for research in this area.

5. References

- Alsheibani, S., Cheung, Y., & Messom, C. (2018). Artificial Intelligence Adoption: AI-readiness at Firm-Level. 9.
- Alsheibani, S., Messom, C., Cheung, Y., & Alhosni, M. (2020). Artificial Intelligence Beyond the Hype: Exploring the Organisation Adoption Factors. 12.
- Bauer, M. (2020). Machine Learning in SME: An Empirical Study on Enablers and Success Factors. 12.
- Bostrom, N. (2017). Strategic Implications of Openness in Development. *Global Policy*, 8(2), 135–148. <https://doi.org/10.1111/1758-5899.12403>
- Buhmann, A., & Fieseler, C. (2022). Deep learning meets deep democracy: Deliberative governance and responsible innovation in artificial intelligence. *BUSINESS ETHICS QUARTERLY*. <https://doi.org/10.1017/beq.2021.42>
- Cabrera-Sánchez, J.-P., Villarejo-Ramos, Á. F., Liébana-Cabanillas, F., & Shaikh, A. A. (2021). Identifying relevant segments of AI applications adopters – Expanding the UTAUT2's variables. *Telematics and Informatics*, 58, 101529. <https://doi.org/10.1016/j.tele.2020.101529>
- Chong, L., Zhang, G., Goucher-Lambert, K., Kotovsky, K., & Cagan, J. (2022). Human confidence in artificial intelligence and in themselves: The evolution and impact of confidence on adoption of AI advice. *Computers in Human Behavior*, 127, 107018. <https://doi.org/10.1016/j.chb.2021.107018>
- De Silva, D., & Alahakoon, D. (2021). An Artificial Intelligence Life Cycle: From Conception to Production. *ArXiv:2108.13861 [Cs]*. <http://arxiv.org/abs/2108.13861>
- European Commission. Joint Research Centre. (2020). Estimating investments in general purpose technologies: The case of AI investments in Europe. Publications Office. <https://data.europa.eu/doi/10.2760/506947>
- Gansser, O. A., & Reich, C. S. (2021). A new acceptance model for artificial intelligence with extensions to UTAUT2: An empirical study in three segments of application. *Technology in Society*, 65, 101535. <https://doi.org/10.1016/j.techsoc.2021.101535>

- Grady, N. W., Payne, J. A., & Parker, H. (2017). Agile big data analytics: AnalyticsOps for data science. 2017 IEEE International Conference on Big Data (Big Data), 2331–2339. <https://doi.org/10.1109/BigData.2017.8258187>
- Holmstrom, J. (2021). From AI to digital transformation: The AI readiness framework. *Business Horizons*, S0007681321000744. <https://doi.org/10.1016/j.bushor.2021.03.006>
- Jackson, S., Yaqub, M., & Li, C.-X. (2019). The Agile Deployment of Machine Learning Models in Healthcare. *Frontiers in Big Data*, 1, 7. <https://doi.org/10.3389/fdata.2018.00007>
- Kruse, L., Wunderlich, N., & Beck, R. (2019). Artificial Intelligence for the Financial Services Industry: What Challenges Organizations to Succeed. *Hawaii International Conference on System Sciences*. <https://doi.org/10.24251/HICSS.2019.770>
- Levy, K., Chasalow, K. E., & Riley, S. (2021). Algorithms and Decision-Making in the Public Sector. *Annual Review of Law and Social Science*, 17(1), 309–334. <https://doi.org/10.1146/annurev-lawsocsci-041221-023808>
- Mäkinen, S., Skogström, H., Laaksonen, E., & Mikkonen, T. (2021). Who Needs MLOps: What Data Scientists Seek to Accomplish and How Can MLOps Help? *ArXiv:2103.08942 [Cs]*. <http://arxiv.org/abs/2103.08942>
- McCorduck, P. (2004). *Machines who think: A personal inquiry into the history and prospects of artificial intelligence* (25th anniversary update). A.K. Peters.
- Mergel, I., Gong, Y., & Bertot, J. (2018). Agile government: Systematic literature review and future research. *Government Information Quarterly*, 35(2), 291–298. <https://doi.org/10.1016/j.giq.2018.04.003>
- Misra, S. K., Das, S., Gupta, S., & Sharma, S. K. (2020). Public Policy and Regulatory Challenges of Artificial Intelligence (AI). In S. K. Sharma, Y. K. Dwivedi, B. Metri, & N. P. Rana (Eds.), *Re-imagining Diffusion and Adoption of Information Technology and Systems: A Continuing Conversation* (Vol. 617, pp. 100–111). Springer International Publishing. https://doi.org/10.1007/978-3-030-64849-7_10
- Misuraca, G., van Noordt, C., & Boukli, A. (2020). The use of AI in public services: Results from a preliminary mapping across the EU. *Proceedings of the 13th International Conference on Theory and Practice of Electronic Governance*, 90–99. <https://doi.org/10.1145/3428502.3428513>
- Mutawa, M. A., & Rashid, H. (2020). Comprehensive Review on the Challenges that Impact Artificial Intelligence Applications in the Public Sector. *Proceedings of the 5th NA International Conference on Industrial Engineering and Operations Management*, 10.
- Nordström, M. (2021). AI under great uncertainty: Implications and decision strategies for public policy. *AI & SOCIETY*. <https://doi.org/10.1007/s00146-021-01263-4>
- Peretz-Andersson, E., Lavesson, N., Bifet, A., & Mikalef, P. (2021). AI Transformation in the Public Sector: Ongoing Research. 2021 Swedish Artificial Intelligence Society Workshop (SAIS), 1–4. <https://doi.org/10.1109/SAIS53221.2021.9483960>
- Pūraitė, A., Zuzevičiūtė, V., Bereikienė, D., Skrypko, T., & Shmorgun, L. (2020). Algorithmic governance in public sector: Is digitization a key to effective management. *Independent Journal of Management & Production*, 11(9), 2149. <https://doi.org/10.14807/ijmp.v11i9.1400>
- Ranawana, R., & Karunananda, A. S. (2021). An Agile Software Development Life Cycle Model for Machine Learning Application Development. 2021 5th SLAAI International Conference on Artificial Intelligence (SLAAI-ICAI), 1–6. <https://doi.org/10.1109/SLAAI-ICAI54477.2021.9664736>
- Ruf, P., Madan, M., Reich, C., & Ould-Abdeslam, D. (2021). Demystifying MLOps and Presenting a Recipe for the Selection of Open-Source Tools. *Applied Sciences*, 11(19), 8861. <https://doi.org/10.3390/app11198861>
- Schaefer, C., Lemmer, K., Samy Kret, K., Ylinen, M., Mikalef, P., & Niehaves, B. (2021). Truth or Dare? – How can we Influence the Adoption of Artificial Intelligence in Municipalities? *Hawaii International Conference on System Sciences*. <https://doi.org/10.24251/HICSS.2021.286>
- Sorgenfrei, C., Ebner, K., Smolnik, S., & Jennex, M. E. (2014). FROM ACCEPTANCE TO OUTCOME: TOWARDS AN INTEGRATIVE FRAMEWORK FOR INFORMATION TECHNOLOGY ADOPTION. *Tel Aviv*, 20.
- Sun, T. Q., & Medaglia, R. (2019). Mapping the challenges of Artificial Intelligence in the public sector: Evidence from public healthcare. *Government Information Quarterly*, 36(2), 368–383. <https://doi.org/10.1016/j.giq.2018.09.008>

- Uysal, M. P. (2022). Machine Learning and Data Science Project Management From an Agile Perspective: Methods and Challenges. In V. Naidoo & R. Verma (Eds.), *Advances in Logistics, Operations, and Management Science* (pp. 73–88). IGI Global. <https://doi.org/10.4018/978-1-7998-7872-8.ch005>
- van Noordt, C., Medaglia, R., & Misuraca, G. (2020). Stimulating the Uptake of AI in Public Administrations: Overview and Comparison of AI Strategies of European Member States. *EC-AI-WATCH*, 10.
- van Noordt, C., & Misuraca, G. (2020a). Evaluating the impact of artificial intelligence technologies in public services: Towards an assessment framework. *Proceedings of the 13th International Conference on Theory and Practice of Electronic Governance*. <https://doi.org/10.1145/3428502.3428504>
- van Noordt, C., & Misuraca, G. (2020b). Exploratory Insights on Artificial Intelligence for Government in Europe. *Social Science Computer Review*, 089443932098044. <https://doi.org/10.1177/0894439320980449>
- Veale, M., & Brass, I. (2019). Administration by Algorithm? In *Algorithmic Regulation* (p. 30).
- Wirtz, B. W., Weyerer, J. C., & Geyer, C. (2019). Artificial Intelligence and the Public Sector—Applications and Challenges. *International Journal of Public Administration*, 42(7), 596–615. <https://doi.org/10.1080/01900692.2018.1498103>
- Yfantis, V., & Ntalianis, K. (2020). Exploring the implementation of artificial intelligence in the public sector. *International Journal of Machine Learning and Networked Collaborative Engineering*, 03(04), 210–218. <https://doi.org/10.30991/IJMLNCE.2019v03i04.003>
- Zieni, B., Spagnuolo, D., & Heckel, R. (2021). Transparency by Default: GDPR Patterns for Agile Development. In A. Kö, E. Francesconi, G. Kotsis, A. M. Tjoa, & I. Khalil (Eds.), *Electronic Government and the Information Systems Perspective* (Vol. 12926, pp. 89–102). Springer International Publishing. https://doi.org/10.1007/978-3-030-86611-2_7

INNOVATIONS AND STRATEGIES IN A PANDEMIC ERA

PANDEMIC AS AN INNOVATION BOOSTER

Tomáš Pitner

Faculty of Informatics, CERIT, Masaryk University
pitner@muni.cz

Jan Ministr

Faculty of Economics
VŠB-Technical University of Ostrava
jan.ministr@vsb.cz

DOI: 10-35011/IDIMT-2022-77

Keywords

Innovation, pandemics, globalization, policy

Abstract

It has clearly showed up that pandemic has retarded innovations in some sectors and directions while it boosted innovations in other domains forcing businesses to re-orient their markets and change working habits and technology used. Even within IT and its application domains we see contradictory trends. The keynote will identify current trends and risks associated with (possibly recurring) pandemic crises, increased risks of war having global impacts. It shows recent research outputs documenting the profile of innovation decline generally and in ICT. It summarizes policy recommendation to foster innovation and growth endangered by pandemic.

1. Pandemic as a game-changer in global economy

There is no need to repeat how serious and deep the impact of the still ongoing COVID-19 pandemic on the global economy is. Specifically, we will summarize recently emerging research findings revealing the impact of pandemic on innovation processes even over a longer period.

1.1. Channels for impact on economy

Wang et al (2021) argues that in a neoclassical growth model, pandemic shocks threaten economics growth by reduction of both demand and supply. Demand side decline is caused by reduction of consumption of goods – and services in particular – due to governmental restrictions such as lockdowns, worse accessibility to commercial spaces, long-term closure of entire sectors such as HoReCa, reduction of business trips and other events. Similar causes affect the supply side – one could not produce many specific types of services or even goods during pandemic since the lack of personnel and its availability at working place, governmental restrictions such as posing limits to the number of people in shops, restaurants, and transport means.

Carlsson-Szlezak, Reeves, and Swartz (2020a) and Carlsson-Szlezak, Reeves, and Swartz (2020b) suggest three main transmission channels through which the COVID-19 pandemic has a negative effect on the economy. The first is the decreased consumption of goods and services. The second is

the indirect influence working through the shock of financial markets. The third is the impact on the supply-side, which consists of supply chains, labor demand and employment. From country to country, the relative importance of the three channels varies, depending on many factors such as the length and depth of government or voluntary restrictions, the primary structure and orientation of economy (service vs industry-oriented, open vs more isolated), the intensity and structure of the government aids, flexibility of labor power and the like.

Bonadio, Huo, Levchenko, and Pandalai-Nayar (2020) show that 25% of the decline in average real GDP is caused by disruptions in global supply chains. This negative effect is more severe for countries that are highly dependent on international trade, such as Czechia is.

1.2. Impact on economic growth

Puaschunder (2020) mentions that traditional economic growth theories considered capital and labor as essential growth factors for every economy. Exogenous growth theory is centered on exogenous impacts (new technology or natural crises) as major drivers or suspensors of economic growth. Endogenous growth theory in contrast focuses on dynamic interactions between capital and labor but also endogenous growth derived from ideas, innovation, and learning. She states that COVID-19 pandemic demonstrates the need to include health information-related factors into economic growth models can prospectively be useful as it reflects the benefits of available health data to the entire society.

To quantify the impact of pandemic on economic growth, classical studies such as Meltzer, Cox & Fukuda (1999) showed the size of economic impact of another flu pandemic at the scale of USD 70-166 bn. These older studies did not in-calculate impact of commerce which is now fully global in contrast to 90s and earlier years. We can similarly observe that the older models of pandemic impact do not sufficiently describe the COVID-19 pandemic – they predicted the impact of pandemic for big economies such as EU to 2-4% GDP decline while eventually it was around 7% (almost 6% decline for Czechia in 2020 with a 3% growth in 2021).

1.3. Impact on supply chains

Ongoing trend of restructuring business supply chains started to be visible already prior to pandemic, manifested in eg. U.S.-China trade tension. In has, however, strongly gained during the first waves of pandemic when it affected international trade in much larger scale by lockdowns in industry, transport (namely international), and disruptions in logistic chains – evidence of Bank of America (2020) shows that companies in over 80% of global sectors have experienced disruptions in their supply chains during the pandemic.

Businesses reacted partially by “reshoring” the activities to safer and near harbors – Thomas (2020) discovered that 64% of companies across the manufacturing and industrial sectors are likely to bring manufacturing production and sourcing back to North America. Restructuring the supply chain is not a trivial task and will require substantial resources, estimated by Bank of America (2020) to reach \$1T. Reshoring is not just a shift in material and good supply chains, it changes concepts and priorities when planning sites, financing, and scope.

Javorcik (2020) reflects the macroeconomic view on COVID-19 experience: the coronavirus “*will not end globalization, but it will change it*” which requires innovation. E.g., the unprecedented global strive to invent vaccines against COVID-19 is a clear message that global and international cooperation undertakings are vital to achieve significant progress in critical disciplines despite the trends to “nationalize” trade, supply chains, and policies.

2. Innovation affected by pandemics

2.1. Research productivity

Wang (2021) relates the economic growth with the intensity of innovations that are based on research. Thus, he further states that in the idea-based theory of economic growth, the ability of an economy to grow is the product of research productivity and the numbers of researchers:

Economic growth = number of researchers × research productivity

However, at the same time, Bloom et al (2020) showed that the research productivity declines by a couple of percent each year in the long-term run – halving in 13 years – therefore to maintain the growth pace means the necessity to continuously increase the number of researchers.

Before we focus on the adverse effects of pandemic to innovation, we identify the innovation determinants.

2.2. Innovation determinants

Zhang et al (2021) mentions the following determinants of corporate innovation – *domestic credits, financial development, institutional quality, stock market development, and trust*. He also points out that several authors show that *uncertainty shocks* significantly affect corporate innovation. According to him, uncertainty shocks negatively affect the level of investments since they increase financing costs of innovation. Capital expenditures can also be affected due to the fluctuations in bond prices.

Zhang et al has used Pandemic Discussion Index (PDI) for China to measure the intensity and seriousness of ongoing pandemic. It reflects the occurrence of the pandemic-related concepts in Economic Intelligence Unit country reports. PDI as well as lagged PDI are negatively associated with corporate innovations.

Zhang has identified the following statistically significant factors promoting innovations – operation profit, total exports, management efficiency, and government subsidies. Other factors, such as state ownership, the value-added productivity, and the firm age are also positively related to corporate innovation – this is, however, not statistically significant.

2.3. Short-term effects

When pandemic spread out, we saw an extremely fast innovation circle reacting to the urgent situation – shortage of simple protective measures such as face masks, shields, or ventilators. In ICT, pandemic and lockdowns accelerated and scaled online collaboration tools at an unseen pace. (Still lasting) working power shortage will foster replacement of many service workers with robots in sectors sensitive to similar events in future – such as restaurants and hotels. It helps to prevent devastating effects of possible future pandemic waves.

Pandemic has brought one message – one cannot expect to return to previous business and working habits without at least adoption to new conditions. Remote online work, as surveyed by Gartner, substantially changes work as well as HR processes in many businesses – 75% plan to convert 5% permanent on-site jobs to remote ones while 25% businesses convert nearly 20% to remote. They see advantages such as better employee experience, larger talent acquisition base outside of commuting area – while providing larger freedom to organize working time and reach work-life balance bringing benefits to employees.

2.4. Long-term effects

In a recent paper, Nicholas Bloom (2022) from Stanford's Institute for Economic Policy Research, summarized the profound changes of recent two years in working habits – 47M of Americans changed their jobs due to salary requirements or other factors. Now businesses challenge a new trend – workers refusing to go back to their offices. Employers requiring their employees to be 5 days a week in the office see not more than half of employees really coming. A fresh study documented by Bloom reveals that for almost half of employees, participation in interviews and finding a new job is easier than in the offline, in-office system. It contributes to willingness of managers to tolerate not-returning to office. Bloom advises simple steps to attract the workers back to offices in a reasonable manner – calculate how many hours are needed for in-person collaborative work, idea creation, mentoring, or client meetings. Then concentrate the common hours into working days (eg. mid-week) and motivate employees to come. They might be more motivated to do so as the face-to-face days will be less frequent and more productive while still preserving enough time for individual deep work.

2.5. Impact on innovation

Innovations have a very long-term impact on growth and prosperity, so according to (Gorlick, 2020). *“The new ideas we are losing today could show up as fewer new products in 2021 and beyond, lowering long-run growth”*.

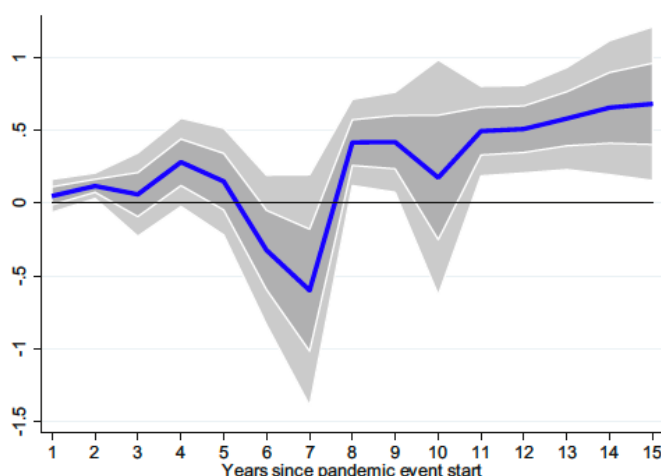


Figure 1 Response of innovation output to pandemic episode (Wang et al, 2020)

Wang assumes that “a pandemic poses a threat to both research productivity and the number of researchers. Pandemic shocks can first lead to a reduction in the number of researchers due to a high death toll, transition of large number of researchers to other activities, many researchers losing their jobs. Research productivity is also expected to fall as the social environment that affects the intensity of creativity is affected (see Amabile et al., 1996). In other words, innovation requires a stimulating and supporting environment and pandemics threaten the nature of creativity that is essential for research productivity.” Thus, the previous generic advises reflecting changing priorities of employees should be adopted to workflows of research and innovation teams, too.

Wang further demonstrates his key finding related to decelerating effect of pandemic on innovations. The effects of past pandemics on research productivity – and therefore on innovation output – are *felt for approximately seven years* from the onset of the pandemic, see Fig 1. This result, whilst in line with the current expectations of the impact of COVID-19 on economic growth, they show a much *longer-term effect on innovation output that the one anticipated*.

2.6. Differences between countries and sectors

Wang (2020) shows that the Manufacturing and the Construction sectors are immune to the pandemic shock. The Information and Communication sector (growth, see Fig 2) is highly dependent on innovation that are promoting faster to production than in other sectors and enable business growth.

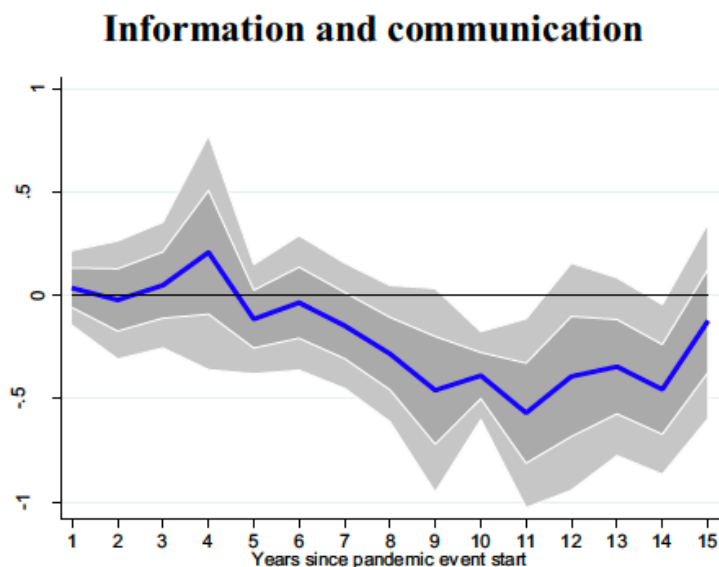


Figure 2 Growth in ICT sector after pandemic episode (Wang et al, 2020)

3. Policy response

Finally, given the ongoing COVID-19 pandemic, in this section, we discuss some very important policy implications that stem from our research. Wang underpins the need for government initiatives that remedy the effect of the pandemic shock, especially with the need for respect to the idiosyncrasies of the innovative sectors across countries.

3.1. R&D investment

A typical direct instrument for governments would be increase in investment. Abi Younes et al. (2020) argue that R&D investment is pro-cyclical and tends to decrease when firms are faced with financial constraints. It can thus be derived that economic decrease caused by pandemic will result in decline in R&D&I investment. However, according to Jorda et al. (2020), "*pandemics (increased infection and death toll) increase real wages for survivors in the long run but are less likely to improve their research productivity. Therefore, the increased R&D investment may not be able to represent an increased innovative ability during and after pandemic episodes.*"

Zhang (2021) specifically recommends that "*...government subsidies should be increased to promote corporate innovation, and increasing total exports is helpful to increase corporate innovation. ... government support can decrease the operating costs, and this policy implication can increase corporate innovation. In developing economies, ... governments have more importance in supporting corporate innovation. It is also important to note that investments in human capital are an important channel to promote corporate innovation. Investments in human capital can increase managerial efficiency.*"

3.2. Effects and limitations

Wang (2020) claims that, *“first, pandemic poses a clear threat to research productivity in the long-run, policies that may reduce the effect of the “Great Lockdown” on research productivity are needed. Second, whilst the pandemic shock influences global innovation output, the results vary by country and sectors of economic activity. The response to COVID-19 needs therefore to have a global character but countries also need to introduce support schemes for the sectors that are more exposed to the pandemic shock. Overall, policies which target the more innovative firms are expected to remedy the effect of COVID-19 on future growth. Third, the pandemic shock is expected to have a strongly negative effect on patent applications. Governments, need to be prepared to support innovators in the immediate aftermath of the pandemic. Patent offices may have to speed up the process of approving new patents.*

Significant advantage of innovative ideas is their ability to be reused unlimited times without impact on quantity and quality – in contrast to material assets. As Bloom (2020) follows: *“Supporting inventors and expediting the patent application process is therefore key in supporting economic growth. Finally, innovation output is significantly and negatively affected by the duration of the pandemic, and it is therefore important to implement support policies for the duration of the pandemic rather than as one-off expenditures only.”*

3.3. Responses in critical sectors

For business sectors critical to the stability of society, such as *agri-food sector*, the recent COVID-19 pandemic experience already helped to formulate strategic policy recommendations for governments. We can be largely inspired by recommendations set by Barrett et al (2020) where many of them are applicable to any critical sector beyond agriculture and food industry:

- *Fund and build trust in first-rate science – it requires adequate precrisis investments in scientific and engineering capacity. Misrepresentation and denialism of science can massively obstruct the impacts of even well-funded science. Thus, rapid, and accurate science communication is increasingly important.*
- *Emphasize high-frequency monitoring. Systemic shocks require predictive and near real time monitoring of fast-changing conditions. Innovations in remote sensing, data science, digital records, monitoring biomarkers for disease in human and animal waste streams, and crowdsourcing open new opportunities to improve the timeliness and cost-effectiveness of community driven as well as external responses to systemic shocks.*
- *Be predictive and start to implement measures well before the actual risk comes – as they need certain time to develop, creating them just in case of urgent need is too late.*
- *Strengthens supply-chain resilience – diversification, flexibility, modularity, and redundancy.*
- *De-globalization must be limited otherwise we compromise sustainability and decrease cooperation that has shown helpful when combating pandemic.*

4. Conclusion

We show that after a pandemic, there is a disruption in innovation production for about 7 years, likely due to a decline in research productivity. Given that COVID-19 is expected to be a major constraint on research productivity, especially during the lockout, the effects of the pandemic on future innovation output and subsequently on growth can be expected to persist long.

As mentioned by Wang et al (2020), “*the main result in the effect of pandemic shocks on aggregate innovation output is driven primarily by a significant reduction in innovative activity in the Information and Communication technology sector.*”

To summarize policy recommendations for governments and administration:

- Drop in future economic growth can be attributed to slow down in innovations during pandemic, namely in the ICT sector.
- Governments should primarily support innovators.
- Governments speed up patent application processing.
- Governments and grant agencies should continue to support *open science* as “ideas are not rivals” despite the nationalistic and de-globalization trends.

5. References

- Abi Younes, G., Ayoubi, C., Ballester, O., Cristelli, G., de Rassenfosse, G., Foray, D., Zhou, L. (2020). COVID-19: Insights from innovation economists. *Science and Public Policy*, 1–13.
- Amabile, T. M., Conti, R., Coon, H., Lazenby, J., & Herron, M. (1996). Assessing the work environment for creativity. *Academy of Management Journal*, 39(5), 1154–1184.
- Bank of America Global Research. (2020). Tectonic shifts in global supply chains. https://www.bofaml.com/content/dam/boamlimages/documents/articles/ID20_0147/Tectonic_Shifts_in_Global_Supply_Chains.pdf
- Bank of America Global Research (2020). The USD 1 trillion cost of remaking supply chains: Significant but not prohibitive. https://www.bofaml.com/content/dam/boamlimages/documents/articles/ID20_0734/cost_of_remaking_supply_chains.pdf
- Barrett C.B. et al. (2020). Socio-technical Innovation Bundles for Agri-food Systems Transformation (Ithaca and London: Cornell and Nature)
- Barrett, C.B. et al. (2021). *Environ. Res. Lett.* 16 101001
- Bloom, N., Bunn, P., Mizen, P., Smietanka, P., & Thwaites, G. (2020). The impact of Covid-19 on productivity. NBER Working Paper no. 28233.
- Bloom, N., Jones, C. I., Van Reenen, J., & Webb, M. (2020). Are ideas getting harder to find? *American Economic Review*, 110(4), 1104–1144.
- Bloom, N. (2022). The Great Resistance: Getting employees back to the office, Stanford University. Available <https://siepr.stanford.edu/publications/work/great-resistance-getting-employees-back-office>
- Carlsson-Szlezak, P., Reeves, M., & Swartz, P. (2020a). Understanding the economic shock of coronavirus [online]. *Harvard Business Review*. Available <https://hbr.org/2020/03/understanding-the-economic-shock-of-coronavirus>
- Carlsson-Szlezak, P., Reeves, M., & Swartz, P. (2020b). What coronavirus could mean for the global economy [online]. *Harvard Business Review*. Available <https://hbr.org/2020/03/what-coronavirus-could-mean-for-the-global-economy>
- Gorlick, A. (2020). The productivity pitfalls of working from home in the age of COVID- 19. Retrieved from <https://news.stanford.edu/2020/03/30/productivity-pitfalls-working-home-age-covid-19>
- Jorda, O., Singh, S. R., & Taylor, A. M. (2020). Longer-run economic consequences of pandemics. NBER working paper no. 26934.
- Meltzer, M. I., Cox, N. J., & Fukuda, K. (1999). The economic impact of pandemic influenza in the United States: Priorities for intervention. *Emerging Infectious Diseases*, 5(5), 659.
- Puaschunder, J. M. (2020). Economic growth in times of pandemics. In *ConScienS Conference Proceedings* (pp. 1-9). Scientia Morality Research Institute.

- Thomas. (2020). Supply chain dive: 64% of manufacturers say reshoring is likely following pandemic survey. May 14. <https://business.thomasnet.com/press-room/news-highlights/supply-chain-dive-mfg-reshoring-is-likely>
- Wang, L., Zhang, M., & Verousis, T. (2021). The road to economic recovery: Pandemics and innovation. *International Review of Financial Analysis*, 75, 101729.
- Zhang C., Hu Y., Huang L. & Huang Y. (2021). Effects of Pandemics on Corporate Innovation: Evidence from the Chinese Firms. *Front. Public Health* 9:780348. doi: 10.3389/fpubh.2021.780348

THE PREPARATION OF YOUNG PEOPLE FOR MANAGEMENT PROFESSIONS

Věra Radváková

Faculty of Informatics and Statistics
Prague University of Economics and Business
vera.radvakova@vse.cz

DOI: 10-35011/IDIMT-2022-85

Keywords

Method, methodology, implicit and explicit comprehension, graduate theses

Abstract

The aim of the paper is to find out whether students preparing for a managerial profession pay sufficient attention to the methodology of their research. The conclusions are based on a detailed analysis of students' diploma and bachelor theses at the Faculty of Informatics and Statistics of Prague University of Economics and Business (FIS VŠE) and at the Faculty of Education of Charles University (PedF UK). From many of the theses, it is clear the student understood the need to choose the most appropriate way to declare the accuracy and reliability of the data obtained. Whether he can explain the criteria of his choice and can describe the methods he used and with which he came to concrete conclusions. All findings are compared at the level of graduate theses.

1. Introduction

Schools and universities strive to best prepare their students for different positions. Professional skills are undoubtedly important for the readiness of university graduates for future employment. However, this is not the only component that should be considered when talking about adequate preparedness. This varies according to the organization's requirements for the graduate. Management requires special skills and training. The work is based on organizing and securing all activities leading to the fulfilment of the goals of the organization. If managerial skills can be divided into interpersonal (manager's responsibility for communication inside and outside the organization), information and decision-making, it is clear that the creation, collection, sorting, filtering and use of information are basic skills. Even in decision-making, it is precisely information that the manager transforms into values important for the company's management system.

The question is to what extent the education system leads the next generation to work actively with information and information resources. Whether university students are always forced to follow the exact goal and methods of their thesis. Whether they can ask exactly what, why and how they will work towards the goal. How to choose the overall methodology. It is the methodology that always reflects the approach to solving the given problem. It is necessary for a future manager to gain the ability to choose adequate methods with respect to the choice of objectives and the nature of observed phenomena.

The paper is based on a study aimed at finding out at what level university students decide on the methodology of their final theses. The author compares whether there is a shift in mastering the

methods of work in master's theses in comparison with bachelor's theses. It also statistically processes what percentage of monitored students of the study program School Management at the Faculty of Education and the Information Management, Information Media and Services and Applied Informatics programmes actually pay attention to the methodology of their research and what working methods they prefer.

2. Methods and Materials

The analysis is based on data from a survey conducted by the author. This survey was carried out gradually in the academic years 2018/19, 2019/20, 2020/21. In 2018/19 only master's theses that were defended in the summer semester were evaluated. In the years 2019-2021 diploma and bachelor theses were analyzed during the winter and summer semesters. The study is based on the analysis of a final number of 180 master's theses and 142 bachelor theses. Five data collections were carried out to meet the objectives. We divided the data into three groups. We have determined the criteria and the evaluation scale. Based on a detailed evaluation, graphs of relative quantitative expression were processed (Corbiová & Strauss, 2009).

The author works on the assumption that students will always design concepts for data collection so that they are sure that the data will support the objectives of the thesis and answer the research questions they have asked themselves in it. It must declare the accuracy and reliability of the data, which must be clearly described in the methodology.

In addition to the analysis and interpretation of the first chapters of the final student thesis, it is necessary to mention the method of systematic observation, as the author has been teaching the Diploma Seminar at the Department of Systems Analysis FIS Prague University of Economics and Business for nine years.

The purpose of the research was to find out the percentage of students that devote themselves to the methodology of work in their final thesis. In addition to the topic, goals, motivation, or hypotheses and research questions, do they have at least the mentioned (in the best case described) methods that they used in their thesis. We also determined the degree of methodological understanding. 322 respondents participated in the research study (63% men, 37% women). These were students of the final year of bachelor's studies at the School Management (PedF UK), Information Media and Services and Applied Informatics (FIS VŠE) and master's studies in Information Management (FIS VŠE) and School Management (PedF UK).

Table 1. Number of analysed final theses, source: own research

	FIS VŠE	PedF UK	Total
Master's	120	60	180
Bachelor's	114	28	142

Within the interpretation, passages were examined where students implicitly devote themselves to methodology (or should devote themselves to methodology). After considering whether it is really a choice of methodology or partial methods by the student, we recorded this fact in writing in the data collection. These data show the values and facts that we continue to work with and on which the conclusions of the entire research survey stand.

3. Results

During the analysis of a final thesis, an increased level of attention was paid to the *introduction*, *conclusion*, *first chapter*, i.e., those parts where students explain the objectives and focus of their

thesis (Duman & Inel, 2019). If we did not find the methods used in these sections, we analyzed the whole thesis and observed whether the methodology is explicitly or implicitly applied by the student elsewhere. We analyzed master's theses and bachelor's theses separately. At the end, we confront the mastery of, or rather the understanding of, the methodology for all bachelor's and master's students. The differences are recorded in the last fourth graph, which we consider to be most important.

The results can be divided into the following three groups.

3.1. Final thesis of first group

Master's and bachelor's theses in which students adhere to the basic standard (Ochrana, 2020) for the structure of expert work IMRaD (Introduction, Methods, Results and Discussion). In these discussed final theses, it is usually explicitly described in the introduction and indicated in the text which methods of scientific work the author used. We most often read the following terms.

Sample 1: *Methods used, Methodology, Methods of achieving goals, Methodology of Master's thesis, Methods and methods of achieving goals*, etc.

The methodology is often highlighted in the text and graphically. Some students used the term Methodology, which may come about through translation from English, but the importance and essence of the methodology of expert work is obvious to the author.

3.2. Final thesis of second group

This group includes mainly master's theses, in which nowhere is the term methodology or method of work indicated or even stated, but it is implicit from the text that the author is aware of the need to describe the methodology of work in some way; see examples 2–4. In the individual examples, we do not intentionally state the source, i.e., the authors of the submitted theses.

Sample 2: The practical part of the thesis a questionnaire is described and evaluated

Sample 3: The thesis will be based mainly on foreign sources... it will continue to draw on the personal experience of the author and his colleagues at work... will also use unrealistic test data from the test system.

Sample 4: The described state is verified in the next part by empirical research, which...

3.3. Final thesis of third group

This group includes both bachelor's and master's theses (defended in all cases). In these theses, the procedures by which the student came to the results and conclusions are completely missing. The theses have in the structured introduction, or in the first chapter, the subtitle Objectives and methodology. In this part, the topic and goal of the expert work are always explained on an average of 20 lines, but there is no mention of the methodology, of the way the author will proceed. It is not at all clear from the following text whether the author is aware of the need to describe the process of his work in some way.

3.4. Extent of comprehension of methodology of thesis

The following graph (Radváková & Lőster, 2018) focuses only on the researched master's theses. It states the degree of comprehension of the methodology in the master's theses of respondents from FIS VŠE and from PedF UK.

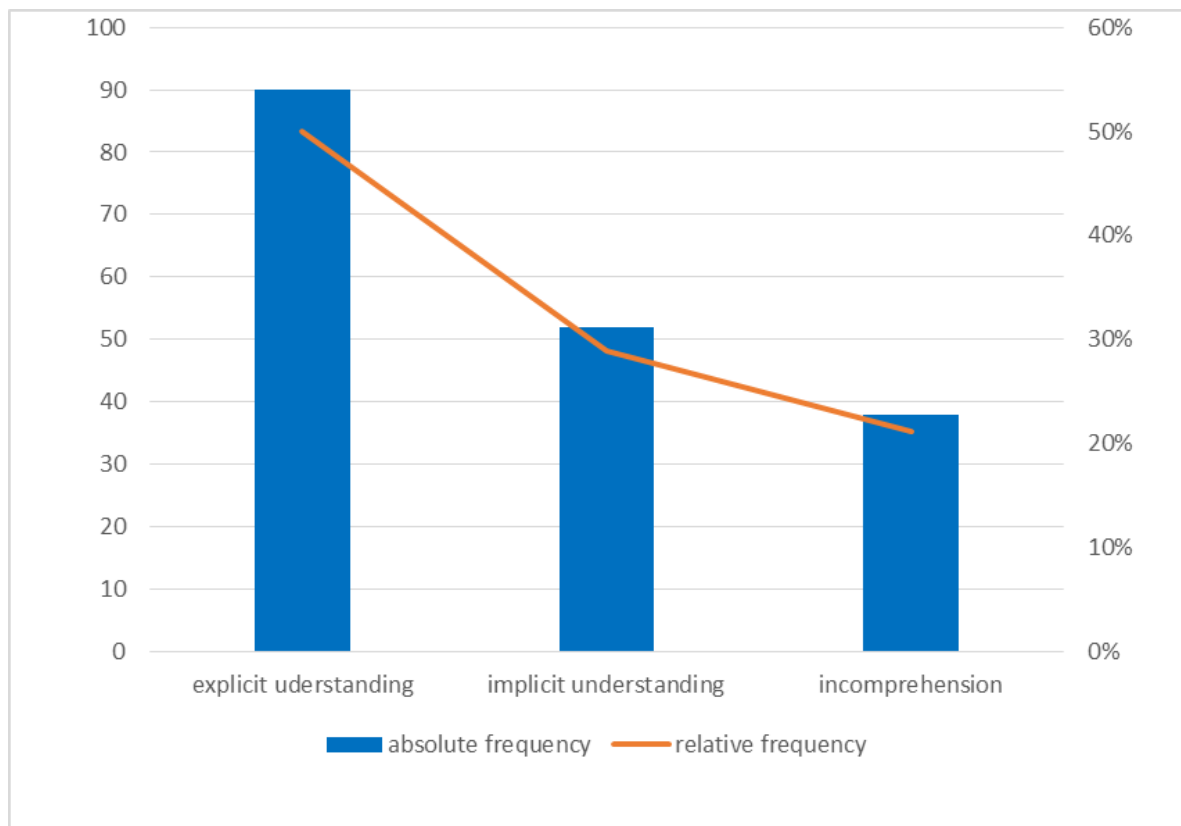


Figure 1: Graph of the degree of comprehension of the methodology at the authors of master's theses, source: own research

It is surprising, above all, how many the master's theses of future managers – more than 20% – do not have any procedures for their work at all; how to achieve the set goal, how they will obtain data. Even bachelor's theses should be more than a mere compilation. This is completely unacceptable for master's theses. Among respondents we very often came across the term description. It is clear from Example 5 that some authors present descriptiveness directly and are not aware of the limitations of such a procedure.

Sample 5: In Chapter 1 I will describe the individual... in the following chapter describes these structuresin Chapter 4 describes the commonly used... from these chapters should then arise and be described...

At another level, we would evaluate a scientific description that is the result of a specific scientific observation, i.e., an accurate record of the observed phenomena. We have not encountered such a description, which is based on concepts that describe the objects of research in terms of their quantitative and qualitative characteristics, in the researched theses.

Graph 2 focuses only on bachelor theses. It again indicates the degree of understanding of the methodology.

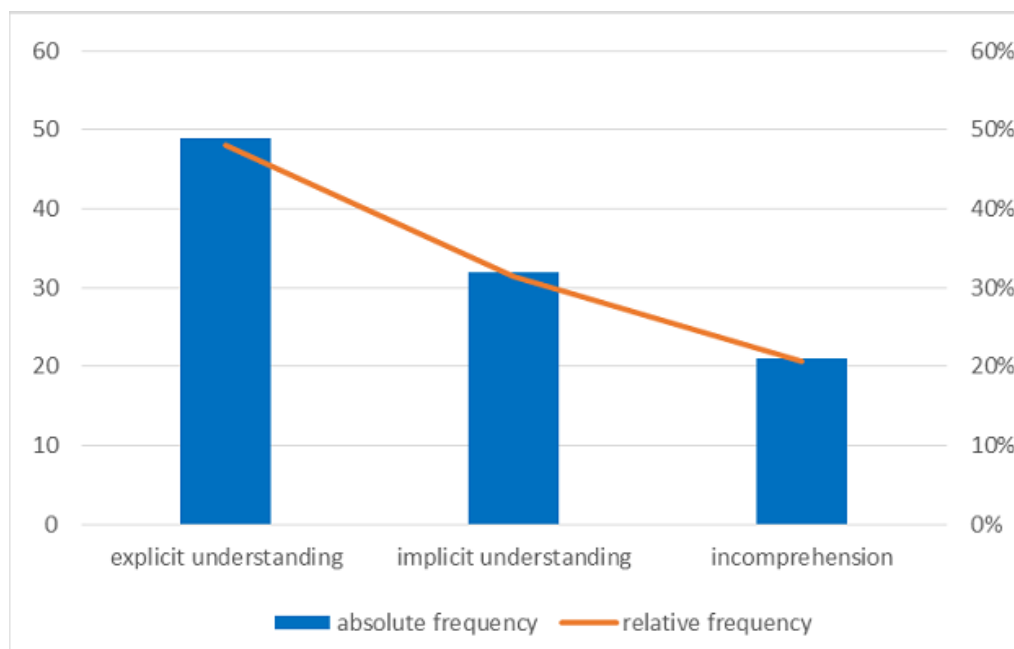


Figure 2: Graph of the degree of comprehension of the methodology in the authors of bachelor's theses, source: own research

Greater balance is evident from the graph. However, none of the respondents, who fall into the 21% failing to comprehend the necessity of the methodology, mentions the procedure of their scientific research in any of the sentences. The authors of several bachelor's theses (all from FIS VŠE) are clearly aware of the need for methodology within the practical part of their thesis, but they do not deal with the methodology of the whole thesis – see Sample 6.

Sample 6: *In my bachelor thesis I map the most frequently used methodologies for system management.... I divide these methodologies*

The following graph 3 can be interpreted from several angles (Walker, 2013). Master's theses belong to the higher, second level of university studies; from this point of view it is good that we see in the graph a shift in a clear (explicit) understanding of the necessity of academic thesis methodology from 39% of bachelor's theses to 58% of master's theses. On the other hand, it is striking that it is not explicitly clear and given to almost half (42%) of the examined authors of master's theses that each specialist thesis must have a clearly defined methodology. Moreover, the graph does not flatter the students or their teachers, given that as many as 20% of master's theses do not have a methodology at all, not even a mention of the progress of their research. In this part of the graph, it may come as a surprise that in bachelor's theses it is 17%, albeit only 3%, but still fewer students. The interweaving of the graphs is also interesting. It seems that while the authors of master's theses either have a clear idea in the methodology or do not address it, the authors of bachelor's theses hesitate with understanding (44% implicit understanding, 39% explicit understanding). The survey does not address the question of whether it is really ignorance of the methods of academic work or students have merely forgotten to write ways to research their thesis. We therefore have an unanswered question as to whether a number of misunderstandings, or a proper description of the methodology, are related to ignorance or inattention.

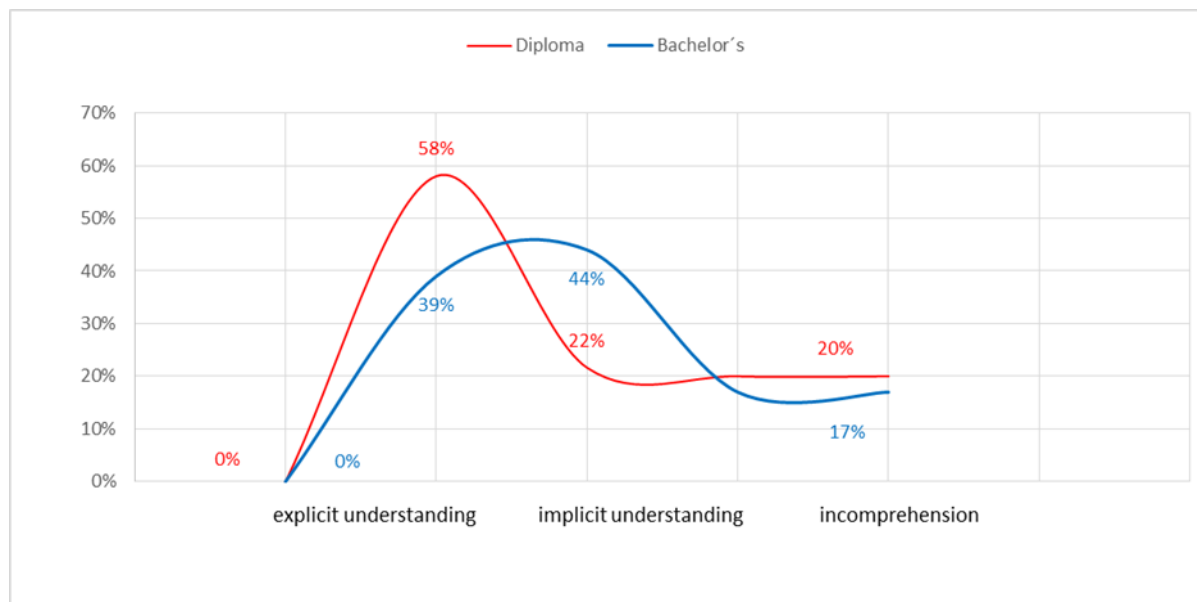


Figure 3: Differences between master's and bachelor's theses for all respondents, source: own research

4. Discussions and conclusions

While the difference between the master's and bachelor's thesis is clearly given, the degree of understanding and the importance of the methodology for the whole thesis remains quite similar for the authors of all final theses. We are aware of the limits of our research; we were only concerned with the degree of awareness that it is necessary to describe the methodology in every academic work. We did not examine how effectively and correctly the student uses the method.

We have explored the question of whether and at what level today's students and future managers at universities become acquainted with possible methods of academic work. If there are subjects that would have a syllabus on selected methods or offer the opportunity to try individual methods in seminar and year papers. The study also suggests why students prefer quantitative research at the expense of qualitative research, and whether they are aware of the potential risks and limitations of statistics. We did not include in the paper data from a survey in which we monitor where and how methods of academic work are taught at Czech universities. It would be interesting to analyze the bachelor's theses of students who have completed such a course and compare their work with others. Do date we have also not compared the master's theses of technical and humanities students. We are therefore aware of the limits of our current research and are collecting data for further specialized discussions.

5. References

- Corbiová, J., & Strauss, A. (2009). *Základy kvalitativního výzkumu*. Brno: Albert.
- Duman, A., & Inel, Y. (2019). Review of Master's Theses in the Field of Social Studies Education between 2008 and 2014. *Universal Journal of Educational Research* [online].2019, 7(1), 66-73.
- Doucek, P., Maryška, M., Nedomová, L. & Novotný, O. (2011). Competitiveness of Czech ICT industry-Requirements on ICT HEIs Graduates. In: *Liberec Economic Forum*. Liberec.
- ČSN ISO 690. (1996). Praha: Český normalizační institut.

- ČSN ISO 690-2. (2000). Elektronické dokumenty nebo jejich části (informace a dokumentace) – část 2. Praha: Český normalizační institut.
- Eco, U. (1997). Jak správně napsat diplomovou práci. Olomouc: Votobia.
- Evropská komise. (2014). Report on the responses to the Public Consultation on the Review of the EU Copyright Rules. (online). 2014. (cit 2016-06-24) Dostupné z http://ec.europa.eu/internal_market/consultations/2013/copyright-rules/docs/contributions/consultation-report_en.pdf.
- Ochrana, F. (2020). Metodologie vědy. Praha: Academia.
- Radváková, V., & Sigmund, T. (2020). Základy odborné práce. Praha: Oeconomica.
- Radváková, V., Lőster, T., Mazouch, P., Sigmund, T. & Vltavská, K., (2018). Metody vědecké práce. Praha: Oeconomica.
- Walker, I. (2013). Výzkumné metody a statistika. Praha: Grada.

THE “SEE DANTE MODEL” FOR RESOURCE MANAGEMENT IN EDUCATIONAL AREA

Petr Rozehnal, Karel Hlaváček, Aleš Lokaj

Faculty of Economics

VŠB – Technical University of Ostrava

petr.rozehnal@vsb.cz, karel.hlavacek@vsb.cz, ales.lokaj@vsb.cz

João Samartinho

Instituto Politécnico de Santarém, Portugal

samartinho@esg.ipsantarem.pt

DOI: 10-35011/IDIMT-2022-93

Keywords

I&T Governance, I&T Management, Enterprise Architecture, Education, Distance Learning.

Abstract

DANTE – an international project and its first results are presented by this paper. The project is dedicated to develop guidelines for higher education institutions how to develop and run digital courses as a reaction to situation caused by hygienic restrictions during the coronavirus pandemic. Major changes have been realized at and since that time, so educational institutions should be better prepared for similar situations in the future. Be more flexible and adaptable – this approach to IT assets management in education is described. It is based on the identification of the most important elements in educational capability and their inter-relations. Knowledge of the internal structure of the organization supports key stakeholders in a better understanding of the possibilities and limits of organization. In this way, decision-making and long-term planning can be improved.

1. Introduction to DANTE project objectives

The main objective/idea of the DANTE project is the support of education at HEIs (Higher Education Institutions) through supporting digital competences among teachers, academic staff and university students and establishing a cooperative network among educational institutions from five different European countries.

Although the universities are ready to provide high-quality education to their students, thanks to the situation we have been facing since the coronavirus pandemic, the education strategies, approaches and methodologies had to be adjusted to this situation. It is necessary to provide university teachers with the necessary knowledge, skills, equipment and sources needed to smooth switch from the face-to-face teaching to digital (online) education.

DANTE has been designed to establish five quality Intellectual Outputs that enable the mainstreaming of digital education (DE) to increase digital competence of teachers and other education and training staff. These Intellectual Outputs (IO) are:

1. DANTE market research and survey report.
2. DANTE guidelines - HOW TO develop a digital course.
3. DANTE guidelines - HOW TO set up the IT infrastructure for a digital education.
4. DANTE guidelines - HOW TO communicate with students and motivate them in DE.
5. DANTE digital courses in the field of Business and Economics.

In the paper we discuss the output IO3 which is called Guidelines - How to develop IT infrastructure for digital education. The focus of this module is on strategic IT infrastructure management. The approach to the solution is based on the areas of information and technology (I&T) management and on the frameworks used in practice for the area of IT/Business alignment (IT, Information Technology).

The project was initiated as a result of restrictions during the Covid pandemic, when the education sector had to reorganize its processes to provide mainly distance form of learning.

IO3 addresses, among other things, the following issues:

- How to set up the infrastructure that is needed for the complex multimedia interaction of the teacher with the students in the context of hardware and software, processes and information.
- How to use and manage the existing resources effectively to switch quickly from face to face to online teaching.
- How to provide an appropriate environment for sharing and transferring information.

Chapter 2 briefly discusses the theoretical concepts that are used for the solution. Chapter 3 presents the suggestion of the model - levels and positions of the main elements. Chapter 4 follows, where specific elements from the university environment are described. An example of scenario description is also included.

2. Theoretical background

The area of strategic management of business informatics has been a hot topic for a long time. Secondary reasons have changed over the decades, but primary reasons remain: support of business goals, efficient use of resources, risk mitigation (ISACA, 2018a). Secondary reasons currently affecting management include IT services, ongoing digital transformation (Matt, Hess, & Benlian, 2015; Nielsen, 2019). The fundamental challenge for the management of enterprise informatics is IT/Business alignment, because if there is a harmonization of the use of information technology resources for the realization of business plans, then the meaning of their application is fulfilled.

With regard to the goal of project, to support the preparation of IT infrastructure for education, we have chosen IT Governance and Enterprise architecture as the key areas.

Enterprise governance of information and technology

IT Governance or in the newer terminology Enterprise governance of information and technology (EGIT) focuses on I&T for enterprise risk management and value creation? (ISACA, 2018a). Moreover it should be a part of the corporate governance system (OECD, 2015). COBIT 2019 framework builds on the long development in the field of strategic IT resource management framework for business support. Methodologically, COBIT is based on balancing the interests of stakeholders and optimizing the use of resources (in the sense of finding the right level of risk, portfolio of resources, etc.).

The development of a governance system is based on the components and their active management. At the same time, a respect for the interrelationships (holistic approach) and the specifics of each organization is important (ISACA, 2018b).

Enterprise architecture

Enterprise architecture (EA) is an area that supports the organization of IT infrastructure to be aligned with business goals (Kotusev, 2020). EA can be seen as an approach, as a process, as an expression of structure (model). EA is widely discussed and scientifically researched, frameworks and software support are available. TOGAF (OpenGroup, 2019) is one of the methodological frameworks for EA. At the theoretical level, TOGAF provides a structured view of IT resources and infrastructure. It is important to note that EA is not only about IT (resources), but also about business perspectives (goals, processes, role of people etc.).

Both areas mentioned above support management, harmonize goals and requirements with the use of I&T, are based on a holistic management approach, use best practice, independent of the specific technology etc.

Thus, these areas are a suitable theoretical basis for the identified problem area, because the aim of the project is not to find a solution suitable for a strictly defined, specific situation, but rather general recommendations and definitions of possible solution scenarios.

3. Approach to solution design

The project solution process is based on its internal structure, where the set goals are divided into individual sub-parts, the so-called Intellectual Outputs. The solution is thus divided into two levels: complex project level and sub-levels. In this paper, we focus only on the part of IO3: preparation of IT infrastructure. The overall solution is beyond the scope of this paper but the context is important because we use information and results from other IOs in IO3.

The main design phase of the solution for IO3 is described in Figure 1.

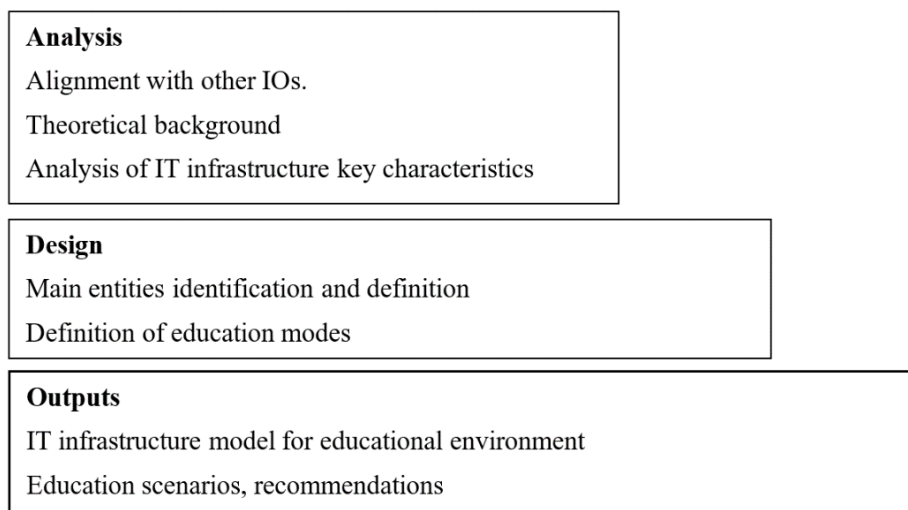


Figure 1 Approach to solution

Philosophically, the solution is based on identifying elements and defining the structure of the educational process. Conceptually, it's the same as EA approach in TOGAF framework, where the Content Metamodel is used to display the main elements of the system and their interrelationships (OpenGroup, 2019, Chapter 30). Identification of key elements, layers and their relationships or

meaning is used as an approach to solutions in various areas (Pitner & Ministr, 2017). The reasons argued (Chan & Reich, 2007; Coltman et al., 2015) when stated that digital transformation is between technology and governance system. Management activities represent the purposeful organization, combination, use, etc. of the organization's resources. These activities must be carried out smartly, efficiently, with an appropriate risk. Therefore, knowledge of objectives on the one hand and knowledge of resources on the other is the basis for successful management.

SEE DANTE Model (Smart Education Environment DANTE) describes IT infrastructure management, see Figure 2. Thus, we combine a general idea of management elements at different levels of management with a specific definition of the education scenario. The global (strategical) and IT assets (operational) issues are taken into account for the management of the IT infrastructure.

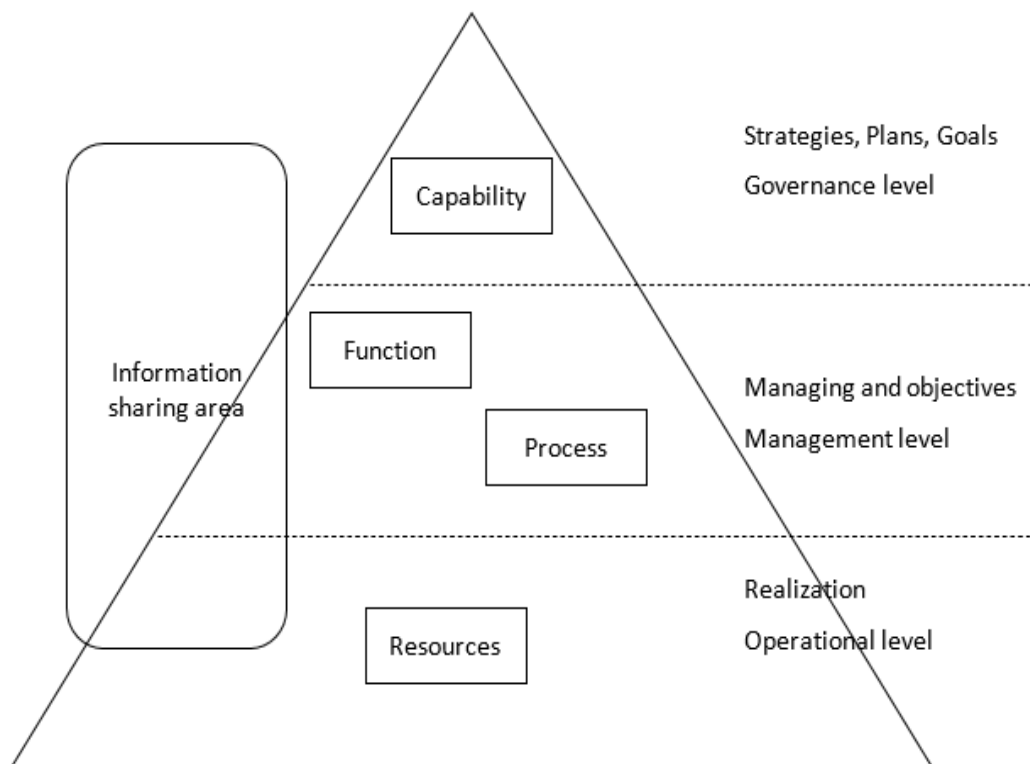


Figure 2 SEE DANTE Model structure

The model is based on:

- Respect for different levels of management.
- Identification of key elements of management at the general level (during implementation with knowledge of the specifics of the organization, knowledge of the state of AS-IS).
- Information and communication sharing across the organization.
- Knowledge of context (e. g. continuity of processes, knowledge of resources, etc.), knowledge of the interrelationships between the elements in the system.

As can be seen, the general approach of the EGIT area, namely the COBIT framework (ISACA, 2018a) is applied where key decisions are set at the top level of the organization (governance level) and further through processes (management level) implemented with the help of resources (operational level).

4. Outputs and results

Top-down decomposition was used, from the position of university/faculty management (there is no difference in the solution). Thus, in the initial stages, the situation at several universities (Czech Republic, Poland, Portugal, Iceland, Slovakia) was analyzed in order to define typical elements important for digital education and also related to IT support.

Decomposition of education capability

The result was a breakdown into three levels: capability - function - process. Capability is the long term and stable ability of an organization. A Business capability is delivered by function and function is realized by/supports process (OpenGroup, 2019). Key processes involved in the education field have been identified. Processes are classified according to functional areas that have a specific character (it is worth to note that there are not only education activities but also management activities like organizing the schedule, study agenda etc.). Figure 3 illustrates the structure.

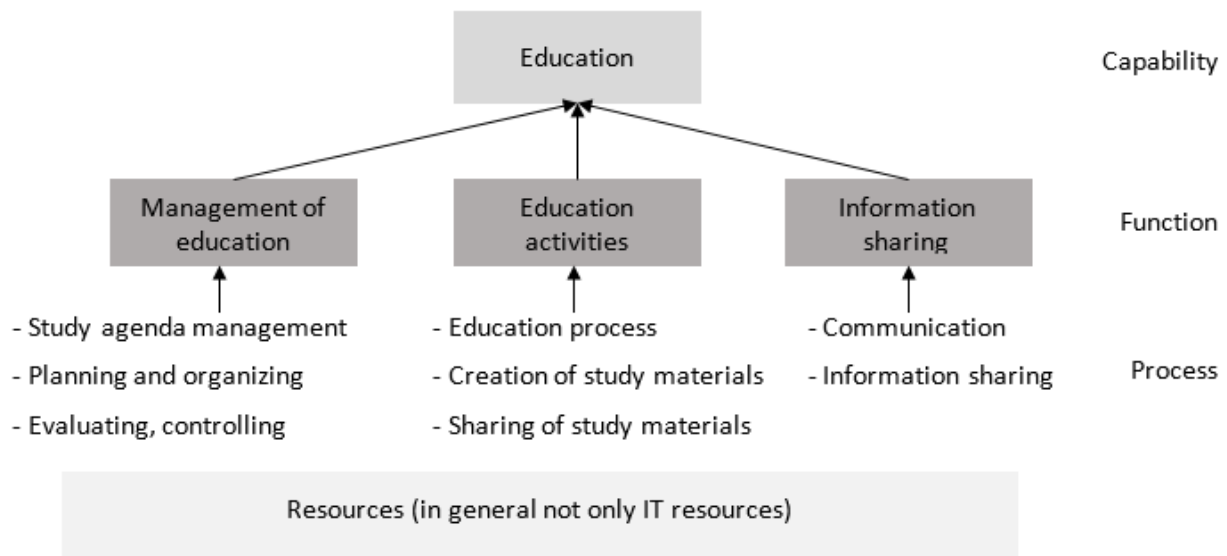


Figure 3 Decomposition of key elements

In this way, the initial structure for organizational and management activities was created. The solution is open and independent, as it is not necessary to identify specific technologies, software, etc. However, the ability to express the essence is fulfilled. If necessary, the application of specific technologies can be mapped at lower levels of management. This only makes sense for a specific situation - the organization.

The aim of the proposed solution is a conscious decomposition of the entire educational capability into partial elements, identification of their relationships. At the general level, we thus achieve a conceptual idea, independent of the technologies used. At the implementation level, it is then possible to transfer the model to a specific situation with the identification of specific sources. We used EA artifacts, see below. Examples are: LMS system - Moodle; SW for real time communication - MS Teams; Mail applications - MS Exchange, etc. Also in the organizational form: Guidelines for the form of realization of teaching; operation of the department in the organizational structure of the organization, etc.

We have identified also different form of educational scenarios. We described them and expressed their contexts within SEE DANTE Model.

Educational scenarios

The typical form of education before pandemic restrictions was teaching “On campus”– face to face at the university. The resources which support this form of teaching are: classrooms with hardware and software equipment, a support of IT department specialist, a local network connection to Internet etc.

The situation was quite different in the “distance form” of teaching. Students were at home (many teachers as well), they were using their own devices, software, Internet connection etc. We can talk/think about “other” IT resources or their provision. The classroom is replaced by an online environment. The same function but the process is affected by different resources. Internet connectivity is the responsibility of students (in the case of the teachers at home office, this also applies to employees). The same resources but their ownership and management are different. An example of a scenario mapping is in Table 1.

Management of resources depends on form of education and we can identify and analyze different teaching scenarios. This should support the flexibility of resources and their planning. Management of infrastructure (in IO3 IT infrastructure) is an activity that must be managed in a long-term and sustainable perspective. Therefore, the basic principles that express the conceptual value orientation were also defined within the solution. The principles should be the starting point for the design of the solution, as they express the general standard required by the organization (e.g. compliance with laws, business continuity, sharing information).

Architectural artifacts matrices and catalogs (OpenGroup, 2019, chapter 31.6.) were used to identify different forms of the teaching scenarios. We used matrices for (1) description of educational scenarios – form of education versus typical characteristics; (2) description of processes versus IT resources that are needed for this realization. Catalogs were used for (1) description of IT resources – application/IS, hardware equipment; (2) definition of principles.

Table 1 Example of matrix with scenario (Note: only a brief description without comments)

	Time	Location Teacher / Student	Support – teaching Teacher / Student	Support – content Teacher	Management of the educ. process Staff, teacher / Students	Form	HW/SW equipment Teacher / Student
1	Synchronous	On campus / On campus	Yes / Yes	Yes	Without restriction	Face to face	UNI IT assets – all participants
2	Synchronous	On campus / Home	Yes / No*	Yes	Without restriction / Limited	Distance learning	UNI IT assets / Own IT assets
...							
X Y	Synchronous	Home / Home	No* / No*	No*	Limited / Limited	Distance learning	Own IT assets - all participants

The model provides conceptual solutions for planning and organizing resources for different teaching situations - including identification and management of study-related activities. As mentioned above, the area of education should be covered from a holistic point of view.

It is appropriate to mention at least two areas: the study agenda and information sharing. Systems supporting the registration of studies, its organization, creation of schedules, evaluation of studies, etc. At present, there is a visible general trend of massive digitization of business processes precisely for their possible implementation regardless of location.

Related to this is the ability to actively manage data and information and share information in the organization.

Information sharing

Model can be easily applied to processes that have a clear structure and are well defined. The situation is worse in the area of information sharing.

The need for information space is a condition for flexible management, because rapid transfer of information among system participants facilitates a change in their behavior. It allows to influence them in the desired direction.

The SEE DANTE model and used artifacts allow to describe the processes related to the transfer of information in the context of other processes, used systems, etc. For example, we have mapped the use and importance of different applications for the transfer of information in different forms of education. The problem occurs with the correct deployment of the information channel for a specific situation/specific information. Can general recommendations, patterns be applied? Should communication channels be supplemented by other types (elements of social networks), otherwise integrated? (Pavliček & Doucek, 2016).

5. Conclusion

It is obvious that the original decomposition of the key capability - education, through functions and processes can lead to (IT) resources. Their diversity and availability are the basis for flexible management. Different resources and their combinations are used for different teaching scenarios.

This is important for a long-time strategic decision. We were able to identify a typical consequence of the pandemic, when the demand for portable devices and equipment to support communication increased. These resources were not previously required. Their deployment was not predicted and this limited flexibility. As a result, the continuity of education was threatened. In the analytical part of the project, the considerations that all universities need basically the same functionality were confirmed. They build their infrastructure based on the need for identical functions and need to ensure the same processes. The solution architecture should be oriented to these needs, they should not be oriented to one or another specific software. The choice of application is subject to its quality, ability to meet needs.

At the beginning of the article, we mentioned the challenges for IO3 in DANTE project. We believe that the maturity of processes, knowledge of IT resources and interrelationships, prepared learning scenarios, appropriate information sharing can help improve management not only in times of crisis. These approaches are based on best practice, just like in the COBIT framework.

The approach of the SEE DANTE model is based on the ability to know the processes and resources necessary for their implementation. This supports adaptability and flexibility and the ability to predict possible developments in the future.

6. Acknowledgement

This paper was supported within Digital Area for Networking Teachers and Educators project - 2020-1-CZ01-KA226-HE-094368.

7. References

- Chan, Y.E. and Reich, B.H. 2007. IT alignment: what have we learned? *Journal of Information Technology* 22, 4 (2007), 297–315.
- Coltman, T., Tallon, P., Sharma, R. and Queiroz, M. 2015. Strategic IT alignment: Twenty-five years on. *Journal of Information Technology* 30, 2 (2015), 91–100.
- ISACA. (2018a). COBIT® 2019 Framework: Introduction and Methodology. Schaumburg: ISACA.
- ISACA (2018b). COBIT® 2019 Design Guide: Designing an Information and Technology Governance Solution. Schaumburg: ISACA.
- Kotusev, S. (2020). The Hard Side of Business and IT Alignment. *IT Professional* 22(1), 47-55.
- Matt, C., Hess, T. & Benlian, A. (2015). Digital Transformation Strategies. *Business & Information Systems Engineering* 57(5), 339-343.
- Nielsen, M., M. (2019). Governance lessons from Denmark's digital transformation. *Proceedings of the 20th Annual International Conference on Digital Government Research*. June 2019, pp. 456–461.
- OpenGroup. (2019). TOGAF® Standard, Version 9.2. [Online]. Available at: <https://pubs.opengroup.org/architecture/togaf9-doc/arch/index.html> [cited 2022-03-12].
- OECD. (2015). G20/OECD Principles of Corporate Governance. OECD Publishing, Paris.
- Pavliček, A. & Doucek, P. (2016). Social Media and Social CRM. In: Tjoa A., Xu L., Raffai M., Novak N. (eds) *Research and Practical Issues of Enterprise Information Systems. CONFENIS 2016. Lecture Notes in Business Information Processing*, vol 268. Springer, Cham.
- Pitner, T. & Ministr, J. (2017). Innovation of the Information Management in Compliance Management Area. In *IDIMT-2017 - Digitalization In Management, Society And Economy*, pp. 71-78.

AUDITING REMOTE WORKPLACE SECURITY

Ladislav Vaněk

Faculty of Informatics and Statistics
Prague University of Economics and Business
xvanl24@vse.cz

DOI: 10-35011/IDIMT-2022-101

Keywords

COBIT 19, COVID-19, IT audit, RACM, audit activity, audit objectives, processes, remote workplace security, risks

Abstract

Remote workplace security (RWS) is an area that maps the security of the defined work procedures of managing the work of employees outside the company's internal environment, which is in many ways riskier and more demanding for the company to be managed effectively. The importance of this area increased with the advent of the COVID-19 pandemic when most companies had to produce a series of measures that led to at least a partial introduction of work from the home office (HO). In a very short period of time, they faced the dilemma of allowing employees to work from home instead of working within the secure perimeter of the corporate network. These measures have undoubtedly led to a change in the approach of companies and the introduction of new working procedures and tools. For many companies, this has been a general change in the philosophy of human capacity management approaches and a change in processes evaluation. The aim of this paper is to present a comprehensive best practice overview on how to approach an audit activity on Remote workplace security.

1. Introduction

From the company's point of view, remote workplace security (RWS) is a crucial area that should be given due attention (Georgiadou et al., 2022). Moreover, the importance of this area has grown in the context of the escalation of the COVID-19 crisis, where most companies have relied on the transition to partial or almost complete work from the home office (HO). This situation persists in some form until the time when the pandemic is receding. Still, companies are increasingly using work from home. The standard is already based on hybrid-functioning (combining work from the office and home) and the so-called new normal in the workplace (Vermani & Sharma, 2021). The new normal will only partially restore the pre-pandemic setting, while remote working will still be widely used.

The risks associated with the use of the remote workplace with the growth in the volume of its use and the number of tools used are growing. Furthermore, from the point of view of performing internal audit activities and coverage of the continuous audit lifecycle, it is necessary to cover this area as well.

The rapid evolution of the COVID-19 pandemic triggered an equally urgent transition toward the setup of remote working facilities (Diab-Bahman & Al-Enzi, 2020). The question remains whether

the COVID-19 pandemic was the actual trigger for this change, or whether it only accelerated it and, if so, what impact it had and how it affected the course of action of this rapid change (Ng et al., 2021). Because of the unexpectedness of the event, security might have been managed in a non-uniform way as organizations rushed to manage this new and evolving environment. The need to rapidly allow employees to work remotely might have overshadowed the enforcement of security controls.

Some studies (Mihailović et al., 2021) show that the transition to HO during a pandemic has *led to the increased flexibility of work arrangements, employee autonomy, reduction of operating costs, risks of miscommunication, coordination of business activities, the possibility of supervision and organizational support, while the decline in productivity could also occur, due to the merging of the private and business spheres.*

The implications of COVID-19 on remote working security controls, changes in the way companies operate, and how audit teams and other control functions have to face these challenges are addressed in several articles (Florea, 2021; Appelbaum et al., 2020). However, resources directly focusing on setting up the RWS audit procedure were not found.

However, the COVID-19 pandemic has resulted in a significant change and the perception of cyber security risks (Anders, 2020). Working from home brings new security threats as a result of this distributed work environment and puts employees at much greater risk than in on-premises corporate networks. As an example, home connections are less secure, and cybercriminals could have an easier entry into the company network. Furthermore, the explosion of various online tools, solutions, and services for collaboration and productivity tends to have the bare minimum of security default settings, and updates from third-party vendors can change security preferences and be easily overlooked. In this context, the “attack surface” gets more prominent and threats such as phishing and ransomware can more easily evade corporate defenses. At the same time, in a traditional office setting, the natural collaboration of co-workers lowers such risks.

Therefore, this is an area that needs to be given due attention considering sudden changes. For this reason, it is necessary to evaluate this area from the point of view of audit activities and to address possible recommendations. In the context of this article, it is a matter of risk identification, definition of key questions and controls, which can be used to test and verify the RWS area.

2. Methodology

The author of this paper seeks to find an answer to the research question *What are the main audit objectives and key questions to be answered by planning the audit activity?*

The aim of this paper is to provide a comprehensive best practice overview of how to approach the RWS audit and what areas to consider. The purpose is to offer material from which individuals focusing on the analysis and audit of the RWS area can emerge. The recommendations are based on a literature review, best practices in the field and the author's professional experience. The research results are summarized in Chapter 3 and divided into sections 3.1-3.4 devoted to the *Audit objective and key questions*, then *Identified risks* and *Analyzed areas*, and finally the definition of RACM (Risk and control matrix).

The continuity of COBIT 19 objectives (based on best practices and described in Chapter 3.1) and identified risks (based on the author's expected audit activity scope and experience) are then linked in Chapter 3.2 - Table 1 so that there is a clear link between risks in RACM and previous parts.

RACM is a repository of identified risks within the audited process/area and control that mitigate these risks. The essence of RACM for a risk assessment should be understood as one of the foundation methods of performing audit activities (Pelletier, 2008).

3. Results

The objective of the audit activity covering the RWS area is to provide reasonable assurance that the area is addressed adequately in terms of the company's identified risks. Every company should be aware of the increased risks in the code of remote access of employees and others to the company data. The aim should be to identify the risks, manage them, and, if necessary, find suitable procedures for their mitigation. One way to verify this is to perform an audit activity, for which we will present the basic assumptions below.

The results are divided into three sections, with specific recommendations for auditing the RWS area. This is a list of recommendations for the objectives of the audit activity, the identified risks, and the areas that this audit activity should cover. Of course, the outputs are supposed to be not final and can be further developed or expanded within a specific activity.

3.1. Audit objective and key questions

The objective of this audit activity is to ensure that the internal control system currently in place can guarantee an adequate level of information security also in the new remote working scenario.

Affected processes are identified processes related to the audited issues that should be covered by this audit activity (engagement). The processes and objectives concerned were determined primarily from the COBIT 19 methodology (ISACA, 2018), taking into account ITIL (ITIL, 2020) and ITAF (ISACA, 2020). The application of changes within the COBIT 19 objective in the context of the changes caused by the COVID-19 crisis (Svatá, 2021) was examined, and two use-cases of this application to the changing IT governance environment were presented.

Within the defined scope of audit activity, the following objectives were identified from COBIT 19 (ISACA, 2018), which are primarily affected by the audit activity (objectives can of course be extended/modified in the context of how the audit activity is focused - i.e., precisely how the scope of the audit activity is determined):

- APO12 Managed Risk - the goal is to *integrate the management of IT-related enterprise risk with overall enterprise risk management and balance the costs and benefits of managing IT-related enterprise risk*. In the context of audit activity, the focus is on whether the risks associated with RWS are effectively evaluated and managed.
- APO13 Managed Security - the goal of the objectives is to *define, operate and monitor an information security management system*. Therefore, the purpose is to cover the area of information security management system (ISMS), which aims to provide *a standard, formal and continuous approach to information security management, enabling secure technology and business processes aligned with business requirements*.
- DSS05 Managed Security Services - the goal is to *establish and maintain information security roles and access privileges and perform security monitoring*. In the context of audit activity, the focus is primarily on remote access and control component management (e.g., mobile devices, teleworking).

The audit areas are divided into two groups, which are factually related. Still, each relates to a different area and the audit activity's key questions (KQ) - *PEOPLE & ORGANIZATION* and

TECHNOLOGY. For each area, key questions were subsequently defined according to the audit objective and should be answered during the conduction of audit activity.

Area: PEOPLE & ORGANIZATION

- KQ1: Did the company provide the employees with clear indications on how to work remotely in a secure way?
- KQ2: Did the company assess and manage the risks arising from the extensive adoption of a remote working model?

Area: TECHNOLOGY

- KQ3: Are devices secured with appropriate technological measures when not connected to the corporate network?
- KQ4: Is remote access to corporate resources secured?
- KQ5: Are suspicious security events related to remote activities timely detected and included in the security monitoring process?

3.2. Identified risks

Working from home opens companies to new security issues as employees are at much greater risk when working outside corporate premises and networks. Home connections are less controlled, and cybercriminals could easily access company data and applications. Home premises could be prone to the risk of accidentally sharing confidential information (from shoulder surfing to eavesdropping), which used to be limited to employees with high mobility rates in the past.

The dramatic increase in the usage of additional non-standard online collaboration tools (cloud storage, social networks, video conferencing systems) to increase remote working productivity may have also increased the attack surface. In a traditional office setting, the natural collaboration may have also increased the attack surface of co-workers and lower such risks.

Furthermore, security countermeasures have not been adapted to the increase of the attack surface due to missing risk impact analysis and project implementation, leading to a rise in cyber-attacks which might imply reputational risk and economic losses.

- R1: The remote working security is not organized in a structured manner, implying that relevant steps might not be taken into account, due to an insufficient local framework, risk assessment and security awareness, leading to both security and regulatory issues which might imply reputational risk and economic losses.
- R2: Lack of endpoint security management related to remote access due to inappropriate implementation of security protection and detection measures, lack of established processes and practices related to mobile devices management, monitoring/reporting activities may increase the risk of successful cyber-attack, which in turn, can lead to a data breach, system failure, economic losses and/or reputational risk.
- R3: Insufficient security management of employees' remote access due to insufficient security practices and lack of remote access monitoring, can lead to a data breach, system failure, economic losses and/or reputational risk.
- R4: Lack of security monitoring processes of endpoints not connected to the corporate network may lead to untimely detection and response to security incidents which may, in turn, lead to potential data breaches and cyber-attacks, which in turn, can lead to a data breach, system failure, economic losses and/or reputational risk.

The risks (R) that arise from the definition of the scope of the audit activity, i.e., the area covered by the audit activity, are presented below. According to the Analyzed area, these risks are then evaluated and tested within predefined controls by the audit team.

The link between the identified risks (R), Key issues and COBIT 19 objectives listed in Chapter 3.1 is outlined in *Table 1*.

Table 1: Identification of the Risks, Key questions and Relevant COBIT 19 Objectives

Risk (R)	Key Question (KQ)	COBIT 19 Objectives
R1	KQ1, KQ2	APO12
R2	KQ3, KQ4	APO13
R3	KQ3, KQ4	APO13, DSS05
R4	KQ5	DSS05

3.3. Analyzed areas

Below are selected areas that can be tested by the audit team within the performed activity. Areas are based on the definition of the scope according to the individual COBIT 19 objectives in the previous steps so that the *key questions (KQ)* are answered and the defined *risks (R)* are evaluated within predefined controls – *Control title + description* (defined in *RACM*).

- Remote Working Governance - Security Management processes ensuring the adoption and implementation of policies/practices defining the expectations and security requirements related to remote working.
- Data Loss Prevention (DLP) - Appropriate design and effectiveness of DLP solutions on devices and web apps/cloud storage.
- Endpoint Security - Design and effectiveness on Endpoint Detection and Response capabilities; Endpoint encryption; Patch management; Antivirus solution.
- Remote Access Controls to the company network and cloud services - Secured implementation and configurations of VPN / VDI, MDM / MAM and cloud services (e.g., Microsoft 365 and other solutions).
- Collection of Remote Working events for Security Monitoring - Appropriate design and effectiveness of security event collection from endpoints during remote working.

3.4. Risk and control matrix

The risk and control matrix (RACM) represents a matrix of defined risks and controls, which are then used to verify/test defined risks. Risks are then assessed and evaluated using defined controls (C). The purpose of RACM is, based on identified risk levels, to plan audit testing and other follow-up activities. Activities involved in the creation of RACM should include rating or ranking of risks, identifying controls, assessing each control's design and effectiveness, and, of course, analyzing the testing results and any recommendations and audit findings.

Table 2: RACM

Risk	Control title	Control description
R1	Remote workplace-related company guidelines	A comprehensive remote-working policy/procedure defining remote work expectations and security requirements is in place.
	Risk Assessment	A risk assessment related to the sudden extension of the remote working model to all employees and consequent review of current internal regulations has been performed.
	Security Awareness	Remote working security requirements are formally communicated to all staff and awareness training (including phishing simulations) is regularly performed/delivered. The results of awareness training are documented and evaluated.
R2	Data protection on devices and applications	DLP policy exists and DLP rules are defined by business requirements. DLP solution is implemented on devices connected and unconnected to the network and DLP solution related to data handling on web-based app/in Cloud storage (e.g. Cloud access security broker (CASB)) is implemented.
	Endpoint encryption	Requirements for endpoint encryption (e.g. BitLocker) to protect the devices from unauthorized access are defined and implemented. A process exists to monitor and follow-up on non-compliant devices.
	Patch Management	A process exists to regularly patch operating systems and applications on endpoints to ensure they are up to date. Non-compliant endpoints are monitored and timely followed up.
	Endpoint Protection solutions	An Antivirus/Anti-malware/EDR solution/Firewall is installed and operational on endpoints with an up-to-date configuration.
	Mobile device management (MDM)	An established MDM policy/procedure is in place and the respective MDM solution is properly implemented, with exceptions regularly monitored and reviewed.
R3	VPN/VDI solution	A defined VPN/VDI solution is in place and adequately configured to protect remote access to critical systems/data. A process is in place to restrict and manage the lifecycle of VPN/VDI access.
	Office 365 security (If applicable)	A policy/procedure is in place to implement the security best practices/controls for Office 365 applications in relation to remote access.
R4	Collection of Remote Working events for Security Monitoring	Specific events related to remote working such as endpoint malware infections, identity, access authentication requests and failures, etc. are collected (for SIEM ingestion).

4. Conclusions

RWS is an area that has come to the fore in the context of the COVID-19 crisis and should be given sufficient attention. The essential areas that should be covered within the audit activity focusing on this area were presented.

One of the key parts that must be determined in implementing any audit activity is its scope and focus. This is determined by the audit objectives and key question that needs to be answered during the audit. Objectives were divided into two groups, namely PEOPLE & ORGANIZATION and TECHNOLOGY. Subsequently, the risks associated with the area covered by the audit activity are identified. The task here is to determine the potential risks in the given processes and the potential impacts on the audited company. Subsequently, to cover these risks, the analyzed controls are defined within RACM. The audit team determines whether the companies' risks are sufficiently mitigated by testing these areas and the defined controls from the analyzed areas.

The presented paper is neither a plenary nor a complete guide on auditing the RWS area; it should be perceived as a recommendation or guide on starting and conducting an auditing activity. Within the performed audit activity, several variables (type of organization and its management, market

specificity, geolocation, etc.) significantly affect the performed audit activity. It is necessary to address them accordingly and, if necessary, modify the focus and scope of the audit activity.

5. Acknowledgement

The paper was supported by specific project IG409031 "Úloha interného auditu v kontextu COVID-19 a zvýšených hrozeb informační bezpečnosti" granted by the Internal Grant Agency of Prague University of Economics and Business, the Faculty of Informatics and Statistics.

6. References

- Anders, S. B. (2020). Cybersecurity Resources for a Remote Workforce. *The CPA Journal*, 90(7/8), 72–73.
- Appelbaum, D., Budnik, S., & Vasarhelyi, M. (2020). Auditing and Accounting During and After the COVID-19 Crisis. *The CPA Journal*, 90(6), 14–19.
- Diab-Bahman, R. & Al-Enzi, A. (2020). The impact of COVID-19 pandemic on conventional work settings. *The International Journal of Sociology and Social Policy*, 40(9/10), 909–927. <http://dx.doi.org/10.1108/IJSSP-07-2020-0262>
- Florea, R. (2021). Implications of COVID-19 Crisis on Risk Management, Audit and Controls Activities. *Economy Transdisciplinarity Cognition*, 24(2), 39–49.
- Georgiadou, A., Mouzakitis, S., Askounis, D. (2022). Working from home during COVID-19 crisis: A cyber security culture assessment survey. *Security Journal*, 35 (2) 486-505. <https://doi.org/10.1057/s41284-021-00286-2>
- ISACA (2018). COBIT® 19 Framework: Governance and Management Objectives, 2018, ISBN 978-1-60420-764-4
- ISACA (2020). IT Audit Framework (ITAF™): A Professional Practices Framework for IT Audit, 4th Edition, 2020, ISBN 978-1-60420-834-4
- ITIL (2020). ITIL(R) 4 Essentials, IT Governance Publishing, 2020, ISBN 1787782182
- Jones, A. (2022). Remote Work Policies To Make Hybrid Scheduling Work. *Workforce Management (Time and Attendance) Excellence Essentials*. <https://www.proquest.com/docview/2645207000?accountid=17203>
- Mihailović, A., Smolović, J. C., Radević, I., Rašović, N., & Martinović, N. (2021). COVID-19 and Beyond: Employee Perceptions of the Efficiency of Teleworking and Its Cybersecurity Implications. *Sustainability*, 13(12). <http://dx.doi.org/10.3390/su13126750>
- Ng, M. A., Naranjo, A., Schlotzhauer, A. E., Shoss, M. K., Kartvelishvili, N., Bartek, M., Ingraham, K., Rodriguez, A., Schneider, S. K., Silverlieb-Seltzer, L., & Silva, C. (2021). Has the COVID-19 Pandemic Accelerated the Future of Work or Changed Its Course? Implications for Research and Practice. *International Journal of Environmental Research and Public Health*, 18(19). <http://dx.doi.org/10.3390/ijerph181910199>
- Pelletier, J. (2008). Adding Risk Back Into the Audit Process. *Internal Auditor*, 65(4), 73–77.
- Svatá, V. (2021). Cobit 19 and Covid 19: Is there any relationship?. 29th Interdisciplinary Information Management Talks-Pandemics: Impacts, Strategies and Responses, IDIMT 2021, 147-152.
- Vermani, S., & Sharma, S. (2021). New normal in the workplace post Covid-19. *International Journal of Innovation and Applied Studies*, 33(1), 12–16.

DECISION SUPPORT FOR THE CHOICE OF A METHODOLOGICAL FRAMEWORK FOR IT SERVICES

Blanka Bazsová

Department of Systems Engineering
VŠB-Technical University of Ostrava, Faculty of Economics
blanka.bazsova@vsb.cz

Jan Ministr

Department of Applied Informatics
VŠB-Technical University of Ostrava, Faculty of Economics
jan.ministr@vsb.cz

DOI: 10-35011/IDIMT-2022-109

Keywords

Analytical Hierarchical process, methodology, multicriterial analysis, process management, services

Abstract

The use of certified process management methodologies in companies providing IT services is currently a necessity to maintain their competitiveness. This article focuses on the evaluation of the methodological frameworks used in the IT process management - ITIL and COBIT. The aim of this paper is to design and evaluate a multi-criteria evaluation model that considers the criteria for their selection. The design of the multi-criteria model is created according to the Analytical Hierarchical Method (AHP). This model evaluates the optimal alternative of the methodology. The IT company focuses on the implementation of process management IT frameworks and offers consulting and software support in the information technology processes. It is necessary to make arguments that are based on a sophisticated evaluation of the criteria for implementation the specific framework. The results of the evaluation using the AHP method showed that the ITIL methodology achieved the highest score as COBIT.

1. Introduction

Service is a mean of providing value to the customer through the outputs that the customer wants to achieve without owning specific costs and risks. ICT services are provided to external and internal customers. The IT company is faced with the decision of which methodology to recommend to the customer and to start implementing for him. This survey provides possibilities to choose from one of the methodologies, ITIL or COBIT. The reason is that IT company which helps to implement both methodologies want to recommend the methodology according to the sophisticated tool. The IT company wants to help its customer such as products that maximizes utility evaluation. The methodology that best meets the given criteria will be recommended and offered as the most suitable for the given customer. The choice of a methodological framework presents a complex

problem, which is based on the expectations of the stakeholders to determine the selected criteria and information about the proposed methodological frameworks, including practical experience with their implementation.

Service management is a set of specific organizational competencies needed to provide value to the customer in the form of services. A service is the result of a process that is represented by a structured set of activities designed to achieve a specific goal. The IT process can define policies, norms / standards, guidelines, activities, and work instructions as needed. Rubio & Arcilla (2020) pointed out that one of the main points when implementing the Information Technology Infrastructure Library (ITIL) is which order processes must be implemented.

As a state, Voříšek (2015), according to the success of the IT services, it is possible to measure it using various indicators. Decision making is one of the basic managers' activities. It cannot be solved without qualitative analysis based on managerial experiences. Quantitative analysis is based on mathematical tools. Decision-making theory and methods have been applied in many fields. There were some applications in the ICT services provided, but only a few applications in the field of methodology comparison are in the field of IT services.

2. IT service management frameworks

IT services are managed by using two main methodologies – Cobit and ITIL.

2.1. COBIT® 2019 FRAMEWORK

This framework is designed to be overarching, meaning that it is consistent with most relevant standards, frameworks, and regulations. It is a framework for the governance and management of enterprise IT that focuses not only on IT services and technologies, but on the entire enterprise to achieve defined business objectives. Framework makes a clear distinction between governance, which ensures that stakeholder needs into corporate objectives and management that plans, develops, and monitors activities. COBIT defines the components to build and sustain a governance system: processes, organizational structures, policies and procedures, information flows, culture and behaviors, skills, and infrastructure. COBIT also defines the design factors that should be considered by the enterprise to build a best-fit governance system and addresses governance issues by grouping relevant components into governance and management objectives. Principles consists of two sets - requirements for an enterprise information management and technology system and governance framework. These requirements are to: provide stakeholder value, holistic approach, dynamic governance system, governance distinct from management, tailored enterprise needs and end-to-end governance system. Governance framework implements principles conceptual model, open and flexible model, standards framework, and regulations.

Components of a governance system consist of components such as processes, organizational structures, principles, policies, and frameworks, information and culture of individuals, people, and their skills and competencies, and last component are services.

The design factors for the success of IT use consist of factors such as enterprise strategy and enterprise goals. Benefits of successful COBIT implementation are as follows:

1. Benefits realization consists of creating value for the enterprise through IT,
2. Maintaining and increasing the value derived from existing IT,
3. Investments and elimination of IT initiatives and assets that are not creating sufficient value.

4. Risk optimization entails addressing the business risk associated with the use, ownership, operation, involvement, influence, and adoption of IT within an enterprise.
5. Resource optimization ensures that the capabilities are in place to execute the strategic plan.

2.2. ITIL methodology

ITIL methodology is based according to the ITIL® Foundation (ITIL, 2019) on some general principles:

Framework makes a clear distinction between:

- governance, which ensures that stakeholder needs are translated into corporate objectives, priorities, and decision-making;
- management that plans, develops, and monitors activities so that they are consistent with the direction set by management.

Main features:

- defines the components to build and sustain a governance system: processes, organizational structures, policies and procedures, information flows, culture and behaviors, skills, and infrastructure;
- defines the design factors that should be considered by the enterprise to build a best-fit governance system;
- addresses governance issues by grouping relevant governance components into governance and management objectives that can be managed to the required capability levels.

The principles consist of two sets:

- First set of principles describes the basic requirements for an enterprise information management and technology system. These are the following 6 principles:
 1. Provide stakeholder value;
 2. Holistic approach;
 3. Dynamic governance system;
 4. Governance distinct from management;
 5. Tailored enterprise needs;
 6. End-to-end governance system.
- Second set of principles for a governance framework that can be used to create a governance system for the enterprise. These are the following 3 principles:
 1. Based on conceptual model - identifies key components and relationships among components, to maximize consistency and allow automation.
 2. Open and flexible - governance framework that allows for new content and the ability to address new issues in the most flexible way, while maintaining integrity and consistency.
 3. Aligned to major standards framework and regulations.

Objectives always relates to one process. Objectives are divided into five groups of domains, one for governance and four for management:

- Governance objectives are grouped in the Evaluate, Direct, and Monitor (EDM) domain. In this domain, the governing body evaluates strategic options, directs senior management on the chosen strategic options, and monitors the achievement of the strategy. This domain contains 5 described processes.
- Align, Plan and Organize (APO) addresses the overall organization, strategy and supporting activities for IT. This domain contains 14 described processes.
- Build, Acquire, and Implement (BAI) treats the definition, acquisition, and implementation of IT solutions and their integration in business processes. This domain contains 11 described processes.
- Deliver, Service, and Support (DSS) addresses the operational delivery and support of IT services, including security. This domain contains 6 described processes.
- Monitor, Evaluate and Assess (MEA) addresses performance monitoring and conformance of IT with internal performance targets, internal control objectives, and external requirements. This domain contains 4 described processes.

The components of a governance system consist of seven components:

- Processes describe an organized set of practices and activities to achieve certain objectives and produce a set of outputs.
- Organizational structures are the key decision-making entities in an enterprise.
- Principles, policies, and frameworks translate desired behavior into practical guidance for day-to-day management.
- Information is widespread throughout any organization and includes all the information produced and used by the organization.
- Culture, ethics, and behavior of individuals and of the enterprise are often underestimated as factors in the success of governance and management activities.
- People, skills, and competencies are required for good decisions, execution of corrective action and successful completion of all activities.
- Services, infrastructure, and applications include the infrastructure, technology, and applications that provide the enterprise with the governance system for IT processing.

Benefits of successful implementation are:

- Benefits realization consists of creating value for the enterprise through IT, maintaining and increasing value derived from existing IT, investments, and eliminating IT initiatives and assets that are not creating sufficient value.
- Risk optimization entails addressing the business risk associated with the use, ownership, operation, involvement, influence and adoption of IT within an enterprise.
- Resource optimization ensures that the appropriate capabilities are in place to execute the strategic plan and sufficient, appropriate and effective resources are provided.

3. Decision making model

The Analytical Hierarchical Process (AHP) is based on the evaluation of each group of criteria and sub-criteria. By using this method, the global significance for the criteria and local significance for

the sub-criteria is calculated. The evaluation of the criteria and sub-criteria represents the following matrix:

$$\begin{array}{c|cccc}
 & c_1 & c_2 & c_3 & c_n \\
 \hline
 c_1 & 1 & s_{12} & s_{13} & s_{1n} \\
 c_2 & 1/s_{12} & 1 & s_{23} & s_{2n} \\
 c_3 & 1/s_{13} & 1/s_{23} & 1 & s_{3n} \\
 c_n & 1/s_{1n} & 1/s_{2n} & 1/s_{3n} & 1
 \end{array} \quad (1)$$

where $S = \{s_{ij}\}$, where $i, j = 1, 2, \dots, n$.

The sum of local significances is equal to 1 (100%). The sum of global significances must also be equal to 1 (100%). When calculating significances, the Saaty's matrix of mutual comparison of all criteria to each other is used (Saaty, 2006). The resulting significance is equal to the geometric mean of the product of the individual paired comparisons. Saaty (2006) uses the 9-escalate scale of the criteria evaluation, which is described in Table 1.

Table 1 Saaty's criteria evaluation; Source: Saaty, 2006

Value	Criteria Evaluation
1	equal importance among elements i and j
3	moderate importance of i element before j element
5	strong importance of i element before j element
7	very strong importance of i element before j element
9	the extreme importance element i before j

The Saaty's matrix has two main attributes, reciprocity and consistency. The condition of reciprocity is considered as:

$$s_{ij} \approx \frac{w_i}{w_j} \quad (2)$$

Consistency is evaluated by the ratio of consistency (CR). The consistency value must be $CR < 0.1$, where

$$CR = \frac{CI}{RI} \quad (3)$$

where RI is the random index.

When

$$CI = \frac{\lambda_{max} - n}{n - 1} \approx \frac{w_i}{w_j} \quad (4)$$

where λ_{max} is the own number and n is number of criteria.

We determine the weight of each criterion according to the geometric mean:

$$w_i = \frac{(\prod_{j=1}^n s_{ij})^{1/n}}{\sum_{j=1}^n (s_{ij})^{1/n}} \quad (5)$$

The final option rating is then expressed in the following relation:

$$U_i = \sum_{j=1}^k u_{ij} \times w_j \quad (6)$$

Where U_i represents the general significance of variant i with respect to the objective of the decision-making process. U_{ij} expresses the significance of the variants for the individual criteria, and w_j expresses the significance j of that criterion. (Bazsová, 2016)

The utility function assigns a utility to each alternative. The overall utility of each alternative is determined based on the knowledge of the weights of the criteria. The one with the highest utility is then selected as the best option.

4. Data and Methodological Frameworks as Variants for Decision-Making Model

There was an input analysis with the customer provided by the Attn Consulting company. Many main aspects were selected for the selection of the useful and appropriate methodology. From this input analysis, 2 main groups of aspects as super-criteria were chosen, internal possibilities and external requirements. Regarding the AHP methodology, six sub-criteria were also selected: the evaluation complexity of methodology, service management concept, coverage of processes, stakeholder participation, and possibility of certification. The suggested methodological framework has been divided into two groups – internal requirements and external consequences. Internal requirements contain Service Management Concept, Coverage of Processes and Coverage of Services. External consequences contain Complexity of Methodology, Stakeholder Participation and Possibility of Certification. The solution to this complex decision-making problem is based on the collection of information on given methodologies and the selection of criteria for their evaluation. The principles of the ITIL and COBIT methodologies are described above.

5. Results

The criteria were evaluated according to the proposed groups of criteria. All criteria have an increasing tendency. Therefore, it was maximized. The evaluation of the groups of criteria was provided using the Saaty's matrix, which is part of the AHP method. The results are displayed in Figure 1.

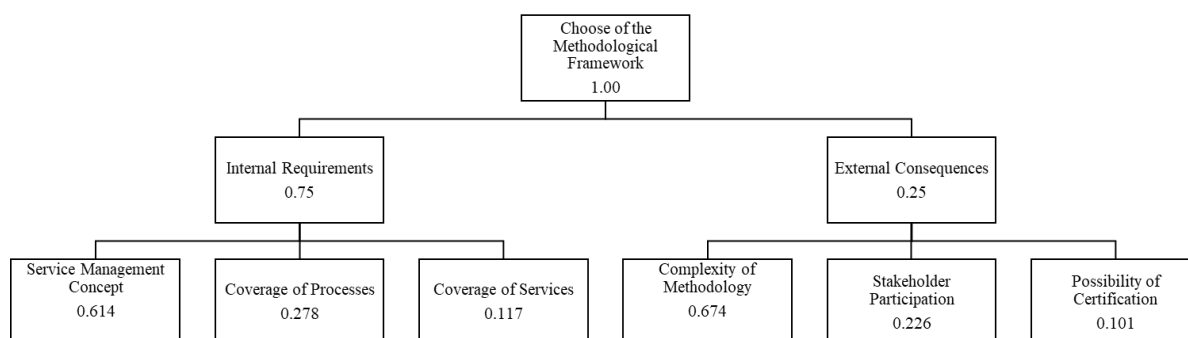


Figure 1 Calculation results of weights in multi-criteria model for preparation of the evaluation. (Own processing)

Table 2 shows the weighted evaluation of the proposed criteria using the AHP method. As we can see, for example, for sub-criterion C11, the global weight is 46.08%. This value was calculated by first calculating the global weights of the main groups, i.e., the super-criteria (internal and external criteria). Using the global weight of the super-criteria (internal), we calculate the global weight of this criterion as a product: local values (calculated as geomean subgroups) of sub-criterion C11

(0.614) and global weights of the internal criteria criterion (0.75). The result is 0.4608, in percentage it is 46.08%. Evaluation of the criteria shows that the most important for the user is the complexity of the methodology (50.54%), on the second position is the service management concept (46.08%), and the least importance has the possibility of certification (7.55%), see Table 2.

Table 2 Evaluation of the multi-criteria model by using AHP method; Source: Own processing

Sub-criteria	Sub-criteria description	ITIL	COBIT	Global Weights	ITIL	COBIT
C11	Service management concept 30	0.333333	0.666667	46.08%	0.153602664	0.307205328
C12	Coverage of processes 35	0.666667	0.333333	20.13%	0.307205328	0.067092143
C13	Coverage of services 35	0.5	0.5	8.79%	0.230403996	0.043957789
C21	Complexity of methodology	0.666667	0.333333	50.54%	0.307205328	0.168452643
C22	Stakeholder participation	0.333333	0.666667	16.92%	0.153602664	0.11276775
C23	Possibility of certification	1	0	7.55%	0.460807992	0
Total:					1.613	0.699

The overall benefit assessment was calculated according to Equation (6). The partial utility for criterion C11, for example for the ITIL methodology, was calculated by multiplying the global weight (46.08%) by the weighted partial utility (0.33). This partial weighted utility was calculated according to the distribution of the partial evaluation of the criteria and the sum of the evaluated criteria for both variants. As we can see in Table 2, a higher overall utility was achieved with the ITIL methodology (1.613). According to the applied AHP method, the IT company should recommend and implement the ITIL methodology.

6. Conclusion

This application using the AHP method shows that the choice of methodology should respect the requirements and preferences of the specific user. On the other hand, evaluation according to such set criteria is also valuable for other companies that decide to implement one of the mentioned methodologies. In the next research, it is valuable to use another decision-making method, such as ELECTRE or TOPSIS method, to compare the results achieved.

The paper considered implementing the groups of criteria by implementation even of the ITIL or COBIT methodologies at the decision-making process. The AHP method was used in the decision-making model. There have been used 6 sub-criteria and 2 groups of super-criteria. The most important methodology that can be implemented is ITIL. The overall utility evaluation showed the highest score. It is shown in Table 2. The IT company recommended to the customer to implement the ITIL methodology.

7. Acknowledgement

This paper was supported within SGS Project SP 2022/74 “Computational Intelligence in the Prediction of Economic Quantities, Data Mining and Economic Process Modeling”.

8. References

- Bazsová, B. (2016). Proposal and Evaluation of the Competency Model of the Academic Employee. In: Proceedings of the International Scientific Conference Quantitative Methods in Economics, Vrátna, Slovakia, 25-32. ISBN 978-80-972328-0-1.
- Bernard, P. (2012). COBIT®5 A Management Guide. VW 's-Hertogenbosch: Van Haren Publishing, ISBN 978-90-8753-701-2
- Bucksteeg, M. et al (2012). ITIL 2011. Brno: Computer Press. ISBN 978-80-251-3732-1.
- ISACA (2019). COBIT® 2019 Framework: Introduction & Methodology. Schaumburg: ISACA. ISBN 978-1604206449
- ITIL® Foundation. (2019). ITIL 4 Edition. Norwich: The Stationery office. ISBN 978-0113316076
- Ministr, J. & Pitner, T. (2017). Process Support of Information Security according to COBIT (R) 5. In: Proceedings of the 12th International Conference on Strategic Management and its Support by Information Systems (SMSIS), Ostrava, Czech Republic, 418-424. ISBN 978-80-248-4046-8
- Ministr, J. et al. (2021). Enterprise IT innovation through EGIT and CoBIT® 2019. In: Proceedings of 29th Interdisciplinary Information Management Talks (IDIMT), Kutná Hora, Czech Republic, 153-159, ISBN 978-3-99113-261-5
- Rubio, RL, & Arcilla, M. (2020). How to Optimize the Implementation of ITIL through a Process Ordering Algorithm. Applied Sciences- Basel, 10(1), 34.
- Saaty, TL (2006). Fundamentals of decision making and priority theory with the analytic hierarchy process. 2nd ed. Pittsburg: RWS Publications, Analytic hierarchy process series, v. 6. ISBN 0-9620317-6-3.
- Voříšek, J. (2015). Principy a modely řízení podnikové informatiky. Praha: Oeconomica, VŠE. ISBN 978-80-245-2086-5.

HOW MANY CONFERENCE SUBMISSIONS SHOULD WE EXPECT IN TOTAL? AN EMPIRICAL MODEL PREDICTING THE TOTAL NUMBER OF SUBMISSIONS

Lubomír Štěpánek, Filip Habarta, Ivana Malá, Luboš Marek

Faculty of Informatics and Statistics

Prague University of Economics and Business

lubomir.stepanek@vse.cz, filip.habarta@vse.cz, malai@vse.cz, marek@vse.cz

DOI: 10-35011/IDIMT-2022-117

Keywords

Conference submission, submission number, total submission number prediction, empirical model, preliminary submission number estimates, submission deadline extension management

Abstract

Considering a usual format of a scientific conference, the number of total conference proceeding submissions behaves like a random variable and, thus, due to randomness, may sometimes result in an unexpected number of submissions. That could be an issue whether, mainly, the total number of submissions at the conference submission deadline is lower than expected. Although there is empirically based evidence that, e. g., the submission rate increases as the deadline approaches, numerical statistical modeling of the submissions' number in time before the deadline is generally missing. This work uses real data of conference submission times and numbers and models the number of submissions as a time-variant variable. Furthermore, we predict the total number of conference submissions using preliminary submission estimates obtained at a given time before the submission deadline. That may help the conference committee realize whether they may expect a feasible high submission number in total or must consider a submission deadline extension, considering that the entire submission number may be insufficient. Finally, we try to on-the-fly estimate the time moment before the deadline when roughly a half (a quarter, a tenth) of a total number of submissions is generally submitted to make deadline extension management possible.

1. Introduction

The behavior of conference proceeding submission in time may differ across various fields and research communities; however, some aspects seem to be common regardless of the research and conference area. Typically, when the submission deadline is relatively a long way away, the number of submissions increases slowly since authors are not so strongly motivated to speed up their work on the submission finishing. On the other hand, once the submission deadline is quickly approaching, the number of submissions increases rapidly and increases as fast as the submission deadline is closer. Consequently, most submissions were often submitted a few hours before the deadline incomes, which might be even a bit stressful for the conference organizing committee.

The total number of conference proceeding submissions within a well-established conference event may be estimated using historical data since the submission evidence from previous conference iterations is usually available. However, multiple (stochastic) factors still might affect the total

number of submissions. As an example, a newly announced competitive conference event not taken into account in advance, another kind of distractor resulting in decreased willingness to submit a proceeding for a given conference, or, on the other hand, e. g. a cancelation of a similar conference(s) in the same field that tends to increase the total submission number.

While the number of submissions higher than initially expected may not be an issue since only those of the highest quality are in the end accepted for publication, the total submission number lower than expected may cause the conference's economic or reputation issues. Moreover, as mentioned above, since most of the proposals are usually submitted "in the last minute" and the conference organizing committee cannot be sure till "the last" minute whether the number of submissions would be sufficient, there is room for mathematically based empirical modeling of submissions number as a variable dependent on time to deadline. On-the-fly, i. e. a running estimation of a total number of submissions based on a current submission number at a given time point before the deadline, may enable to confidently manage the submission deadline or other conference marketing if needed.

As a tool of choice, when the estimated total number of submissions seems to be significantly lower than expected, a conference committee may extend the deadline or boost up the conference (online) marketing to increase its visibility for an end audience, which also can reduce registration fees or offer additional publication opportunities to improve the conference's attractiveness for submission. First, of course, the initial information about an insufficient number of submissions is needed, though.

The number of research works dealing with the topic so far is limited. The first kick-off made on the issue of conference registration numbers in time, somewhat like submission numbers in time, came from Alfi, Parisi & Pietronero's (2007) "APP" model. The authors claimed the number of registrations is inversely proportional to the time to the deadline; however, they do not work out the mathematics behind their idea much since their publication is only short correspondence communication. The work is improved by Flandrin (2009), where a bit different, rather sigmoid model for a total number of submissions is applied; the author is inspired by commonly used biological models for animal population survival and motivation (Richards, 1959; Birch, 1999). Considering other covariates may predict the total submission number, more complex models such as Poisson regression (Berk & MacDonald, 2008; Perperoglou, 2011) or generalized additive models (GAMs) may be applied (Wood, 2006).

In this work, we adopt some of the "APP" model's features but improve them substantially and, particularly, go more into mathematical details and predictions. Compared to Frandrin, we use a different model and construct a running, on-the-fly prediction of the total number of submissions that is mathematically rigid, feasible, and applicable to practical conference management.

The manuscript proceeds as follows. Firstly, we describe open data used for a total number of submissions' predictions and depict in detail the mathematical approaches and derivations of the predicting model. The model background and idea are in the initial phases of derivations supported by graphical data analysis follow, indicating our mathematical assumptions are feasible and meet the real data. After that, we numerically estimate the parameters of our model for the data using the least square summations method. Finally, we made numerical predictions of the total number of submissions using a preliminary, on-the-fly estimate of submissions in a time point when roughly a half (a quarter, a tenth) of total conference submission is made. Such an estimate lets us conveniently guess the total number of submissions at the deadline.

2. Data and research methodology

In the following sections, we introduce the data applied and describe the background of the empirical model predicting the number of submissions in time to the deadline and the total submission number.

2.1. Data used for the “number of submissions in time to deadline” modeling and prediction

The data we used to verify our empirical model depicting the number of submissions as a variable of time to the deadline comes as publicly available from the Neuronal Information Processing Systems (NIPS, also known as NeurIPS) conference (Murray, 2022). They describe a number of submitted proceedings in distinct time points from call of papers announcement to the submission deadline, as collected between the conference iterations years 2003 to 2008. The numbers of submissions vs. times to deadlines are plotted in Figure 1.

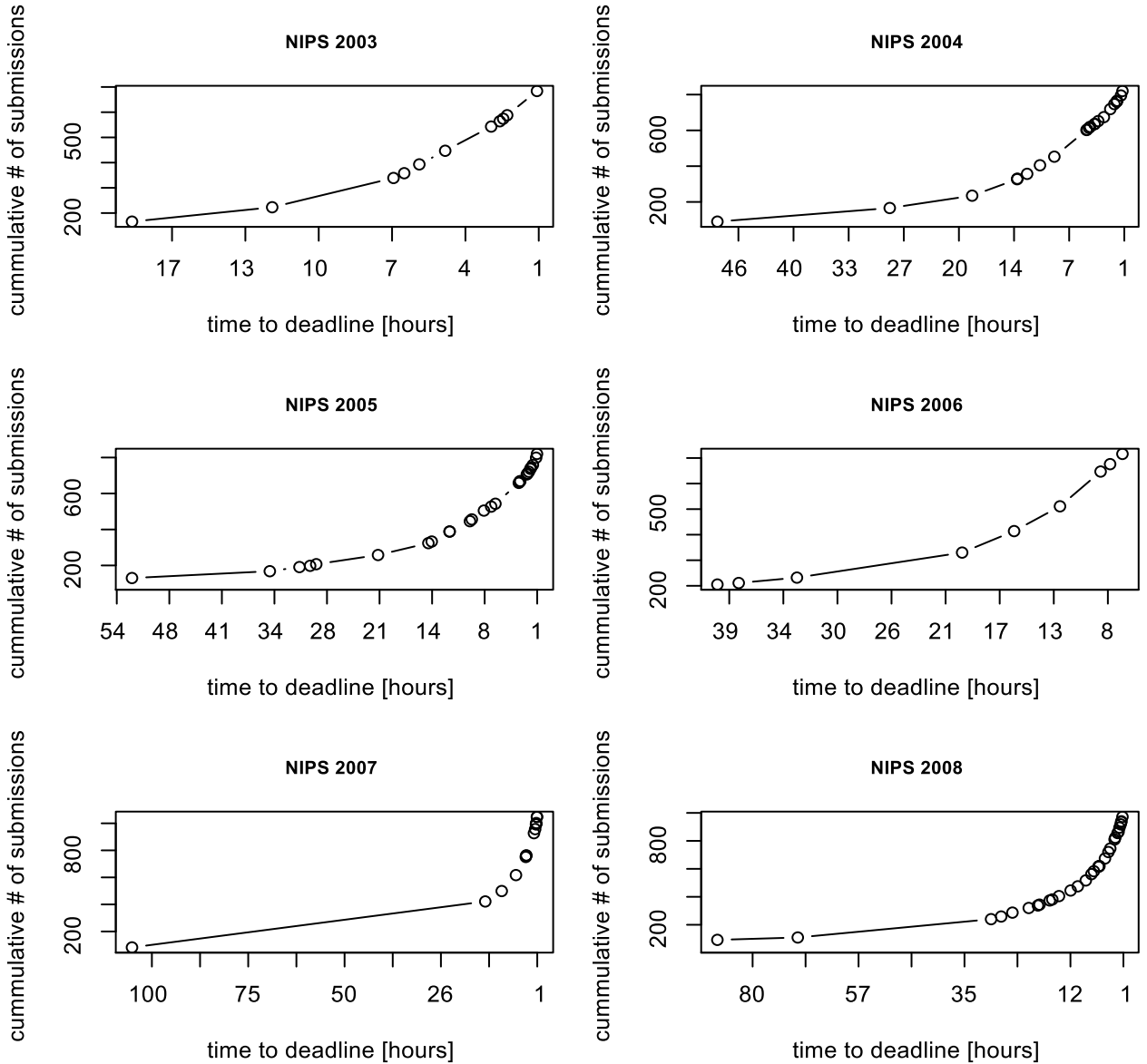


Figure 1. Numbers of submissions as functions of time to a deadline for different years of NIPS conference.

2.2. Mathematical background of the “number of submissions in time to deadline” model

Assuming the rate of conference submission $r(t)$ at a time point t is inversely proportional to time $t_d - t$ remaining to the submission deadline (which is set to a time point t_d), we get

$$r(t) = a + \frac{b}{t_d - t}, \quad (1)$$

where terms $a \geq 0$ and $b \geq 0$ describe a nature of the submission rate $r(t)$. While the term a rather says what the (constant) baseline submission rate, i. e. number of constantly submitted proceedings per week or per month, is, the term b indicates how significant the component inversely proportional to the time $t_d - t$ remaining to the submission deadline is.

Assuming the number of submissions at time point t , so that the time point t is between the time point of call for papers announcement (starting the submission process) and the time point for a deadline t_d (closing the submission process), is a continuous variable, which is acceptable due to relatively high number of submissions, we get, applying the formula (1), the total number of submission $n(t)$ at time point t as a definite integral (2) of

$$\begin{aligned} n(t) &= \int_{t_a}^t r(\tau) d\tau = \int_{t_a}^t \left(a + \frac{b}{t_d - \tau} \right) d\tau = [a\tau - b \log(t_d - \tau)]_{t_a}^t = \\ &= at - b \log(t_d - t) - (at_a - b \log(t_d - t_a)) = \\ &= a(t - t_a) + b \log \frac{t_d - t_a}{t_d - t}, \end{aligned} \quad (2)$$

where $t_a < t < t_d$. Straightforwardly, using the formula (3) we get also a total number of submissions at a time point $t = t_d$ for the submission deadline as

$$n(t_d) = \lim_{t \rightarrow t_d} \left\{ a(t - t_a) + b \log \frac{t_d - t_a}{t_d - t} \right\}, \quad (4)$$

which obviously runs into a problem due to the term $\log \frac{t_d - t_a}{t_d - t}$ that asymptotically becomes $\lim_{t \rightarrow t_d} \left\{ \log \frac{t_d - t_a}{t_d - t} \right\} = \log \frac{t_d - t_a}{t_d - t_d} = \log \frac{t_d - t_a}{0} = +\infty$, i. e. the integral from the formula (3) becomes in(de)finite. To overcome this struggling, we may assume that the total number of submissions is already reached at a time point $t = t_d - \Delta$ for some small $\Delta > 0$ that may be even pragmatically interpreted. In reality, let's say, the submission is possible to make fifteen or ten minutes before the time point of the deadline but no later, due to technical stuff needed to be done throughout the submission, e. g. personal information inserting, file with submitted proceeding uploading etc.

That being said, the time point $t = t_d - \Delta$ for small $\Delta > 0$ is considered as a real submission deadline, and the total number of submissions using the formula (3) is as follows,

$$\begin{aligned} n(t_d - \Delta) &= \lim_{t \rightarrow t_d - \Delta} \left\{ a(t - t_a) + b \log \frac{t_d - t_a}{t_d - t} \right\} = \\ &= a(t_d - \Delta - t_a) + b \log \frac{t_d - t_a}{t_d - (t_d - \Delta)} = \\ &= a(t_d - \Delta - t_a) + b \log \frac{t_d - t_a}{\Delta} \approx a(t_d - t_a) + b \log \frac{t_d - t_a}{\Delta}. \end{aligned} \quad (5)$$

A reasonable estimate for the constant $\Delta > 0$ that may also be called as “a time technically needed for a submission doing”, is about $\Delta \approx 15 \text{ minutes} = 0.25 \text{ hours}$.

What is also worth to be mentioned is that the model for the total number of submissions following the formula (5), using the constant $\Delta > 0$ as an estimate of time needed for finishing a submission, tends for whatever value of $\Delta > 0$ to underestimate the total number of submissions, i. e. $n(t_d - \Delta) \leq n(t_d)$ as comes also from the formula (4). However, from a managerial point of view, that is a much more minor issue than overestimating the total submission number since if a conference committee receives more submissions than expected, those of low quality may be rejected in the review phase.

2.3. Fitting of the “number of submissions in time to deadline” model

Although we see the model for the total number of submissions following the formula (3) is nonlinear in time t , it is still linear in coefficients a and b for the special terms $(t - t_a)$ and $\log \frac{t_d - t_a}{t_d - t}$, respectively. Thus, we might estimate the model coefficients as \hat{a} and \hat{b} using sums of residual least squares (Charnes, Frome & Yu, 1976). Supposing that $n(t)$ is an observed number of submissions at a time point t and $\hat{n}(t)$ is the model-based estimation of the number of submissions at the time point t , then the model coefficients are estimated as those minimizing the sum of residual squares, so,

$$\begin{aligned} (\hat{a}, \hat{b}) &= \operatorname{argmin}_{(a,b) \in \mathbb{R}_{0,+}^2} \left\{ \sum_{\forall t} (n(t) - \hat{n}(t))^2 \right\} = \\ &= \operatorname{argmin}_{(\hat{a}, \hat{b}) \in \mathbb{R}_{0,+}^2} \left\{ \sum_{\forall t} \left(n(t) - \left(\hat{a}(t - t_a) + \hat{b} \log \frac{t_d - t_a}{t_d - t} \right) \right)^2 \right\}. \end{aligned} \quad (6)$$

Inspecting the formula (3) more in detail, we also realize the model for the total number of submissions does not contain an absolute term (an intercept), independent on the time point t . Although that may result in some asymptotic limitations (since Gauss-Markov theorem – claiming the model is the best and the same quality as if estimated by maximal likelihood – does not apply for models with no intercepts), the rationale behind is easy to understand – at a time point $t = 0$, we suppose $n(0) = 0$ submitted proceedings, thus, the missing absolute term is accepted for the model (3). The quality and performance of the fitted predicting models is evaluated both graphically and using R^2 metric, depicting what proportion of a dependent variable’s variability is explained by the model.

2.4. Using the “number of submissions in time to deadline” model for the prediction of the total number of submissions

Assuming the model for submission number following the formula (3) is estimated and estimates \hat{a} and \hat{b} are the best in terms of least squares, we may do a prediction of the number of submissions $\hat{n}(t)$ at a time point t using (3), and a prediction of the total number of submissions $\hat{n}(t_d - \Delta)$ at a time point $t_d - \Delta$ using (5), so

$$\hat{n}(t) = \hat{a}(t - t_a) + \hat{b} \log \frac{t_d - t_a}{t_d - t}, \quad (7)$$

$$\hat{n}(t_d - \Delta) = \hat{a}(t_d - \Delta - t_a) + \hat{b} \log \frac{t_d - t_a}{\Delta}, \quad (8)$$

for a feasible low constant $\Delta > 0$.

Even more, using the fitted model and formula (7), we might construct an empirical cumulative distribution function and estimate a time point t_q when roughly q -part, marked as $n(t_q)$, of the total number of submissions has been already submitted, where $t_a < t_q < t_d$. As a feasible q -part,

we consider a half ($q = 0.50$), a quarter ($q = 0.25$), or a tenth ($q = 0.10$) of expected total submissions.

Once we know the time point t_q , we know that q -part of the total expected submission number was submitted $(t_d - t_q)$ time units (hours, days, etc.) before the submission deadline. Finally, we can easily estimate the total number of submissions as $\frac{n(\hat{t}_q)}{q}$. The higher is the value $0 < q < 1$, the more precisely the term $\frac{n(\hat{t}_q)}{q}$ should estimate the total submission number (in theory, when $q = 1$, all submissions are submitted at the time point $t_q = t_1 = t_d$, i. e. the submission deadline, as is also clearly predicted using $\frac{n(\hat{t}_q)}{q} = \frac{n(t_1)}{1} = n(t_1) = n(t_d)$).

The estimate $\frac{n(\hat{t}_q)}{q}$ made $(t_d - t_q)$ time units (hours, days, etc.) before the submission deadline enables to managerially evaluate whether the current, on-the-fly number of submissions seems to be sufficient or not.

3. Results

Using the least square approach as described in (6), we fit the models predicting the number of submission $n(t)$ in a given time point t for each dataset, i. e. for each year of NIPS conference iteration (2003--2008). Estimated coefficients \hat{a} and \hat{b} and the models' R^2 metrics are in Table 1.

Table 1. Estimated coefficients \hat{a} , \hat{b} and R^2 metrics for models of number of submissions in time to deadline.

dataset	\hat{a}	\hat{b}	R^2	dataset	\hat{a}	\hat{b}	R^2
NIPS 2003	16.75	93.70	0.981	NIPS 2006	-26.38	240.11	0.999
NIPS 2004	25.77	134.64	0.989	NIPS 2007	22.10	118.99	0.994
NIPS 2005	70.15	90.40	0.987	NIPS 2008	6.70	162.32	0.995

As we can see in Table 1, with exception for dataset NIPS 2006 for which the estimated coefficients behaves relatively differently than in other models, all models are of very good quality (R^2 metrics are close to 1.000), and surprisingly, regardless of various observed total numbers of submissions, the coefficient \hat{a} seems to be in an interval about $\hat{a} \in \langle 30 \pm 25 \rangle$ hours⁻¹ and the coefficient \hat{b} seems to be in an interval about $\hat{b} \in \langle 120 \pm 30 \rangle$. Thus, both are relatively constant across various datasets.

Once the models were estimated, as shown in Table 1, predictions of numbers of submissions were made using the fitted models. A quality of the predictions is graphically demonstrated in Figure 2. Obviously, the predicted submission numbers at given time points are in general very close to the observed submission numbers, despite the idea of the models for submission numbers prediction is relatively simple.

Table 2. Predicted time points t_q [hours] before the submission deadline when roughly q -part of the total submissions has been submitted.

dataset	$q = 0.10$	$q = 0.25$	$q = 0.50$	dataset	$q = 0.10$	$q = 0.25$	$q = 0.50$
NIPS 2003	26.2	12.5	5.0	NIPS 2006	57.8	39.9	19.8
NIPS 2004	64.6	41.3	10.5	NIPS 2007	140.7	62.7	14.9
NIPS 2005	60.1	45.2	14.0	NIPS 2008	108.1	46.1	12.5

Finally, using the fitted models, predictions of time points t_q before the submission deadline when roughly q -part of the total submission number has been submitted, were done for $q \in \{0.10, 0.25, 0.50\}$, as we can see in Table 2.

Those predictions might be made approximately also using the plots in Figure 2. While the first 10 % of a total number of submissions is usually done between two to six days before the submission deadline, the first 25 % of the total submitted proceedings commonly come one to three days before the submission deadline, and, finally, the first 50 % of total submissions is submitted within the last day (!) before the submission deadline.

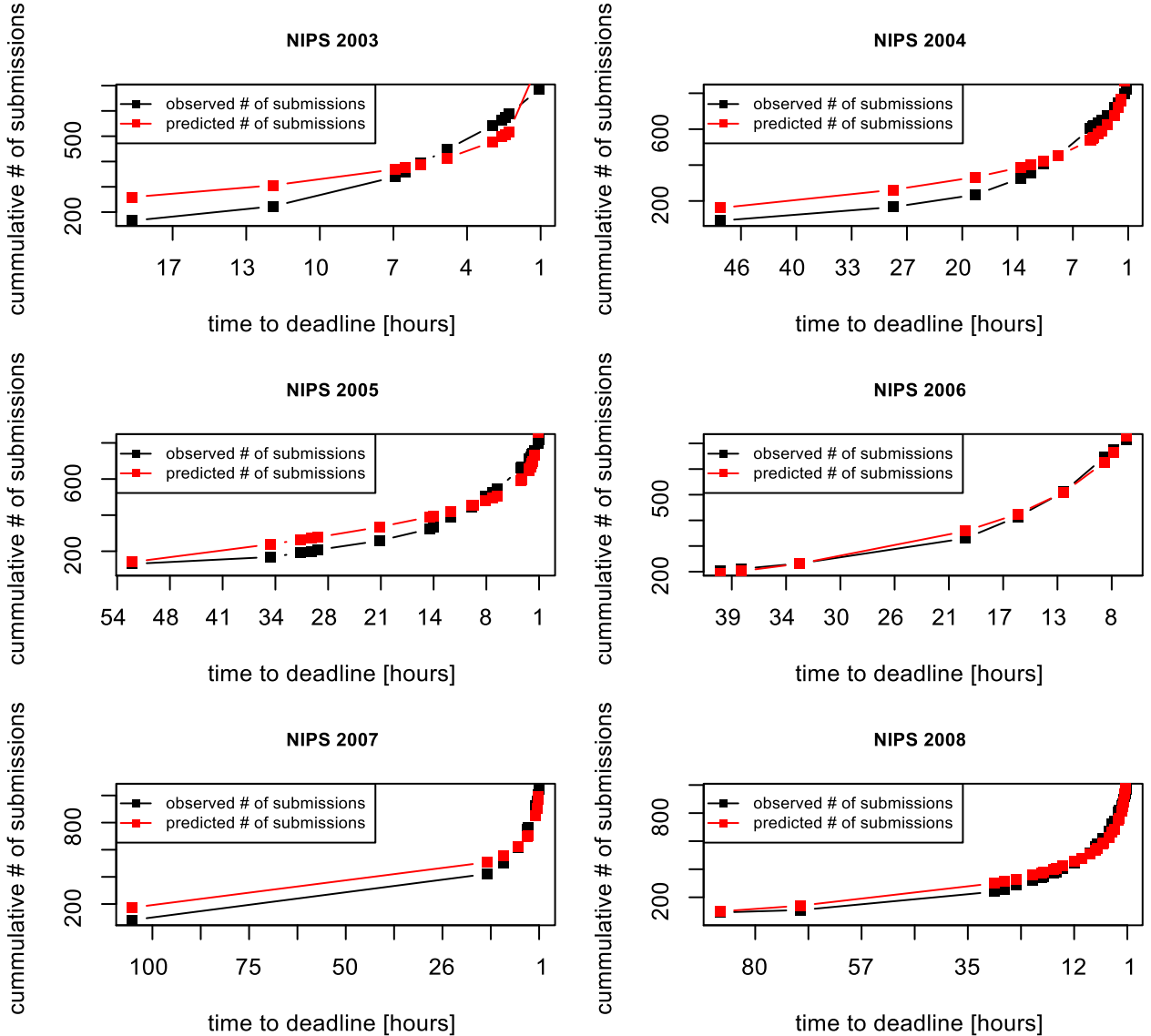


Figure 2. Observed numbers of the submissions and their predictions for distinct years of NIPS conference.

4. Discussion and conclusion

Many authors submit their proceedings to conferences at the last minute. Therefore, an assumption that the rate of submissions is inversely proportional to the remaining time to the deadline seems valid. We derived mathematics behind such an idea and built an empirical model, predicting a number of submissions at a given time point. We fitted the models and estimated their coefficients using freely available data from the NIPS conference. Both graphical and numerical evaluation (using R^2 metric) illustrated that the models predict the submission numbers relatively closely. Moreover, intuitively and checking the plots, the precision of the predictions increases as the time point used for the predictions moves closer to the submission deadline. That is according to our

expectations – firstly, with the approaching deadline, more and more submissions have been usually submitted, which increases the amount of available data and predictive confidence; secondly, at time points very close to deadlines, lack of remaining time prevents an unexpectedly huge number of submissions, that could not be predicted using the model.

The data and models showed that most of all submissions are done within the last week before the deadline. Moreover, the second half of all submissions may be expected throughout the last day (!) before the deadline. Although the submission habits may differ between various fields of science, all datasets used in our analyses and models demonstrated no significant reason for panic when only around one-tenth of the expected total number of submissions is submitted one week before the submission deadline. Consequently, as managerial advice to conference committees, there is no need to extend the deadline a few days before its original setting just because the currently submitted proceeding number seems insufficient. However, the narrow domain of the used data and their time origin may limit the results.

While not having appropriate data, the model may be transferable even to other domains. Thinking out of a box, we may try to predict a total purchase number done before an end of a sale, or a total number of bids in an auction, measured in time. That idea requires further ongoing research.

5. Acknowledgement

This paper is supported by OP VVV IGA/A, CZ.02.2.69/0.0/0.0/19_073/0016936 grant by Internal Grant Agency of Prague University of Economics and Business.

6. References

- Alfi, V., Parisi, G., & Pietronero, L. (2007). Conference registration: how people react to a deadline. In *Nature Physics* (Vol. 3, Issue 11, pp. 746–746). Springer Science and Business Media LLC. <https://doi.org/10.1038/nphys761>
- Berk, R., & MacDonald, J. M. (2008). Overdispersion and Poisson regression. *Journal of Quantitative Criminology*, 24(3), 269–284. doi:10.1007/s10940-008-9048-4
- Birch, C. (1999). A new generalized logistic sigmoid growth equation compared with the Richards growth equation. *Annals of botany*, 83(6), 713–723. doi:10.1006/anbo.1999.0877
- Charnes, A., Frome, E. L., & Yu, P. L. (1976). The Equivalence of Generalized Least Squares and Maximum Likelihood Estimates in the Exponential Family. In *Journal of the American Statistical Association* (Vol. 71, Issue 353, pp. 169–171). Informa UK Limited. <https://doi.org/10.1080/01621459.1976.10481508>
- Flandrin, P. (2010). An empirical model for electronic submissions to conferences. In *Advances in Complex Systems* (Vol. 13, Issue 03, pp. 439–449). World Scientific Pub Co Pte Lt. <https://doi.org/10.1142/s0219525910002554>
- Murray, I. (2022). Conference submission times. https://homepages.inf.ed.ac.uk/imurray2/submission_times/.
- Perperoglou, A. (2011). Fitting survival data with penalized Poisson regression. *Statistical Methods & Applications*, 20(4), 451–462. doi:10.1007/s10260-011-0172-1
- Richards, F. J. (1959). A flexible growth function for empirical use. *Journal of experimental botany*, 10(2), 290–301. doi:10.1093/jxb/10.2.290
- Wood, S. N. (2006). *Generalized additive models*. Philadelphia, PA: Chapman & Hall/CRC.

COMPLEX DIGITAL APPROACHES FOR CRISIS MANAGEMENT – BLACKOUT IN PANDEMIC TIMES

REQUIREMENT FOCUSED INTERVENTION- MATCHING FOR PANDEMIC MANAGEMENT: NATIONAL PERSPECTIVES FOR INVOLVEMENT OF EVIDENCE BASED LESSONS LEARNED

**Karin Rainer, Alois Leidwein, Markus Hoffmann,
Nicole Kramreither**

Austrian Agency for Health and Food Safety (AGES)
karin.rainer@ages.at

Georg Neubauer, Bernhard Bürger, Dražen Ignjatović

AIT Austrian Institute of Technology GmbH (AIT)
georg.neubauer@ait.ac.at

Georg Aumayr

Johanniter Österreich Ausbildung und Forschung GmbH (JOAFG)
georg.aumayr@johanniter.at

Ruth Kutalek

Medical University of Vienna, Center for Public Health
Dept. of Social and Preventive Medicine
ruth.kutalek@medunivwien.ac.at

Janika Saretzky

ERC Experience Research & Consulting
janika.saretzki@experience-research.at

DOI: 10-35011/IDIMT-2022-127

Keywords

Pandemic management, lessons learned, intervention-matching, coordination of data, SARS-CoV-2, COVID, decision support approach, analysis integration, use cases, validation, taxonomy, AGES Austrian Agency for Health and Food Safety

Abstract

COVID-19 still represents one of the greatest global challenges of the last decades in terms of medical, coordination and management aspects, but also on the societal and economic level. Even after more than two years, the rapidly changing requirements that the emerging variations of the virus call for, show that Austria – as the majority of countries and organizations – is still struggling with a stringent and pertinent management approach. The call for a comprehensive, applicable and

interoperable solution portfolio including evidence-based analysis of current processes/structures, tools and infrastructures as well as lessons learned from the current pandemic response, is evident.

The enhanced “ROADS to Health”-approach, currently evaluated by national funding agencies, reflects this aim: a holistic solution set aiming at a technologically supported, lessons learned based system for the pandemic management for the future. ROADS focuses on a basis for optimized crisis management for future pandemics/epidemics from a holistic, user-centric perspective. The concrete goal is to create a basis for a technologically supported measure matching to current requirements for decision-makers and critical infrastructures. Thus, interventions or future mitigation measures for the management of a pandemic are matched with concrete and current requirements.

This measure matching will build upon the existing "Portfolio of Solutions" (POS) platform developed by AIT. Relevant medical/epidemiological, social, economic and legal fundamentals and different types and characteristics of pandemics/epidemics will also be considered (infection routes, morbidity and mortality risks, affectedness: age, gender ...) as well as various needs, given resources and processes. International lessons learned from the COVID-19 crisis, knowledge and results from merging practical experiences from crisis management feed into a concept design to facilitate and initiate technological support for enhanced future pandemics/epidemics tackling and potentially for other crisis situations. This keynote paper will draft the frame of this model by presenting the underlying background and basis of the ROADS to Health-solution set and open the floor for a wider range of perspectives of optimization in pandemic and crisis management.

1. Background and motivation for enhancing pandemic management

The enhanced ROADS to Health-approach is focusing on generating the basis for situation-based measure matching for pandemics/epidemics. In this context, measure matching refers to the alignment of measures with requirements. After an initial concept to enhance the pandemic management (Rainer et al. 2021) it became evident, that emerging international "lessons learned" from the COVID-19 pandemic as well as the active integration of stakeholders and end users have to be the strong backbone for any such objective. This is valid, as the research of the European-funded project STAMINA (Nr. 883441) has shown that, from a generic point of view, the pandemic management in different countries follows similar structures (e.g., reflected in the CompCoRe network).

Looking back in time, in 2019/20, like many other countries, Austria was inadequately prepared for a pandemic. The uncertain medical and epidemiological information landscape at the beginning made decision-making regarding public health strategy and measures difficult, fluid and highly disputed (Abrams et al. 2020). Development of strategies for COVID-19 management therefore took place under thorough media scrutiny and was communicated externally and internally with varying degrees of emphasis. Internally, the focus was on maintaining the functionality of the health care system with the premise of minimizing interference in socio-economic life.

Pandemic planning in Austria prior to COVID-19 focused on specific pathogens such as Influenza or Ebola and thus was more reactive than preventive or pro-active (BMGF 2006). Available processes and interfaces were not geared to pandemics, conflicts of competence slowed and limited the impact of interventions. Measures, even within an EU member state or even a federal state, varied and were applied differently. Knowledge about stock and procurement of resources (from protective equipment to hospital beds) and the risks of vulnerable groups was limited. Pandemic management measures resulted in part from a "trial and error" mode, focused on what was feasible, and inevitably, as a result, were in part disproportionate, as numerous protocols and internal reports

underpin (e.g., Analysis of GECKO protocols, no date, Traffic Light Commission recommendations, no date; National Vaccination Panel recommendations, no date; Future Operations Platform protocols (internal), or Protocols of the judicature of the VfGH).

The current Epidemics Act of Austria is, in its main features, a re-enactment of the 1913 Act on the Prevention and Control of Communicable Diseases. Data protection, the European Convention for the Protection of Human Rights and Fundamental Freedoms (ECHR) and the principle of proportionality were not an issue at that time. Thus, it became evident, that a more occasion-based legislation was absolutely essential.

There was and is currently no unanimous social and scientific consensus on how “Corona” should or should have been managed and how a transition to a previous state of normality could be shaped.

The measures in corona management, whether lockdowns, social distancing, communication of hygiene measures, and especially the possibility of vaccination, were successful insofar as they led to a flattening of the epidemic curve in the first 3 corona waves. Overloading of health care systems was prevented, and excess mortality was significantly curtailed (see e.g., AGES COVID dashboard, no date; GÖG data platform, no date, and AGES Wissen aktuell, no date). However, the measures set in the course of pandemic management led to partly massive social, economic (Corona relief measures: info, relief and simplification, no date), political and psychological side effects. These side effects were perceived as collateral damage by parts of the society (Impact of COVID-19 on mental health and well-being in Austria - an exploratory study, no date; Impact of the COVID-19 pandemic and containment measures on the mental health of children and adolescents, no date).

Taking the right action at the right time and having knowledge and availability of resources is critical in pandemic management. Supporting this is the overall approach of the ROADS to Health-concept. To better address this issue in the future, ROADS aims at developing a foundation for optimized risk and crisis management for future pandemics and epidemics.

2. Challenges and parameters of pandemic management approaches

Pandemics are multi-faceted; this fact can lead to very specific and high-level challenges in the implementation of the technological solution for the purpose of improvement of measures of pandemic management:

- Pandemics are dynamic and their evolution is often difficult to predict --> the ROADS-approach aims to enable dynamically adaptable scenario generation of pandemics.
- Pandemics are not spatially limited, but spread rapidly and often unnoticed --> ROADS addresses to help and find measures more quickly.
- Public acceptance and cooperation are critical. Accordingly, maintaining the credibility of the authorities that propagate and implement countermeasures is essential, among other things through adequate risk communication strategies --> the ROADS concept promotes the possibility of transparent communication of measures taken through the context of scientific studies.
- It is not possible to estimate in advance for which population groups the disease poses the greatest risk --> ROADS thus deliberately includes the aspect of vulnerable and marginalized groups (Rainer et al. 2016). Gaps specifically related to vulnerable groups have to be capitalized. On these aspects and how vulnerable groups can be best reached by community engagement activities, an inclusion of the findings of the FFG project CAVE (<https://projekte.ffg.at/projekt/4101160>) is key.

- To date, little consideration has been given to integrating legal parameters into the development of technology-enabled pandemic management systems --> ROADS incorporates legal, ethical, and gender/diversity aspects into its research from the outset.
- Adequate decision support for pandemic managers is very challenging. This is due to the fact that the processes to be considered are not limited to the medical domain, but have to take into account socio-economic dimensions, for example. This results in a large number of scenarios, which can be used to compare the current situation during decision support processes. Beyond the large number of scenarios, a comprehensive set of indicators is also needed to provide the best possible decision support --> the innovative ROADS concept provides this essential support.

The clear distinction from other crisis situations illustrates the urgent need for further research on these and other pandemic-specific problems to identify vulnerability factors and derive resilience strategies that can serve as parameters for action identification in a future evidence-based, legally compliant pandemic management strategy.

3. Specific objectives and perspectives for an enhanced ROADS-approach

The specific objective of ROADS is to develop the need and basis for a technologically supported measure matching for decision-makers and critical infrastructure providers. This should support and enhance a clearly structured pandemic management in the future.

Technical systems have to be involved to help making decisions in pandemic management faster and more well-founded. For example, early warning systems using just-in-time information aggregation approaches and the distribution of centralized decisions to decentralized structures are relevant (see also Ghita et al. 2020). Other modelling can also be adapted, where data is interpreted using the algorithms underlying the model.

The ROADS approach therefore includes and refers in particular to the following points

- Foresighting technologies (modelling/simulation) for early detection and automation of recommended actions,
- Automated matching of action concepts with the current needs of a pandemic response,
- Optimization of risk and crisis management for pandemic response, taking into account a holistic and overall societal perspective,
- Basics for an optimized management of future and further crises and catastrophes,
- Vulnerable systems/groups and their specific needs.

To this end, the data, measures, experiences and scientific findings from the current crisis have to be processed, evaluated and incorporated in a risk-based manner to describe possible future pandemic scenarios. The review and accompanying development of the concept are supported by the integration of stakeholders and representatives of critical infrastructures who have to be included as vital know how-carriers and requirements-providers.

Practical resilience strategies and measures/packages have to be drawn from this valuable source, which serves as a basis to develop connectable, technical tools/modules for future pandemic management.

The result of the ROADS-approach will be a concept that can be transformed into a requirement specification by the demand side or into a requirement specification by contractors.

Thus, an enhanced concept has to include and address:

1. strategic parameters and objectives
2. measures and bundles of measures
3. critical resources

Besides the technological aspects of an enhanced pandemic management, the inclusion of strategic management is key for a successful and applicable service. Strategic parameters and targets have to be decided politically e.g., zero COVID-approach as propagated in China (Silver 2021) and the quiet plans to pivot from it (Normil 2022), maximum excess mortality 10%, maintenance of supply, etc. Actions are based on these, but also on available resources like protective equipment, laboratory capacity, hospital and ICU beds and facilities, professional human resources, pharmaceuticals, care in nurseries, schools, nursing homes, etc.).

4. Innovative approaches and potential integration components

The procedural and political experiences (both negative and positive), the new cooperation between local authorities and critical infrastructures that emerged during the pandemic, and the scientific knowledge gained will allow us to prepare for improved pandemic management from a society-wide perspective in the future. In parallel to the current refugee situation of the Ukraine conflict and the lessons learned from the Syria crisis, it is evident that after more than 5 years, many experienced personnel are no longer available and new experiences are being built up. In terms of crisis-oriented knowledge management, a review of experiences, information sources, measures, etc. is thus also an important point for strengthening the resilience of the Austrian healthcare system for the pandemic.

Newly developed ROADS components provide the necessary groundwork for this.

The taxonomy available to date, via the Portfolio of Solutions (Ignjatović et al. 2019), will be fundamentally repurposed for use in pandemic management. Innovative aspects such as the pandemic parameters as well as the creation of a stringent logic/taxonomy for the definition of objectives and the requirements derived from them, are being re-conceptualized and developed in form of a demonstrator. Using agile software development methods, the catalogued components (scenario parameters/objectives & needs/measures) are connected and validated in an exemplary manner. Evidence-based foundations such as scientific studies/sources as well as experience reports are made available to the decision-makers as a context in order to make the measure matching comprehensible, transparent and communicable.

Through these innovative components, the foundation is laid to support pandemic management of the future on both a qualitative and quantitative level. The concept of measure matching thus forms an essential core point for the further development of the current status quo and for better preparation for future scenarios.

Lessons-learned will be addressed and overall societal effects will be included and constructively considered. The further development of the demonstrator and the transfer into a prototype, which is the basis for a usable and applicable technological development, therefore puts the innovative elements of ROADS into a practical context.

The project team will use these experiences and findings to elaborate the need and basis for a technologically supported measure matching for decision makers inside and critical infrastructures.

ROADS to Health has to consider and include relevant medical/epidemiological, social, economic and legal fundamentals. The different types and characteristics of pandemics/epidemics also have to

be taken into account as they are of utmost importance: infection pathways, morbidity and mortality risks, affectedness: age, gender, etc. The ROADS concept has to tap on a national but also international level relevant scientific publications and public as well as internal Austrian epidemiological data. (AGES COVID-Dashboard, no date) (GÖG Data Platform, no date) (Lancet COVID-19 Resource Centre, no date) (Springer-Link, no date) (European Journal of Epidemiology, no date) (JAMA Network, no date) (Österreichische Plattform Gesundheitskompetenz (ÖPGK), no date) (RKI, no date) (DGPI, no date) (ECDC, no date) (CDC, no date) (WHO, no date). The legal questions have to be tackled early and in depth also to grant the applicability of the approach (Leidwein 2022).

In addition, needs, given resources and processes, vulnerability, resilience and risks of population groups and of critical infrastructures, with regard to pandemic management as well as in the overall societal context are included. Both national and international data, studies, and the experiences of stakeholders have to be taken into account. The measure matching concept has to integrate strategic goals, operational decision parameters of possible measures and processes as well as their effects on society as a whole and the overall prevailing resource requirement.

The innovation content of ROADS has also to be based on the lessons-learned of stakeholders from the COVID-19 crisis and results from the combination of practical experiences from crisis management and the needs of critical infrastructures, scientific findings, published studies into a concept design to be able to technologically support future pandemics/epidemics and possibly other crisis and disaster cases.

Stakeholders have to actively support the ROADS approach to guarantee practical relevance. The ROADS concept has to be validated on the basis of selected and challenging "use cases" in order to support the implementation of the developments and technological results in the direction of commissioning and procurement ("proof of concept"). Despite the focus on the crisis scenario "pandemic", the ROADS approach aims to develop a concept for practical application also for small-scale disease outbreaks/scenarios and to be able to provide decision support for this in later implementation as well. One of the most important lessons learned from the current pandemic is the fact that many measures need to be dynamically reconsidered and adapted again and again. The ROADS approach aims to create a framework (a concept for measure matching) that enables these adaptations to be made at an early stage and on an evidence-based decision-making basis. This also includes adapting internationally available knowledge quickly and securely to the situation in Austria.

Although the investigation of procedures that may need to be improved and the retrospective reflection of decisions made in the context of the COVID-19 pandemic is an undertaking often undertaken in current science, the consolidation of (inter-)national knowledge described in the present project by the complementary structuring of corresponding findings is to be rated as highly innovative. Due to the high specificity of the topic and its relevance for society as a whole, the consideration of ethical and legal aspects should be emphasized. In combination with the further findings on resilience and vulnerability of the structures involved, this can be seen as an important basis for future developments. Figure 1 illustrates the approach ROADS intends to take to develop a framework for semi-automatic measure matching. A central element of this approach is the taxonomy of PM functions, which is used as a basis for comparing elements that are tagged with terms from this taxonomy - they are used to describe the elements, and their similarity can be calculated automatically based on the overlap of the terms. As can be seen in the figure (blue part), this is (already) used to match described processes with gaps. By using PM taxonomy in describing scenarios, an additional step is taken towards a more comprehensive understanding of the problems involved in managing crisis situations, as the scenarios can also include the knowledge and

experience of the experts who deal with them on a daily basis, thus ensuring the practical relevance of the proposed approach.

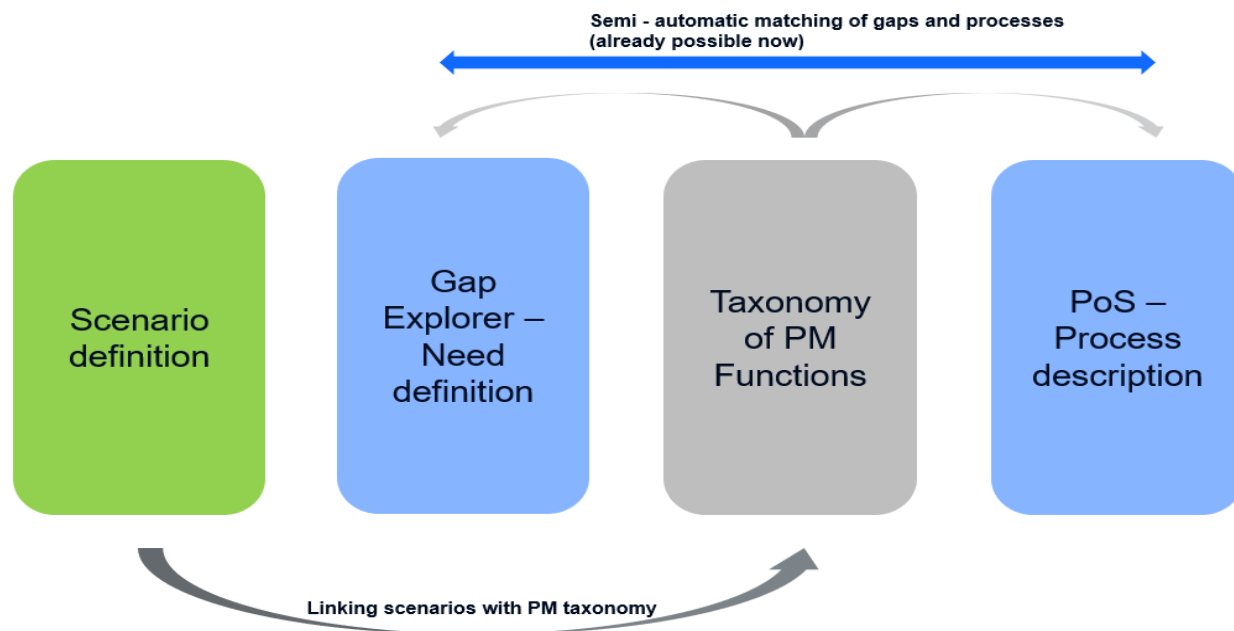


Figure 1: Semi - automatic matching of gaps and processes

5. Beneficiaries and users of the ROADS to Health-concept

The outcome of ROADS approach aims to create a concept for an optimized risk and crisis management for pandemics/epidemics of the future.

The involvement of stakeholders and critical infrastructures not only allows to incorporate the needs of decision makers and critical infrastructures in order to develop a valid concept, but also facilitates the inter-institutional implementation.

The concept developed in the framework of ROADS could more precisely impact

- strategic parameters and objectives,
- measures and bundles of measures,
- resources and their handling.

For decision-makers involved in crisis management as well as affected infrastructures, ROADS has the potential to provide an essentially structured decision-making basis for an efficient and targeted setting of measures within the framework of crisis management as a collection of measures known in advance. The consideration of resilience parameters, vulnerability factors and legal assessments is considered to be particularly profitable for a holistic crisis management.

The COVID-19 pandemic illustrates that early identification and protection of vulnerable groups are important priorities. Vulnerable groups include not only those at highest risk of becoming infected and severely ill, but also those groups of people who are particularly affected by pandemic management measures, both economically (e.g., food service, culture) and socially (e.g., students:inside, single people, single parents, people with immigrant backgrounds).

Critical infrastructures and stakeholders who work with vulnerable groups therefore have to be integrated as well as representatives of critical infrastructures.

Pandemic management measures encroach on fundamental rights and freedoms. In the case of gradual relaxations, equality rights are also particularly relevant. The proportionality of measures depends on the nature and impact of a pandemic/epidemic. ROADS will co-address these aspects for the benefit of stakeholders and norm subjects.

6. Summary and discussion

SARS-CoV-2 is an ongoing challenge that still has to be conquered in many ways. Potentials and gaps to be bridged for setting up a strategic, evidence based and still flexible tool set of solutions to foster preparedness in the future were shown in the course of this paper. Several approaches but also a lot of open questions and an ample field for further research and development, as well as for political and societal preparation and coordinated effort to prepare for a pandemic event of the future became evident. In the last years since the start of COVID-19 it became evident that the measures that were implemented by a variety of involved stakeholders were only very partially able to fulfil the requirements that arose due to the dynamic evolution of the pandemic. One of the reasons for this challenge was caused by the limited systematic overview on the existing gaps of the multitude of involved stakeholders and the non-systematic descriptions of these gaps. On the other hand, the implemented or proposed measures provided by decision makers were rather generic in the way they were described, and it was therefore almost impossible to estimate a priori the potential of those measures to close existing and evolving gaps.

The intervention – measure matching approach explained in this paper offers the opportunity to describe all gaps on the basis of a harmonized “language”, i.e. a taxonomy of pandemic functions. This approach gives the possibility to distinguish and compare the family gaps in a systematic way, as well as to investigate in a quantifiable way the potential of measures or interventions to close such gaps. This is possible because the same taxonomy of pandemic functions is applied to describe these measures. This approach offers the possibility to a priori validate the potential of interventions to close existing gaps, however this does not replace the need to validate measures in practice. For this purpose, there is an additional need to validate the performance of measure in an exercise or trial like approach.

7. References

- Abrams, Elissa M., Marcus Shaker, John Oppenheimer, Ray S. Davis, Don A. Bukstein, Matthew Greenhawt (2020). The Challenges and Opportunities for Shared Decision Making Highlighted by COVID-19, *The Journal of Allergy and Clinical Immunology: In Practice*, Volume 8, Issue 8, Pages 2474-2480.
- AGES COVID-Dashboard. (no date). Von <https://covid19-dashboard.ages.at/> retrieved 13.02.2022
- AGES Wissen aktuell. (no date). Von <https://wissenaktuell.ages.at/> retrieved 13.02.2022
- AIT - Portfolio of Solutions. (no date). Von <https://www.ait.ac.at/en/research-topics/cooperative-digital-technologies/solutions-services/civil-protection-public-services/portfolio-of-solutions> retrieved 13.02.2022
- Analyse der Protokolle der GECKO. (no date). Von <https://www.bundestkanzleramt.gv.at/themen/gecko.html> retrieved 13.02.2022
- Auswirkungen der COVID-19-Pandemie und der Eindämmungsmaßnahmen auf die psychische Gesundheit von Kindern und Jugendlichen. (no date). Von https://www.rki.de/DE/Content/Gesundheitsmonitoring/Gesundheitsberichterstattung/GBEDownloadsJ/Focus/JoHM_04_2020_Psychische_Auswirkungen_COVID-19.pdf?__blob=publicationFile retrieved 13.02.2022

- Auswirkungen von COVID-19 auf die psychische Gesundheit und das Wohlbefinden in Österreich - eine explorative Studie. (no date). Von <https://healtheconomics.meduniwien.ac.at/en/wissenschaftsforschung/projekte/auswirkungen-von-covid-19-auf-die-psychische-gesundheit-und-das-wohlbefinden-in-oesterreich-eine-explorative-studie/> retrieved 13.02.2022
- BMGF (2006) Influenza Pandemieplan Strategie für Österreich. retrieved 13.02.2022
- CDC. (no date). Von <https://www.cdc.gov/> retrieved 13.02.2022
- Corona-Hilfsmaßnahmen: Infos, Entlastungen und Vereinfachungen. (no date). Von <https://www.bmf.gv.at/public/informationen/corona-hilfsmassnahmen.html> retrieved 13.02.2022
- DGPI. (no date). Von <https://dgpi.de/covid-19-survey-update/> retrieved 13.02.2022
- ECDC. (no date). Von <https://www.ecdc.europa.eu/en/covid-19> retrieved 13.02.2022
- Empfehlungen der Ampelkommission. (no date). Von <https://corona-ampel.gv.at/corona-kommission/empfehlungen-der-corona-kommission/> retrieved 13.02.2022
- Empfehlungen des Nationalen Impfgremiums. (no date). Von <https://www.sozialministerium.at/Themen/Gesundheit/Impfen/Nationales-Impfgremium.html> retrieved 13.02.2022
- European Journal of Epidemiology. (no date). Von <https://www.springer.com/journal/10654/> retrieved 13.02.2022
- Mezzour, G., Boudanga, Z., Benhadou, S. (2020). Smart Pandemic Management through a smart, resilient and flexible decision-making System. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLIV-4/W3-2020, 2020, 5th International Conference on Smart City Applications, 7–8 October 2020, Virtual Safranbolu, Turkey (online). Retrieved 25.04.2022.
- GÖG Datenplattform. (no date). Von <https://datenplattform-covid.goeg.at/> retrieved 13.02.2022
- Ignjatović, D., Havlik, D., Neubauer, G., Turptil, S., Gonzales, F., Regeczi, D.: The Portfolio of Solutions. In: Proceedings of the 27th Interdisciplinary Information Management Talks, Kutná Hora, Czech Republic, 4 – 6 September 2019, pp199-206
- JAMA Network. (no date). Von <https://jamanetwork.com/journals/jama/pages/coronavirus-alert> retrieved 13.02.2022
- Labortraining. (no date). Von www.ages.at/en/ages/events/laboratory-practice retrieved 13.02.2022
- Lancet COVID-19 Resource Centre. (no date). Von <https://www.thelancet.com/coronavirus> retrieved 13.02.2022
- Leidwein, A. 2022. FlexLex Seuchenmanagement – Mensch-Tier-Pflanze. (no date). Von www.facultas.at/item/52488157 retrieved 17.04.2022
- Normil, D. (2022). China quietly plans a pivot from “zero VOVID”. Scientists are studying how to live with the virus while avoiding a crisis like in Hong Kong. Science • 3 Mar 2022 • Vol 375, Issue 6584 • p. 949 • DOI: 10.1126/science.adb1762.
- One Health European Joint Programme. (no date). Von <https://onehealthjp.eu/> retrieved 13.02.2022
- Österreichische Plattform Gesundheitskompetenz (ÖPGK). (no date). Von <https://oepgk.at/die-oepgk/> retrieved 13.02.2022
- Portfolio of Solutions, (2019) Project DRIVER+. [online]. Available at: <https://pos.driver-project.eu/en/PoS/solutions> retrieved 28 April 2022.
- Protokolle der Future Operations Plattform (intern). (no date).
- Protokolle der Judikatur des VfGH. (no date).
- Rainer, K., Fastl, C., Leidwein, A., Nemenz, P., Hoffmann, M., Rathammer, K., Kundratitz, V., Neubauer, G., Preinerstorfer, A., Aumayr, G., Scheuer, S., Eisenberger, I., Hofer, A., Scholz, S. (2021) Digital Transformation in Crisis Management. Risk, Vulnerability and Resilience Analyses for Pandemic Management: Challenges and Perspectives of Approaches for the Future. In: Petr Doucek et al. (Eds.). IDIMT 2021. Information Technology, Society and Economy Strategic Cross-Influences. 29th interdisciplinary Information Management Talks. Trauner Linz. 163-174.
- Rainer, K., Leidwein, A., Nemenz, P., Hoffmann, M., Neubauer, G., & Aumayr, G. (2020). Interoperability and crisis management in pandemic outbreak scenarios an overview on different case studies of the austrian approach to

tackle the SARS-CoV-2 spread and adherent management challenges. IDIMT 2020: Digitalized Economy, Society and Information Management-28th Interdisciplinary Information Management Talks.

Rainer, K., Neubauer, G., Ruzsanyi, V., Silvestru, D., Almer, A. & Lampoltshammer, T. (2017). The Potential of Multiple Types of Sensor Data and Information Exchange. Challenges and Perspectives for an Operational Picture for the Response to Crises with Mass Involvement. In: Petr Doucek et al. (Eds.). IDIMT 2017. Information Technology, Society and Economy Strategic Cross-Influences. 25th interdisciplinary Information Management Talks. Trauner Linz. 111-126.

Rainer, K., Neubauer, G., Pointner, K., & Kastel, W. (2016). Inclusion of Marginalized Groups into Crisis Management Processes. Models, Case Studies, and holistic Perspectives. In: Petr Doucek et al. (Eds.). IDIMT 2016. Information Technology, Society and Economy Strategic CrossInfluences. 24th interdisciplinary Information Management Talks. Trauner Linz. 87-100.see e.g. CSH 2020.

RKI. (no date). Von https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/nCoV.html retrieved 13.02.2022

Silver, A. (2021). Covid-19: Why China is sticking to “zero tolerance” public health measures. BMJ 2021;375:n2756

Springer-Link. (no date). Von <https://www.springermedizin.de/coronavirus-covid-19-update/17764850#> retrieved 13.02.2022

WHO. (no date). Von <https://covid19.who.int/> retrieved 13.02.2022

PERSPECTIVES ON THE FUTURE CROSS-BORDER PANDEMIC MANAGEMENT

Georg Neubauer, Dražen Ignjatović, Gerald Schimak,
Johannes Peham, Bernhard Bürger

AIT Austrian Institute of Technology GmbH
georg.neubauer@ait.ac.at

Adam Widera, Michael Middelhoff

University Munster
adam.widera@wi.uni-muenster.de

Florian Gehre, Muna Affara

Bernhard Nocht Institute for Tropical Medicine,
gehre@bnitm.de

Helena Blažun Vošner, Jernej Završnik, Aleksander Jus

Community Healthcare Center Dr. Adolf Drolc Maribor,
helena.blazun@zd-mb.si

Karin Rainer, Alois Leidwein

AGES Austrian Agency for Health and Food Safety
karin.rainer@ages.at

Peter Kokol

Faculty of Electrical Engineering and Computer Science, University of Maribor
peter.kokol@um.si



DOI: 10-35011/IDIMT-2022-137

Keywords

Pandemic, disaster, cross-border pandemic management, COVID 19, STAMINA project

Abstract

Within this paper requirements and related gaps associated with cross-border pandemic management are analyzed. In order to systematically investigate the potential of solutions to close such gaps, trials can be executed and evaluated. Core elements of such trials are specific scenarios that frame the validation of the applicability of solutions. Stakeholders involved in pandemic

management specified a framing for such scenarios such as cross-border common operational picture and resource management, pandemic management during a refugee crisis and sharing of mobile infrastructure to detect pathogens. An insight in these scenarios is given and, finally, solutions having the potential to close at least partially gaps arising in the mentioned scenarios provided from projects such as STAMINA are presented.

1. Introduction

Since the spread of COVID-19 in Europe in the beginning of 2020 the need for cross-border pandemic management became more and more evident. Carrera (2020) points out that since 2007 the WHO declared six Public Health Emergencies of International Concern (PHEIC) such as Influenza in 2009, Ebola in 2014 and 2020 or Zika in 2016. Moreover, a multitude of epidemics affected European countries also on a cross-border level such as measles, West Nile Virus or Dengue Fever. Furthermore, he proposed stronger cross-border collaboration, united coordinated action and enhanced solidarity. The pandemic has considerable impact on border control. Eržen et al. (2020) specified some lessons learned from the pandemic, encompassing enhanced cooperation between guards, custom services and sanitary inspections, as well as the need for enhanced digitalisation. Moreover, they point to the need of improved cooperation between neighboring states regarding early warning and risk assessment. When considering asymptomatic persons, the need of border crossing information exchange turns out to be imperative. Carrera (2020) describes the challenge at the beginning of the pandemic, however huge efforts were made worldwide in the meantime to manage the pandemic, it is therefore interesting to see how the situation is perceived after about two years of dealing with COVID-19.

Mertens (2022) describes a type of “waterbed effect” that took place in the Netherlands, Belgium and Germany. In summer 2021 the Netherlands had a lockdown during the summer vacation, but due to missing harmonization of cross-border management neither Belgium nor Germany implemented similar measures. People from the Netherlands moved therefore to the neighboring countries for shopping and eating and drinking. Another example of lack of cross-border cooperation is the recommendation of an authority in the Netherlands to not get a booster COVID-19 vaccine in neighboring countries. Such a recommendation is remarkable in the light of a common European goal to have as many people as possible vaccinated. Mertens identified three major roadblocks: lack of instruments to coordinate health risk management on a European level, lack of coordination between neighboring countries due to the lack of bilateral agreements and finally missing guidance of cross-border management by national or regional authorities. The author concludes that the existing cross-border pandemic management is not robust enough. A similar effect was observed in March 2021 in Vorarlberg in Austria: the decision to loosen access limitations for the gastronomy (ORF 2021, Vorarlberg Tourismus 2021) due to regional low incidences led to augmented afflux of guests not only from Vorarlberg, but also from neighboring regions and states and consequently increased infection rates. (AGES 2022). This is also an indicator for the population being tired of the pandemic interventions and regulations from government side, that impacted the very core of the lives of people for a longer period. WHO (2020) early identified this “pandemic fatigue” and its effects on the development of the pandemic waves (Rypdal et al 2020); this phenomenon also evidently reflects in the compliance as well as in the denial/countering of official recommendations and regulations.

2. Requirements arising in Cross Border Pandemic Management

In the past, several different attempts were made to describe requirements related to cross-border pandemic management in a systematic way. In 2020, a questionnaire on the different challenges related to the management of COVID 19 was distributed among 590 international stakeholders, 57 completed questionnaires were received (Neubauer et al, 2020). The main outcomes of this investigation were related to communication and information exchange, health aspects such as optimized testing procedures and resource management. The cross-border perspective was explicitly mentioned multiple times. It was stressed, that non-centralized health management systems and federal structures challenge pandemic management. The need for transnational data assessment was high-lighted by stakeholders from several countries as well as the need for transnational communication and sharing of resources. Moreover, the need for harmonized cross-border strategies was mentioned. Several organizations as well as projects identified gaps that are implicitly or explicitly related to cross border pandemic management. An example is the International Forum to Advance First Responder Innovation (IFAFRI, 2022). IFAFRI identified 10 common global capability gaps corresponding to the needs of the global first responders. These gaps are not directly related to pandemic management, nevertheless they are in some cases quite similar to the requests of stakeholders involved in pandemic management. Two examples of the ten IFAFRI gaps are:

- *The ability to incorporate information from multiple and non-traditional sources into incident command operations*
Incident commanders rely on several different information sources for decision support, including sensor data, modelling data, media reports, social media etc. The same is true for decision makers in time of pandemics, e.g., in case of evaluation of the impact of measures such as lockdowns. This is also true for cross border pandemic management, when looking at challenges as the one described by Mertens (2022) in the introduction section.
- *The ability to obtain critical information remotely about the extent, perimeter, or interior of the incident*
The management of incidents of different dimensions such as wildfires or management of events with large crowds need to obtain situational awareness on what is happening at as well as around the incident site. Large number of people, smoke, extreme weather or other parameters can negatively impact the ability to obtain situational awareness. When looking at events like demonstrations against measures related to pandemic management such as lockdowns or implementation of safety measures such as wearing of masks, the availability of a shared common operational picture is relevant for police forces. The timely availability of critical information may also be of relevance for health workers operating in the field, being exposed by unexpected pathogens.

Other international organisations such as the Disaster Risk Management Knowledge Center describe also strategic gaps, but there is no specific focus on pandemic management.

Within the project DRIVER+ the Gaps Explorer was developed as part of the Portfolio of Solutions (Gaps Explorer, 2019). The Gaps Explorer includes strategic gaps on one hand from organisations such as IFAFRI and from research projects such as STAMINA (2019) from the other. In this project gaps specifically related to pandemic management were described. Several of these gaps are also related to cross border pandemic management such as:

- *Cross-agency decision support tools* – assuring coherent and traceable decision making in different, also cross-border operating organisations is imperative for a successful pandemic management

Adequate communication technology for crisis management – crisis communication encompasses communication within an organization, cross-organisation, cross-border communication as well as communication with the public. So far, no solid pandemic communication methodologies were endorsed

- *Secure cross-agency documentation, sharing and tracking* – efficient and secure sharing of information necessary for decision making has proven to be a key challenge in the management of COVID-19, also on a cross border level

The gaps shown in this chapter are reflecting needs on a strategic level and are representative examples. Such gaps often mirror a multitude of needs on a tactical as well as operational level. In the next chapter selected scenarios of cross border pandemic management are described. These scenarios reflect on one hand one or more strategic gaps and provide a context of application and testing for pandemic management solutions (see also chapter 4) on the other.

3. Selected scenarios of cross-border pandemic management

In complex crises, such as the ongoing COVID-19 pandemic, it is evident that the exchange of information between the actors involved is impaired by various types of communication barriers. Obstacles such as different responsibilities, some of which are not clearly delineated, different legal bases, (specialist) cultures and mandates and, as a result, only limited harmonized processes, as well as semantic and other barriers, make cooperation difficult. An overarching requirement for most of all pandemic management scenarios is the need to break down communication barriers and to bridge silos of responsibility. Such barriers have both a technical as well as a sociological dimension. Regarding the technical dimension solutions interoperability between different actors is needed. From the sociological perspective mutual understanding of the involved actors is imperative, encompassing overcoming of semantic barriers. Although it is frequently required that only one definition is assigned to a particular term in a specific domain, it is evident that different terminologies are used within a state, between different organizations and, in some cases, even within an organization, and that different actors also have different understandings of the same terms used. The challenge is that the actors involved have no or only superficial knowledge of other vocabularies not used by them and, in the case of deployment, do not have the time or, in most cases, the opportunity to gain insight into them to better understand their partners. Since the interactants work in different, partly multicultural environments with specific (professional) cultural imprinting (concerning language, behavior, cultural markers, taboos, etc.), this increases the overall probability of misunderstandings and resulting wrong decisions or decisions not made.

3.1. Cross-border Register Systems and Resource Management

The free movement of labour is one of the four fundamental freedoms in the European Union's internal market. Slovenia, like other European Union countries, is facing daily migration of people, and which was a special challenge during the COVID-19 pandemic, for people as well as for healthcare facilities such as Community Healthcare Center dr. Adolf Drolc Maribor (HCM).

HCM is one of the largest community healthcare centres in Slovenia and one of the 16 healthcare facilities responsible for organizing COVID-19 entering point for 5 large geographical areas in Northeastern Slovenia (middle and lower Podravje i.e., Maribor, Ptuj, Slovenska Bistrica, Lenart, Ormož). In these COVID-19 entering points, in accordance with the appropriate indication and compliance with the definition for the notification and monitoring of new coronavirus and instructions for proper swab collection, swab collections were performed. It was necessary to strongly adjust the organization of work in the institution to be able to carry out the implementation

of health care as much as possible within all services and adapt it to the current urgent needs of patients. The services provided by the HCM were swabbing for PCR testing and rapid antigen tests, examinations of COVID-19 suspected patients and implementation of vaccination campaigns for over 300,000 inhabitants, various occupational groups etc. In March 2020 Austria closed 51 small border crossings with Slovenia to limit the spread of coronavirus. Traffic remains unchanged at major border crossings, like the border crossing Šentilj, where daily approx. 14,000 migrate workers in both ways. In accordance with the tightened measures of the Austrian government, the HCM had to carry out swabbing for PCR and rapid antigen tests almost overnight for all workers who crossed the border. Health and other workers from HCM faced many challenges, on this basis we identified measures that would support an effective cross-border pandemic management, such as:

- *Joint central register system - uniform notification of COVID test results* - with regard to cross-border cooperation, it would be very sensible to link at least data on PCR swabs and Digital COVID-19 certificate of recovery, due to problems in the past with migrant workers working in Austria. Due to the lack of harmonized data management between countries for example the Austrian PCR was not registered in the Slovenian system. It was therefore necessary to send patients tested in Austria again for testing in Slovenia to obtain a digital COVID-19 certificate of recovery. Similar problems were faced by Slovenian citizens working in Austria.
- *Joint central register system for bed management* - it would be sensible to interface the systems monitoring the availability of beds in case of overcapacity in Slovenia, because Austria is very close and quickly accessible, at least in the Štajerska region.
- *Joint monitoring the availability of free capacities* of individual hospitals and the availability or utilization of vehicles for secondary or interhospital transport.

3.2. Shared testing capacities in future pandemic scenarios

Similar to the abovementioned Slovenian case, many European countries experienced border closures due to COVID-19, affecting commuter populations and cross-border trade. In the early pandemic phases this was mainly due to a lack of diagnostic capacity at border points to rapidly issue negative PCR tests. Similar scenarios are to be expected in future epidemics of known and unknown pathogens. A successful solution to close the diagnostic gap for efficient cross-border epidemic management was shown in East Africa. The East African Community, as an intergovernmental body for Burundi, Uganda, Rwanda, Tanzania, Kenya and South Sudan, together with the six Ministries of Health, rapidly deployed a fleet of nine mobile laboratories to strategic highways, or directly at border posts. This solution allowed countries to conduct SARS-CoV-2 PCR diagnostics, even in the remotest regions of the South Sudanese-Ugandan border. Together with a rapidly developed, regionally recognized, electrically readable COVID-19 certificate (enabling law enforcement and immigration officers to query the health status of truck drivers and commuters), these mobile laboratories maintained internal trade of goods, food and medical supplies in the region – in particular important for landlocked countries. Building on the African experience, new mobile laboratories of highest biosafety levels, together with AI-based mobile laboratory fleet management systems, are currently being developed in Europe, where new emerging (hemorrhagic) fever viruses are finding their way into the continent.

3.3. Other potential Cross Border Pandemic Management scenarios

Several other potential cross-border pandemic management scenarios were discussed in the frame of the STAMINA project encompassing the management of the refugee crisis on the border to a

country neighboring the Ukraine combined with an epidemic outbreak of a pathogen such as measles or influenza affecting international volunteer teams supporting the refugees in camps. Another border-crossing scenario deals with the impact of the closure of international airports as protective measure in times of pandemics and the potential support for the decision makers of other airports due to the provision of data from a closed airport and the impact of the closure on the pathogen distribution among the working personnel. In general terms, travelling across borders maybe hampered due to the reduction of the security staff during the pandemic not only because of non-availability of sick staff, but also because of people who left their jobs in order to pursue different careers. A scenario partially aligned with the one described in chapter 3.1 deals with the border crossing management and data sharing of a factory or business located in a border region, e.g., a coal mine, where workers from both countries are employed. In such cases the sharing of information on the vaccination as well as the infection and health status in a border crossing is of outstanding importance.

4. Solutions having the potential to close scenario related gaps

The innovation potential of solutions in closing related gaps has to be assessed in relevant and realistic scenarios applying rigorous methods. STAMINA therefore adopts the Trial Guidance Methodology (TGM) (Fonio, Widera, 2020) for pandemic management in form of the Stamina Demonstration Methodology, STADEM (Neubauer et al, 2021). It is an iterative co-creative design approach with the practitioner needs in its focus covering the design, execution, and evaluation of so-called trials. A trial brings together end-users and solution developers in realistic scenarios to assess the impact on crisis management. The data collected during a trial is used to answer research requestions in addressing the identified gaps and to guide future solution developments. A trial is thereby capable to not only demonstrate a solution, but to achieve a deeper understanding of its use in practice.

To fill the specific gaps mentioned above, STAMINA offers different solutions to be trialed in different scenarios in 11 national trials across Europe and one specific cross-border trial. For the handling of a cross-border trial (e.g., as mentioned in chapter 3.1) it is obvious that in all cases an information platform is needed that has access to or can be used by different services to exchange information/data on the availability of resources (e.g., hospitals, intensive care units, ambulances, etc.). Also, with regards to this challenge, a monitoring service and visualisation application is needed. Solutions that STAMINA could provide for this could be the data exchange platform, named Early Warning System (EWS) which interconnects different services such as CrisisHub to report on resources and current event situations with the e.g., EMT (Emergency Maps Tool), but also to issue warnings or alarms about resources shortages, which in turn could also be visualised on EMT. The same solutions can be applied specifically, to support pathogen addressed in chapter 3.2. Apart from that, STAMINA offers a portable solution called SHERLOCK/DETECTR for the rapid detection of SARS-CoV-2 and E. coli (ESBL) which provides a new approach for novel genetic markers enabling rapid detection of SARS-CoV-2 and Enterobacterales in human and environmental samples. LAMP (qcLAMP), another STAMINA solution, also enables real-time colorimetric primers and rapid detection of viruses, in most cases achieving higher sensitivity compared to standard real-time PCR. This includes rapid detection of viral nucleic acids from Measles and West Nile Virus in human samples and SARS-Cov-2 in environmental. Among the available solutions for the scenarios mentioned in chapter 3.3, the most important point is the timely and accurate exchange of information and the possibility of access to a common platform for data exchange (e.g., vaccination status, infection and health status). This becomes especially important when thinking about the airport scenario discussed above. As mentioned above, EWS, CrisisHub or EMT can be seen as well-suited candidates to address these challenges. However,

ENGAGE is also capable of supporting communication about resources and resource management (e.g., hospital beds).

It is important to mention that STAMINA offers a wide portfolio of solutions that allow modelling of pandemic-related situations (e.g., solutions such as FACS, CHARM, ENGAGE) to model and support the management of resources that could be deployed in upcoming and future cross-border scenarios (for more details on the STAMINA solutions see PoS, 2019).

5. Conclusion and Outlook

In this paper examples of cross-border gaps related to the management of pandemics are given, but one has to be aware that gaps vary from country to country as well as versus time and the examples shown here do neither reflect the multitude nor diversity of all cross-border gaps. Some gaps from the beginning of COVID-19 such as the availability of a vaccine have been closed, others such as provision of methods on how to deal with misinformation and fake news in times of pandemics are still not finally solved yet. There are several approaches available on how to identify new gaps such as interviews or questionnaires provided to stakeholders, or knowledge earned in projects such as STAMINA. An insight in strategic gaps identified in STAMINA is available in the Gap Explorer, but a systematic overview on all pandemic management related gaps is not known to us. To identify if existing methods or solutions have the potential to close pandemic management gaps the STADEM methodology was developed in the H2020 project STAMINA (Neubauer et al, 2021). Currently 12 national and one cross-border trial on pandemic management are planned and executed in the frame of the project. The requirements of the STAMINA stakeholders involved in the management of COVID-19 are the basis for the trials, outcomes will show to what degree the tested solutions are able to improve the pandemic management compared to the baseline. Scenarios similar to those described in chapter 3 are central elements for the design of trials.

A central learning from the way COVID-19 was managed so far is that a worldwide crisis cannot be handled successfully by national or regional solo attempts, without global coordination and cooperation (Anschober, 2022). A pre-requirement of a successful border crossing pandemic management is to break down or at least to reduce various types of communication barriers and potential misunderstandings. Moreover, for the management of future pandemics, it can be recommended to handle pandemics as complex events also related to other challenges such as natural catastrophes like floodings, droughts and the climate crisis in more general terms. Avoiding or at least mitigating the impact of future pandemics means to reconsider multiple facets such as land loss and the way urban areas are structured, loss of habitats of species, or travel habits just to name a few. Finally, the willingness of border – crossing cooperation on strategic and political levels is imperative. As long as insular political or organisational targets have higher priorities compared to large scaled, border crossing strategies, successful border crossing pandemic management will always be hampered resulting in adverse effects on the well-being of the affected societies.

6. Acknowledgment

The research leading to these results has received funding from the European Union`s Horizon 2020 research and innovation programme under Grant Agreement n°883441.

7. References

- Ansober, R.(2022): Pandemia, Paul Zsolnay Verlag, pp. 248
- AGES (2022) AGES Dashboard COVID19. [online]. Available at: <<https://covid19-dashboard.ages.at/dashboard.html?area=10>> [Accessed 27 April 2022].
- Carrera. R.M. (2020). The importance of cross-border pandemic preparedness, Eurohealth, Vol. 2 No.3, chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/<https://apps.who.int/iris/bitstream/handle/10665/338954/Eurohealth-26-3-34-eng.pdf>, [Accessed 25 April 2022]
- Eržen, B., Weber, M., Sacchetti S. (2020). How COVID-19 is changing border control, ICMPD, <https://www.icmpd.org/news/how-covid-19-is-changing-border-control>, [Accessed 26 April 2022]
- Fonio, C., Widera, A. (Ed.), (2020) Trial Guidance Methodology Handbook. DRIVER+ (Driving Innovation in Crisis Management for European Resilience), Brussels, 2020.
- Gaps Explorer (2019), [online], <https://pos.driver-project.eu/en/gaps>, [Accessed 27 April 2022]
- IFAFRI (2022), Capability Gaps, [online], <https://www.internationalresponderforum.org/capability-gaps-overview>, [Accessed 24 April 2022]
- Mertens, U.P., (2022). Cross-border cooperation during a cross-border pandemic, Maastricht University, <https://www.maastrichtuniversity.nl/blog/2022/01/cross-border-cooperation-during-cross-border-pandemic>, [Accessed 25 April 2022]
- Neubauer, G., Preinerstorfer, A., Martin, A., Rainer, K., van Berlo, M. (2020). Analysis of gaps arising while managing the COVID-19 crisis, IDIMT 2020 – Digitalized Economy, Society and Information Management, Vol. 49, pp165
- Neubauer, G., Ignjatovic, D., Schimak, G., Widera, A., Middelhoff, M., Scheuer, S., Aumayr, G., Jaho, E., Rainer, K. (2021). The benefits of trials for pandemic management, IDIMT 2021- Pandemics: Impact, Strategies and Responses, Vol. 50, pp197
- ORF (2021) Lockerungen ab 15. März: „Gewisser Mut gehört dazu“ [online], Available at: <<https://vorarlberg.orf.at/stories/3093997/>>, [Accessed 27 April 2022]
- Portfolio of Solutions, (2019) Project DRIVER+. [online]. Available at: <https://pos.driver-project.eu/en/PoS/solutions> [Accessed 28 April 2022].
- Rypdal K., Bianchi, F.M., Rypdal M. (2020). Intervention Fatigue is the Primary Cause of Strong Secondary Waves in the COVID-19 Pandemic, International Journal of Environmental Research and Public Health (IJERPH).
- STAMINA (2020). [online], Available at: <https://stamina-project.eu/about/>, [Accessed 27 April 2022].
- Vorarlberg Tourismus (2021) Branchenbrief März 2021 [online], Available at: <https://gmbh.vorarlberg.travel/aktivitaet/branchenbrief-maerz-2021/>, [Accessed 27 April 2022].
- WHO (2020). How to counter pandemic fatigue and refresh public commitment to COVID-19 prevention measures [online], <https://www.euro.who.int/en/health-topics/noncommunicable-diseases/mental-health/news/news/2020/10/how-to-counter-pandemic-fatigue-and-refresh-public-commitment-to-covid-19-prevention-measures>, [Accessed 25 April 2022].

TOWARDS DIGITALIZING RECONNAISSANCE PROCESSES WITH STAKEHOLDER REQUIREMENT ANALYSIS AND PERFORMANCE INDICATORS

Refiz Duro, Rainer Simon, Dražen Ignjatović, Jasmin Lampert

AIT Austrian Institute of Technology GmbH

refiz.duro@ait.ac.at

Christoph Singewald

SyncPoint GmbH

christoph.singewald@syncpoint.io

DOI: 10-35011/IDIMT-2022-145

Keywords

Digitalization, Reconnaissance, Requirements Analysis, Key Performance Indicators, Information Retrieval, Annotation, Stakeholder Engagement

Abstract

Quick and accurate decision making is of uttermost importance in response to potentially critical situations, especially in the military domain. In order to leverage the increasing amount of available data and data sources, it is necessary to exploit and embrace rapid technological advancements. They offer the potential to process, analyze, filter and deliver information much more efficiently and ultimately to accelerate the decision-making process. This can only be achieved if the underlying system and the internal workflows have been digitalized to a certain level. The transformation from largely analogue to digital processes exploiting technological innovations is, however, a complex endeavor. In this paper, we describe our approach applied to the digitalization of processes in military reconnaissance and intelligence gathering, consisting of two initial steps: 1) requirements analysis with end-user involvement, 2) performance measurements, where key performance indicators serve to evaluate the developed services. To demonstrate our approach, we provide an example of the implementation from the project PIONEER, where both steps were applied in the development of the selected service.

1. Introduction

Digitalization can be considered as a phenomenon of transforming analogue data (e.g., text, video, sound, images) and processes into digital language, thereby implementing digital technologies and bringing added value to the whole economy and society (iSCOOP, 2022; Machekhina, 2017; Reis et al., 2020). This added value can be very specific, such as extracting the necessary information through use of state-of-the-art methods of machine learning, statistical analysis and visualization, all rather difficult to exploit when working in a non-digitalized environment. Digitalization brings along various advantages, such as increased efficiency and productivity, lower operational costs, interoperability and quicker information flow, enhanced operational picture potentially leading to

improved and quicker decision making. Although there are certainly potential side effects and risks associated with digital transformation (e.g., cybercrime, IT operational risks, privacy; (Gimpel & Schmied, 2019; Majchrzak, 2016), digitalization is considered one of the highest priorities within businesses and society. Accordingly, there is a significant presence of research on digitalization within generic subject areas (e.g., business, management and accounting, social sciences, engineering and economics) (Reis et al., 2020), as well as of applications that are often described and implemented within specific sectors, such as manufacturing, transport, e-government, healthcare, waste management, and even gastronomy (Heiets et al., 2022; Jeannot et al., 2022; Kurniawan et al., 2022; Parviainen et al., 2017). Likewise, digitalization and interoperability for armed forces, i.e., military, in general has high priority (PESCO, 2022), where quick and precise decision making is of uttermost importance in response to potentially dynamic situations (Garamone, 2017). There is, however, still a lot of potential for the improvement of the level of digitalization as well as the accompanying automatization processes within the military in general (Carden, 2020). This opportunity comes due to various reasons that have limited digital transformation within the military, such as the familiarity and trustworthiness with the existing systems and processes, the lack of resources, as well as the difficulty to acquire talent (from, e.g., industry) to embrace the high-pace technological innovations and increased data amounts and diversity of data sources (e.g., Big Data, Artificial Intelligence, Internet of Things) (Shafer & Rath, 2020). On the one hand failing to exploit and embrace rapid technological advancements can prove to be critical for security and defense, while on the other hand, increased capabilities can be achieved through data access with approaches to process, analyze, filter and deliver information for decision making in a time length otherwise not achievable. Decision makers and leaders within armed forces, especially those in charge of intelligence and information gathering, are aware of the challenge and that digital transformation is a necessity. The availability of an information system is required, which is capable of integrating different sensor data, merging and evaluating them, archiving them in a structured manner, visualizing them, supporting the creation of intelligence products and distributing them internally, e.g. the responsible commander, with as little delay as possible.

2. Methodology

It is not a simple matter of trying to digitize everything that can be digitized. It is necessary to show a level of added value that can satisfy the targeted end-users through digitalization, as well as to provide clear benefits to and optimization of the process itself. It is necessary to identify the elements and parts of the workflow of processing data and information through the establishment of requirements. A definition of system requirements according to ISO, 2011 is as follows: “A *requirement is a statement that identifies a product or processes operational, functional, or design characteristic or constraint, which is unambiguous, testable, or measurable and necessary for product or process acceptability*”. When expressed in more layman terms, system requirements are the functions that the system as a whole should fulfill in order to meet the expectations of the users. They are formulated in an appropriate combination of textual statements, views and non-functional requirements and provide information about the status of the system in terms of safety, reliability and efficiency. System requirements play an important role in systems engineering because they 1) form the basis for system architecture and design activities; 2) serve system integration and verification; 3) are used as a reference for validation and stakeholder acceptance and 4) provide a means of communication among the various technical project teams. The elicitation of stakeholder requirements begins in the concept definition and is then first developed through interviews and goal analyses. System requirements are considered in detail during system design. Neither phase can be considered complete until consistency between the two phases is achieved, which requires a

series of iterations. In defining the requirements, the “IEEE Guide for Software Requirements Specifications” (1984) is a good place to start.

Furthermore, in order to evaluate the system and to see if the improvements are satisfactory, it is necessary to apply a methodology suitable for the purpose. A standard approach is to employ performance measurements, which is a concept and practice based on the principle that *"you get what you measure, and you can only manage a process if you measure it."* (Hauser & Katz, 1998) For performance measurement, we use the definition in (Kingsbury, 2011): *"Performance measurement is the ongoing monitoring and reporting of program results, particularly progress toward achieving predetermined objectives. It is usually conducted by program or agency management. Performance indicators may relate to the type or level of program activities (process) carried out, the direct products and services (outputs) delivered by a program, and/or the results of those products and services (outcomes). A program may be an activity, project, function, or process that has an identifiable purpose or set of objectives."* Performance measurements are directly related to key performance indicators (KPIs), which are tools for understanding, managing, and improving the activities of a project or, for example, a process. Effective and/or key performance indicators provide an understanding of how well the project/service/tool development is progressing, whether the defined objectives have been achieved, whether the stakeholders and users are satisfied and whether and where improvements are needed. As for the definition of effective performance indicators, there are several, but they can be considered as different versions of the same thing. One of these states that *"a KPI stands for key performance indicator, a quantifiable measure of performance over time for a specific goal"*¹. Usually, a performance indicator is generally expressed by a number and a unit of measurement. The number gives a magnitude (how much the change/improvement should be), and the unit gives a meaning (i.e., what is being measured, e.g., seconds) (Franceschini et al., 2019). In addition, each KPI usually belongs to a specific category. These categories, or "representation goals," are high-level characteristics (or aspects) of a system, project, or process that are reviewed for potential improvement. Basically, KPIs provide teams with goals to strive for, milestones to measure progress, and insights to help stakeholders make better decisions. They provide a focus for strategic and operational improvement, create an analytical basis for decision making, and help focus attention on the important components². To provide an example, a KPI defined as *"Number of different data formats that the system can automatically manage/process/integrate"*, can be placed within a category Interoperability that is *"the ability of the system to exchange and use information (e.g. in a heterogeneous network) to provide up-to-date data and information to all relevant users, with functionalities that deal with different data formats, data accesses and data outputs."* There are other alternatives to measure the performance of services (LBL Strategies, 2017), however, the KPI method allows for a satisfactory level of comprehension of connection between high-level objectives (e.g., digitalization) and defined indicators, significant levels of measurement precision, and applicable monitoring due to real-life units of measurement defined for indicators.

The collection and definition of requirements, as well as of the appropriate performance measurement indicators, set the base for the next steps in the digitalization process including designing system and defining architecture, and the standard practices within software development.

¹ <https://kpi.org/KPI-Basics>

² <https://www.qlik.com/us/kpi>

3. Digitalization of Reconnaissance Workflows: An Example from Austria

The Austrian research project PIONEER addresses the concrete challenge of digitalizing important processes in the military reconnaissance cycle, which is up until now still in its initial stages. In a first step this was achieved by analyzing the status quo and identifying potential points of improvement. The basis for this analysis are solutions and findings from earlier activities, e.g., INTERPRETER³, MAJIIC (NATO, 2015; Preinerstorfer et al., 2018) and -even more importantly- continuous discussions with end users. The main result was that the available ICT support for automated execution of the intelligence gathering and distribution process is still highly limited. Typically, the available sensor data cannot be digitally analyzed and due to the heterogeneity of the data sources it is not possible to fuse the data. During ongoing operations, reconnaissance results are usually transmitted in the form of radio messages, while intelligence products are produced in written form and visualized by manual entries on an analog situation map. In other words, there is insufficient digital, ICT-based support that would enable an automated execution of the information gathering and dissemination process, leading to numerous media discontinuities and inefficiencies in the usage of the scarce intelligence resources.

After this initial step, an effort was made to define a set of requirements, both functional and non-functional, that would cover the full cycle of information flow and processing for military reconnaissance preparing it for digitalization. The requirements, however, cannot merely take into account the current state of technology, but also consider the future technological developments, when possible. Only in this manner will the efforts related to requirements of a reconnaissance system prove worthwhile also for future situations.

For the demonstration of our approach, we selected one foreseen functionality of the envisaged system, namely the task of information extraction from text documents with the help of manual and unsupervised *annotations*. Annotating describes the process of tagging and connecting specific words in document, which can prove as valuable information for reconnaissance and decision making. These words can be entities such as a name of a person, locations, dates, organizations, and so on. Through the annotation process, these entities and the connections between them are integrated in the system as data, and can be exploited in a similar way, e.g., for context understanding, network analysis, geo-visualization. The need for the annotation is expressed by the PIONEER end-users through the following requirement:

- The system must allow content to be tagged (automatically or manually)

In the first instance, the annotation is done manually, however, the process itself is already a digitalization of the information extraction, through exploitation and application of readily available software. The PIONEER demonstrator software leverages the two existing open-source libraries, RecogitoJS and Annotorious, for annotating⁴ (Simon et al., 2017). Both libraries are part of the same software suite, which means they have compatible APIs and features. They are designed to work in a browser-based environment, which means they can be integrated into any website or web-based application. PIONEER contributed to the development of the libraries' ability to handle PDF content. In addition, we customized them with project-specific extensions to meet the needs of the PIONEER information retrieval process. Annotations are stored in a customized backend adapted to the end-user demands and are integrated with the rest of the demonstrator infrastructure.

³ <https://pasa-project.at/>

⁴ <https://github.com/recogito/recogito-js>, <https://annotorious.com>

Figure 1 shows the interface of the browser-based PIONEER demonstrator. A PDF representation of the document to annotate is loaded into the workspace. Words are tagged by selecting them with the mouse (Figure 1a). On selection, an editor popup component provides functionality for tagging entities such as date, person, or organization name, and allows the adding of free-form comments to each entity. Furthermore, it is possible to connect entities with links (Figure 1b), and to provide type information for the link, in order to build knowledge graphs based on the text. To link entities with larger ontologies, there is an additional popup component for browsing and selecting terms from an existing ontology (Figure 1c), which can be configured from different sources. We derived our own ontology from the Multilateral Interoperability Programme Information Model⁵ and extended it with frequently used terms according to schema.org.

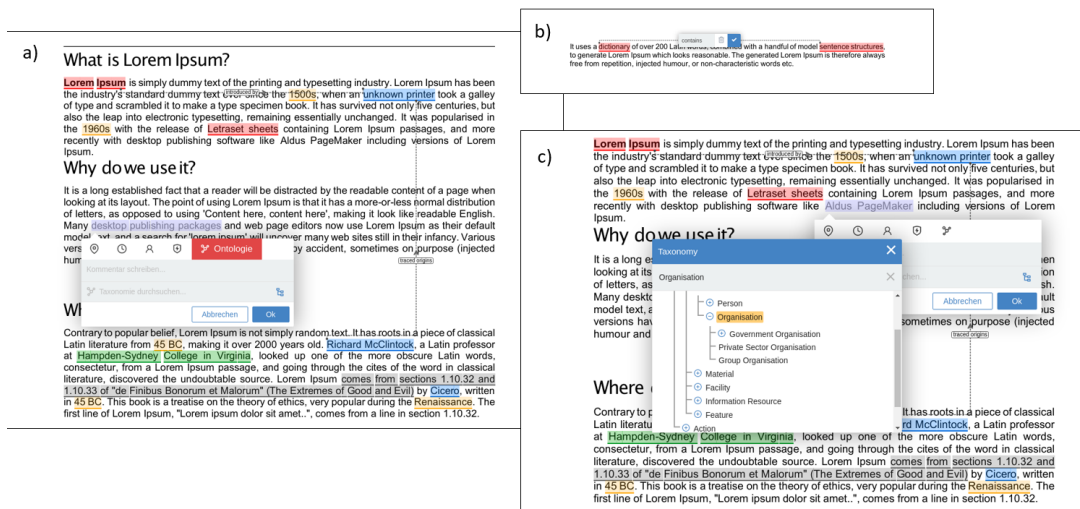


Figure 1: Annotation process tagging and connecting specific words in a PDF document

Moreover, another requirement is addressing the similar topic, and this requirement can be directly combined with the annotation process:

- The system must be able to extract "named entities" from basic data.

This requirement can be addressed for text documents by exploiting a technique known as Named Entity Recognition (NER). The basic idea of NER is to automatically tag and classify words in a document according to pre-defined categories such as person, location or date. This is very similar to the above-described manual tagging. A free, open-source software library for setting up a named entity recognition pipeline is spaCy⁶. It has been programmed from the ground up in Cython⁷ and offers an intuitive syntax for building deployable machine learning services for typical Natural Language Processing (NLP) tasks. Due to following an object-orientated approach it is particularly suited for developers and there are several applications, e.g., for visualizing the found entities in the document, built on top of the library. Currently more than 50 languages are supported by spaCy and an active community is continuously improving the library.

The developed prototype that addresses the mentioned end-user requirements can be evaluated through the defined KPIs, i.e., to apply performance measurement method from Section 2.

⁵ <https://mip.army.gr/en/Home/Apples>

⁶ <https://spacy.io/>

⁷ <https://cython.org/>

However, to answer if we have improvements in e.g., performance, in respect to the current status quo, baseline data needs to be collected for each KPI. Baseline data, the so-called benchmark, is a snapshot of the performance of a process or outcome that is considered normal or average, usually but not unconditionally over a period of time, and provides a reference point for evaluating progress. Several KPIs were identified and defined, all belonging to a category of “Efficiency and effectiveness”, as shown in Table 1. Some of them directly address the annotation process, while other KPIs are more indirect (e.g., “Average processing time”). The defined KPIs are highly relevant for the reconnaissance workflow, while they could be entirely different in description as well as in the rating scale for other use cases.

Table 1: Annotation-relevant KPIs for the military reconnaissance

Key Performance Indicator (KPI)	Definition/Description	Measurement / Rating scale / Unit
Processed documents Integer	Number of documents processed/analyzed within a given time.	Integer (whole number)
Annotation time #1	Time to annotate a text document with X words and Y images.	Seconds
Annotation time #2	Time for annotation of 1 non-full text page.	Seconds
Average processing time	Average time required for a user to successfully complete a task.	Minutes

Regarding the benchmarking and, e.g., KPI “Annotation time #1”, we have established that the current practice requires several minutes to read the text printed on a paper, identify relevant words (i.e., entities) and annotate them by a marker, and potentially transfer the found information (tagged words) to a report or similar physical or digital document. In general, this can be a tedious process prone to errors, and requires a trained and experienced human. By providing the tool described above, we have shown that the same process can be done within a minute: load the document into a workspace, apply the tool functionalities to identify and tag the relevant entities while reading the text, optionally add additional information through the pop-up window, and by the click of a button save the information in a suitable data format, thus making that information available to further processing and, e.g., visualization in a GIS tool.

4. Conclusions

It is an established fact that various sectors significantly benefit from digitalization, primarily by having access to the data and information to which technological innovations can be applied, such as artificial intelligence (AI), cloud computing and internet of things (IoT). We can find that, e.g., manufacturing, e-government, transport and healthcare all show increased efficiency and productivity, lower operational costs, interoperability and quicker information flow and enhanced operational pictures. The same would apply to the military sector, in which quick and enhanced decision making is of utmost importance. There is, however, still a lot of potential to integrate latest technological advancements for the purpose of reconnaissance and intelligence gathering for decision making, and digitalization is the primary basis for it. In this paper, we have shown how to apply two specific steps in the initial stages of the digitalization process.

The first step is the requirement analysis with direct end-user involvement, in which they actively contributed by providing information on needs and expectations for services that a final reconnaissance system should have. Out of the full requirement list (available to PIONEER project partners), a couple were selected for the demonstration for this publication, focusing on tagging and annotation of documents (e.g., Figure 1). This can lead to more efficient data analyses, which could only be carried out manually with great effort. One example of such analyses is the linking of isolated individual observations that at first glance appear to have no relationship to one another. As

the level of information increases, patterns of relationships between observations can be discerned using methods of data analysis and visualization (e.g., pattern wheel, association matrix and activity matrix). With the help of such extracted patterns, conclusions that serve as a basis for decision-making can be drawn. This benefit is primarily visible in the presence of larger amounts of data (i.e., documents) and when collected over medium to longer time periods. However, when this is not the case (e.g., for a couple of dozen documents), the human brain is still better equipped to quickly come to a conclusion just by extracting important information through skimming through the documents. This approach is in opposition to the digital annotation process described in Section 3, which requires more time. Integration of automatic annotation using NER models, would, speed up the process when large amounts of data needs to be processed. However, it introduces the challenge of designing a service that takes into account the model accuracy, but at the same time keeps the human in the loop, which is paramount when decisions based on the used models are expected to be critical.

The second step is the performance measurement, which provides the means in the form of Key Performance Indicators to monitor and evaluate the developed services and draw conclusions if a satisfactory improvement has been achieved or not. It is critical to establish precise KPIs, otherwise their implementation can be misleading and provide incorrect evaluation (see Franceschini et al., 2019 for misuse of indicators). We have defined KPIs that are relevant to the selected demonstration, namely the tagging and annotation of documents (as for the requirement analysis step), which has shown us that even simply, but precisely defined KPIs, together with the established measurement unit can be of great support not only for the measurement of performance and thus improvement, but also for showcasing to end-users the power of digitalization even of an only a small part of the full reconnaissance process.

The approach we have shown here is primarily focused on the military domain. The digitalization process described, however, is very relevant for civil sector applications such as, e.g., crisis response to natural disasters and could be evaluated within relevant frameworks (e.g., Trial Guidance Methodology⁸) directly by first responders. The next steps in the process of digitalization, after requirement analysis and KPI definitions for performance measurement, would logically involve architecture and system design, followed by developments of individual software services and tools, as well as of the full system. The main ingredient is, however, the digitalization, as only then can the data be leveraged, i.e., processed, analyzed, filtered and delivered, and technological innovation be fully embraced.

5. Acknowledgements

The work leading to this publication is being carried out within the PIONEER project (grant agreement number 879712, which is funded by the Austrian Research Promotion Agency (FFG) as part of the FORTE defense research program.

6. References

- Carden, R. (2020). Spotlight on Military Digitisation: Accelerating Digital Transformation. <https://defencedigital.blog.gov.uk/2020/02/26/spotlight-on-military-digitisation-accelerating-digital-transformation/>

⁸ <https://tgm.ercis.org/>

- Franceschini, F., Galetto, M., & Maisano, D. (2019). Designing a Performance Measurement. In F. Franceschini, M. Galetto, & D. Maisano, *Designing Performance Measurement Systems* (pp. 133–205). Springer International Publishing. https://doi.org/10.1007/978-3-030-01192-5_5
- Garamone, J. (2017). Dunford: Speed of Military Decision-Making Must Exceed Speed of War. U.S. Department of Defense. <https://www.defense.gov/News/News-Stories/Article/Article/1066045/dunford-speed-of-military-decision-making-must-exceed-speed-of-war/>
- Gimpel, H., & Schmied, F. (2019, June 8). Risks and side effects of digitalization: A multi-level taxonomy of the adverse effects of using digital technologies and media.
- Hauser, J., & Katz, G. (1998). Metrics: You are what you measure! *European Management Journal*, 16(5), 517–528. [https://doi.org/10.1016/S0263-2373\(98\)00029-2](https://doi.org/10.1016/S0263-2373(98)00029-2)
- Heiets, I., La, J., Zhou, W., Xu, S., Wang, X., & Xu, Y. (2022). Digital transformation of airline industry. *Research in Transportation Economics*, 101186. <https://doi.org/10.1016/j.retrec.2022.101186>
- IEEE Guide for Software Requirements Specifications. (1984). IEEE Std 830-1984, 1–26. <https://doi.org/10.1109/IEEESTD.1984.119205>
- iSCOOP. (2022). Digitization, digitalization, digital and transformation: The differences. <https://www.i-scoop.eu/digital-transformation/digitization-digitalization-digital-transformation-disruption/>
- ISO. (2011). Systems and software engineering—Architecture description. <https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/05/05/50508.html>
- Jeannot, F., Dampérat, M., Salvador, M., El Euch Maalej, M., & Jongmans, E. (2022). Toward a luxury restaurant renewal: Antecedents and consequences of digitalized gastronomy experiences. *Journal of Business Research*, 146, 518–539. <https://doi.org/10.1016/j.jbusres.2022.03.092>
- Kingsbury, N. (2011). Program Performance Assessment. United States Government Accountability Office. <https://www.gao.gov/pdf/product/77277>
- Kurniawan, T. A., Dzarfan Othman, M. H., Hwang, G. H., & Gikas, P. (2022). Unlocking digital technologies for waste recycling in industry 4.0 era: A transformation towards a digitalization-based circular economy in Indonesia. *Journal of Cleaner Production*, 131911. <https://doi.org/10.1016/j.jclepro.2022.131911>
- LBL Strategies. (2017). The Difference Between KPIs, OKRs and KRAs? LBL Strategies. <https://www.lblstrategies.com/whats-the-difference-between-the-kpis-okrs-and-kras/>
- Machekhina, O. N. (2017). Digitalization of education as a trend of its modernization and reforming. *Revista ESPACIOS*, 38(40). <http://www.revistaespacios.com/a17v38n40/17384026.html>
- Majchrzak, A. (2016). Designing for Digital Transformation: Lessons for Information Systems Research from the Study of ICT and Societal Challenges. *Management Information Systems Quarterly*, 40, 267–277. <https://doi.org/10.25300/MISQ/2016/40:2.03>
- NATO. (2015). MAJIIC 2 Architecture Requirements Document (Multi-Intelligence All source Joint ISR Interoperability Coalition). NATO Communications and Information Agency.
- Parviainen, P., Tihinen, M., Kääriäinen, J., & Teppola, S. (2017). Tackling the digitalization challenge: How to benefit from digitalization in practice. 5(1), 15.
- PESCO. (2022). PESCO | Member States Driven. <https://www.pesco.europa.eu/>
- Preinerstorfer, A., Egly, M., Gojmerac, I., Hochwarter, C., Schuster, C., Jandl-Scherf, B., Lernbeiss, H., Radner, S., & Schweighofer, E. (2018). Interoperability Between IT Systems in Austrian National Crisis & Disaster Management. 2018 5th International Conference on Information and Communication Technologies for Disaster Management (ICT-DM), 1–8. <https://doi.org/10.1109/ICT-DM.2018.8636381>
- Reis, J., Amorim, M., Melao, N., Cohen, Y., & Rodrigues, M. (2020). Digitalization: A Literature Review and Research Agenda (pp. 443–456). https://doi.org/10.1007/978-3-030-43616-2_47
- Shafer, C. J., & Rath, C. (2020, April). The Race to Digitalization. www.mca-marines.org/gazette
- Simon, R., Barker, E., Isaksen, L., & De Soto Cañamares, P. (2017). Linked Data Annotation Without the Pointy Brackets: Introducing Recogito 2. *Journal of Map & Geography Libraries*, 13(1), 111–132. <https://doi.org/10.1080/15420353.2017.1307303>

COMBINING SOCIAL MEDIA AND OPEN SOURCE DATA WITH RELEVANCE ANALYSIS AND EXPERT KNOWLEDGE TO IMPROVE SITUATIONAL AWARENESS IN CRISIS AND DISASTER MANAGEMENT – CONCEPT

Dražen Ignjatović, Daria Liakhovets, Rainer Simon, Georg Neubauer, Anita Graser, Mina Schütz

AIT - Austrian Institute of Technology GmbH

drazen.ignjatovic@ait.ac.at, daria.liakhovets@ait.ac.at, rainer.simon@ait.ac.at,
georg.neubauer@ait.ac.at, anita.graser@ait.ac.at, mina.schuetz@ait.ac.at

Siegfried Vössner, Wolfgang Vorraber, Clemens Gutschi

TU Graz - Graz University of Technology

voessner@tugraz.at, wolfgang.vorraber@tugraz.at, clemens.gutschi@tugraz.at

Bernd Resch

Spatial Services GmbH

bernd.resch@spatial-services.com

DOI: 10-35011/IDIMT-2022-153

Keywords

Social Media, Situational Awareness, Information Densification, Relevance Assessment

Abstract

Situational awareness is one of the most important factors for efficient and effective response in crisis and disaster situations. Up-to-date, valid and relevant data is one of the means to support crisis management actions, and the development and use of social media, as it is common nowadays, has become a very interesting research topic. In this paper, we describe a concept for using social media information and open source data in combination with expert knowledge and relevance assessment. The main problem with data collected from these sources is, on the one hand, the large amount and difficulty of processing, and on the other hand, the difficulty of determining its validity. This concept aims to address these two problems and combine the results to propose a solution for better situational awareness in crisis and disaster management.

1. Introduction

Situational awareness is one of the most important, if not the most important factor for providing efficient and effective response in crisis and disaster management. It has to be up-to-date, valid and dynamically adaptive for subsequent effective command and control of emergency forces and

ultimately for ensuring public safety. Open source data (all publicly available data sources such as publicly available social media networks, RSS feeds, news portals, etc.) form an increasingly essential and indispensable data basis for the creation of this situational awareness. The nature of the creation, volume, and dissemination of open source data pose unique challenges for public safety responders in managing the volume of data and in verifying validity and assessing relevance. Despite existing research and application approaches to the collection and analysis of open source data, significant challenges exist in the area of validation and relevance assessment, and thus ultimately in the assured processing of information for an improved and real-time situational awareness. In this paper, we propose a concept for integrating the required experience and expert knowledge of emergency responders and linking respectively “augmenting” this knowledge with open source data to raise the utilization potential of these data sources to a new level of quality.

This paper builds on the work done in the KIRAS project iLike (FFG Project No. 873496) sponsored/funded by the KIRAS security research grant program of the Federal Ministry of Agriculture, Regions and Tourism. It is organized as follows: Chapter 2 describes related work on which this research builds. Chapter 3 describes the proposed approach and is divided into the three topics of algorithms used, involvement of experts, and relevance assessment. Chapter 4 describes how the results will be evaluated and what challenges may arise. Chapter 5 describes an outlook and future work.

2. Related work

As described in Reuter & Kaufhold (2018) a high amount of research such as (Menodza et al., 2010), (Roy et al., 2020), (Imran & Castillo, 2015), (Kaufhold et al., 2020), (Kleffner & Meisner, 2021) has been conducted in the area of crisis informatics, which includes research about the use of social media in public protection and disaster relief missions. In this context Reuter & Kaufhold (2018) refer to the definition of the term crisis informatics by Palen & Anderson (2016) as “a multidisciplinary field combining computing and social science knowledge of disasters; its central tenet is that people use personal information and communication technology to respond to disaster in creative ways to cope with uncertainty”. Research and practical applications of crisis informatics can be structured according to the crisis communication matrix of Reuter et al. (2012), which distinguishes (1) ‘authorities to authorities (A2A) - inter-organizational crisis management’, (2) ‘citizens to authorities (C2A) - integration of citizen generated content’, (3) ‘authorities to citizens (A2C) - crisis communication’, and (4) ‘citizens to citizens (C2C) - self-helping communities’.

An important part of this work is based on research in data analysis and utilizes several methods from this field. Machine learning (ML), especially deep learning (DL), has become one of the core technologies for data-driven automation and building intelligent systems. Originating from artificial neural networks (ANN), DL technology has been successfully applied in various fields, including natural language processing. However, it can be difficult to build a suitable neural network-based model due to the diversity of data and tasks in the real world. DL models have some limitations, e.g., lack of interpretability (“black-box” systems). DL can be divided into supervised (or discriminative) learning, unsupervised (or generative) learning, and hybrid learning that combines both (Sarker, 2021). Although neural methods are claimed to improve classification effectiveness, a comparative study conducted by Washington et al. (2021) on the cost-benefit ratio of neural and non-neural 2-phase approaches (using representations) and end-to-end methods showed that traditional NLP (natural language processing) approaches such as SVM (support vector machine) with TFIDF (term frequency–inverse document frequency) with appropriately tuned parameters are highly competitive on both small and large datasets. Among end-to-end neural methods, architectures such as a 1-layer Long Short-Term Memory (LSTM) or Very Deep Convolutional NN (VDCNN) were found to be very similar to transformer architectures, e.g., BERT or XLNet, in

terms of effectiveness at much lower cost, while the latter brought minor advantages. MetaFeatures' 2-phase approach proved to be very competitive even against the best end-to-end neural methods. Since text data must be converted into a numerical representation to be used with ML models, various embedding algorithms have been developed to provide such vector representations. There are several types of embedding models: context-level learned (e.g., Word2Vec, GloVe), subword-level learned (e.g., FastText), character-level learned (e.g., CNN), contextualized word embeddings (e.g., GPT, BERT). Contextualized word embeddings can produce different representations depending on the context and can represent multiple meanings of the same word and are better suited for unstructured text (Vušak et al., 2021).

Extracting structured knowledge from text data is a challenge, but it is useful in many application areas and has therefore received much attention. Different definitions and representations of knowledge led to the development of different extraction and evaluation methods. Knowledge can be represented as a collection of relational facts. Relational knowledge extraction from text means the identification and classification of text segments corresponding to named entities (Named Entity Recognition, NER) and their relations (Relation Extraction, RE). Supervised learning (training a model with labelled data), remote supervision (using, e.g., knowledge bases as an external ground truth source to obtain a dataset), and unsupervised learning (algorithms that do not require annotated data, e.g., clustering) are used for knowledge extraction (Rui et al., 2022).

The results of the work leading up to the proposed approach have demonstrated that data mining techniques can be successfully used to improve situational awareness when applied to social media and open source data by automatically detecting unusual events and analysing the sentiment of the incoming traffic (Ignjatović et al., 2021 and Simon et al., 2021). When working with social media data, it is important to consider the privacy implications and legal aspects, as it involves person-related data. The KIRAS project QuOIMA has already made some progress in this area and the available knowledge will be taken into account in the proposed approach.

3. weLike Concept

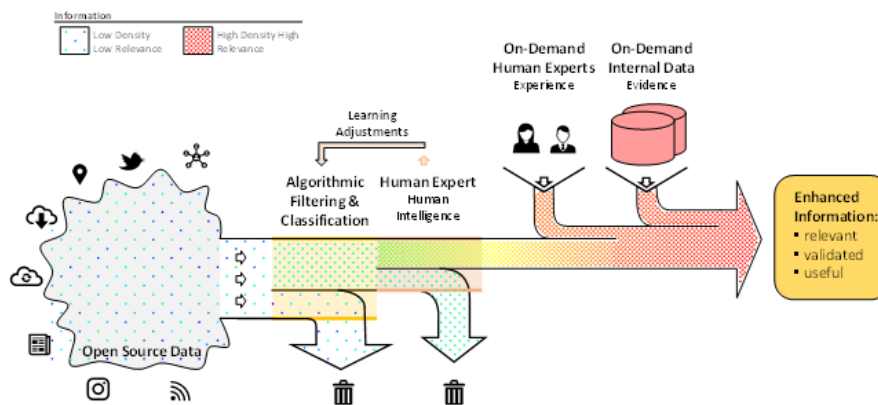


Figure 1: weLike basic concept of information gathering, filtering and densification

weLike's basic functionality is to provide enhanced information with an increased level of relevance, validation and usefulness. The basic concept of data gathering, and processing is shown in figure 1: Tapping into the world wide web of all kinds of publicly available information sources, weLike uses connectors to extract and store basic data streams. By means of algorithmic filtering and classification using machine learning – aka “artificial intelligence”, the information content of these streams is increased – data classified as not important are discarded in order to reduce the data volume and increasing efficiency (Kaufhold et. al. 2020). The next filtering and classification step

is done by applying the experience and “natural intelligence” of human experts. Again, not relevant data is discarded. In order to adapt to changing situations and to increase the performance of the algorithmic filters, weLike provides mechanism for supervised learning by incorporating feedback from the human experts involved in this step. Depending on the situational requirements, weLike allows in a last step to enrich information furthermore by either adding on-demand additional human expertise and/or augmenting the information with existing evidence and data available to the stakeholders, only. The resulting data stream is significantly richer in terms of relevant, validated and useful information supporting situational awareness and operational- as well a strategic-decision making.

3.1. Algorithms for filtering and classification

The suggested concept aims to combine automated data processing with expert knowledge to assess the quality and validity of the information. Suitable indicators and criteria will be identified and specific algorithms developed. Algorithms for automated filtering and classification will focus in particular on aspects of reliability of information sources and relevance of information (e.g. news articles, reports, social media, etc.). At the information source level, analysis of networks and dissemination patterns can provide insights into the motivation and impact of an information source. Expert knowledge is used to develop a set of reliability features for ML algorithms and can also be directly considered when evaluating data sources (e.g., trustworthiness of a particular medium or credibility of a social media account). At the content level, unsupervised ML methods such as clustering, topic modeling, intelligent keyword search, and similarity search can facilitate filtering. Topic analysis can highlight typical topics for a given information source and help evaluate its competence with respect to a given topic. Information extraction techniques such as NER (named entity recognition), relation extraction, topic-based summarization, and claim detection can be used to reduce data volume and support data filtering. The extracted facts enable data enrichment, e.g., linking further important knowledge based on a geographic location.

3.2. Involvement of experts and validated knowledge

To gain situation-relevant and valuable information it is necessary to preprocess the vast amount of harvested open-source data (Kaufhold et. al. 2020). For extracting relevant information from open-source data, expert knowledge is involved (compare figure 1) to set-up and calibrate filtering and relevance classification models. Thereby, calibration relies on situation-specific datasets which are created and maintained by experts. These datasets allow experts to include new information (e.g., search terms), exclude existing information, classify relevant existing information manually, and validate existing classifications. Experts are enabled to adjust the data preprocessing in three different phases of crisis and disaster management:

- Preparation for situations: Preparatory and set-up work is supported by available datasets which may be updated to the certain situation with domain-specific knowledge and expertise of experts.
- Mastering situations: In this active phase during disaster or crisis situations, the planned analysis tool allows experts to validate and add information online which will incrementally expand the calibration dataset and allow for updating the filtering and relevance classification model.
- Situation follow-up: After coping with the situation, new information can be added and assessed and existing information validated by the experts for updating the knowledge database and improve data-sets for future events.

For on-demand context specific information gathering from experts it is important that filtered and preprocessed information is interpreted by human experts. Human experts can bring in tacit, domain and case specific knowledge and thereby enrich the preprocessed information. This context sensitive knowledge is created based on various sources of individual and organizational information and experiences of the individual experts. In this context, the information provided by the planned open source analysis tool described herein represents only one, but a highly relevant source of information among various other sources. The filtering function of the presented system concept helps to overcome the “information overload” almost inherent to open source data analysis (Castillo, 2016) (Shirky, 2008). Nevertheless, experts need to be aware that filters may also introduce biases (e.g. bias regarding the selection of sources (e.g. distribution of user groups active in social media networks), bias due to machine learning/training data). Hence feedback mechanisms need to be integrated into the system concept and end users need to be aware about the limitations and potential biases when interpreting the filtered data.

3.3. Relevance assessment

To address the relevance assessment issue, we consider the following facets:

- Credibility of the content
- Credibility of the medium or channel
- Credibility of the source
- Credibility of the network(s) in which the source is anchored.

In the context of the proposed concept, the focus is on the source, the media used, and the source's networks (see also Brodnig (2021) and Jergitsch (2021)). A key facet of the source is its motivation. In the case of spreading misinformation, the source can:

- Actually believe this misinformation
- Want to attract attention with it
- Or have a market for services or products that it can better serve through misinformation.

In the case of sources, attention must be paid to other aspects, such as expertise in the domain and not just academic degrees per se (fake experts). Other criteria that influence the credibility of the source relate to the methodology of the argumentation, such as the use of probabilities versus the delivery of absolute dogmatic truths. Other criteria include pseudoscientific lines of argument, the use of suggestive questions (loaded questions), or the amplification of the presence of minority opinions (e.g., on herd immunity). Facets of the argumentation chain are another level of consideration:

- Does the source often have logic errors in the line of reasoning? (e.g. chlorine bleach can be used on surfaces for disinfection (correct statement), but it causes adverse effects in the body.
- Does the source raise impossible expectations? (e.g., 100% safe vaccine)
- Does the source use inappropriate or false similes?

When considering the medium used, the business model is of great importance. Social media and tabloid newspaper draw on a large reach (to increase dwell time), which they can trigger well by triggering emotions. Validation of the quality of the content is of secondary importance, if it exists at all. In contrast, quality assuring media claim to provide validated, truthful information for their consumers. A very decisive criterion for media that disseminate scientific information is the

establishment of a reviewing process by peers. The often-existing urge of media (or journalists) to allow the polarity of opinions and to let all sides have their say can lead to a boosting of minority opinions or even of conspiracy narratives.

4. Evaluation plan and Challenges

We are planning to implement the presented system concept on an experimental level (technology readiness level 4 according to the definition of the European Commission (European Commission, 2014)), which enables us to run practical evaluations with experts. Evaluations will be based on two evaluation scenarios that will cover both, live data analysis, and retrospective data analysis (Castillo, 2016). Concrete evaluation scenarios will be defined based on organizational and legal constraints and may be based on plannable major (sports) events for the live data analysis case and existing available data sets (e.g. data collected during public protection and disaster relief missions) for detailed retrospective data analysis. In both scenarios expert feedback will be collected based on questionnaires and analyzed primarily with quantitative data analysis methods.

Beside all technical challenges in terms of data analysis techniques, organizational integration and the creation and calibration of multi-criterial relevance weights, one of the most important challenges is to ensure legal compliance of the system and its use in public safety organizations. Since the system is developed in a European context, legal regulations such as the general data protection regulation (European Parliament and the council of the European Union, 2016) and the recently published European Commission proposal for harmonized rules on artificial intelligence (European Commission, 2021) must be considered already during the development process. Furthermore, depending on the context of use, legal regulations on national, regional and organizational level must be met.

5. Outlook

The work presented in this paper describes a concept for combining social media and open source data with expert knowledge, while also investigating the relevance of information. The technical advantage of the proposed concept lies in the combination of machine-derived information and its human (expert) validation. It is planned to determine the extent to which the concept is applicable in real-world scenarios. Funding from the KIRAS grant program has been requested for this planned work, and it will be conducted over a two-year period. Initial results would then be available in the middle of this period, after the first year. To ensure further developments in this direction, the authors of this paper will publish the results of their work as soon as they are available and the opportunity arises to do so. As far as we are aware, one similar concept exists proposed by Kaufhold et.al. (2020), and it would be of great importance to examine the results as soon as they are available, not only for the area of crisis and disaster management, but also to investigate the applicability in other areas. This would be possible by involving different actors from domains such as pandemic management or terrorist situations. To achieve this, close collaboration is planned with both national and European stakeholders, and funding is being sought for further developments under funding programs such as the EU's Horizon Europe.

6. References

- Brodnig, I. (2021). *Einspruch*. Brandstätter Verlag, ISBN 978-3-7106-0520-8
- Castillo, C. (2016). *Big crisis data: social media in disasters and time-critical situations*. Cambridge University Press.

- E. Vušak, V. Kužina and A. Jović, "A Survey of Word Embedding Algorithms for Textual Data Information Extraction," 2021 44th International Convention on Information, Communication and Electronic Technology (MIPRO), 2021, pp. 181-186, doi: 10.23919/MIPRO52101.2021.9597076.
- European Commission. (2014). Technology readiness levels (TRL), Extract from Part 19 - Commission Decision C(2014)4995.
- European Commission. (2021). Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL LAYING DOWN HARMONISED RULES ON ARTIFICIAL INTELLIGENCE (ARTIFICIAL INTELLIGENCE ACT) AND AMENDING CERTAIN UNION LEGISLATIVE ACTS.
- European Parliament and the council of the European Union. (2016). REGULATION (EU) 2016/679 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation), Official Journal of the European Union, L 119, 1-88.
- Ignjatović, D., Simon, R., Neubauer, G., Pan, J., & Gutschi, C. (2021). Use of social media and open source data to enhance situational awareness in the Austrian crisis and disaster management. IDIMT 2021 - Pandemics: Impacts, Strategies and Responses, 29th Interdisciplinary Information Management Talks, 175-182.
- Imran, M., & Castillo, C. (2015). Towards a data-driven approach to identify crisis-related topics in social media streams. In Proceedings of the 24th International Conference on World Wide Web, 1205-1210. <https://doi.org/10.1145/2740908.2741729>
- Jergitsch, F. (2021): Die Geister, die ich teilte, Residenz Verlag, ISBN 978-3-7017-3533-4
- Kaufhold, M. A., Bayer, M., & Reuter, C. (2020). Rapid relevance classification of social media posts in disasters and emergencies: A system and evaluation featuring active, incremental and online learning. Information Processing & Management, 57(1), 102132.
- Kleffner, H. & Meisner, M. (2021): Fehlender Mindestabstand – die Coronakrise und die Netzwerke der Demokratiefeinde, Verlag Herder GmbH, ISBN 978-3-451-39037-1
- Mendoza, M., Poblete, B., & Castillo, C. (2010). Twitter under crisis: can we trust what we RT? In Proceedings of the First Workshop on Social Media Analytics (SOMA '10). Association for Computing Machinery, New York, NY, USA, 71–79. DOI:<https://doi.org/10.1145/1964858.1964869>
- Palen, L., & Anderson, K. M. (2016). Crisis informatics: New data for extraordinary times. Science, 353(6296), 224–225
- R. Simon, D. Ignjatović, G. Neubauer, C. Gutschi, J. Pan and S. Vössner, "Applying data mining techniques in the context of social media to improve situational awareness at large-scale events," 2021 International Conference on Electrical, Computer, Communications and Mechatronics Engineering (ICECCME), 2021, pp. 1-6, doi: 10.1109/ICECCME52200.2021.9591154.
- Reuter, C., Marx, A., & Pipek, V. (2012). Crisis Management 2.0: Towards a Systematization of Social Software Use in Crisis Situations. International Journal of Information Systems for Crisis Response and Management (IJISCRAM), 4(1), 1-16. <http://doi.org/10.4018/jiscrm.2012010101>
- Roy, KC., Hasan, S., & Mozumder, P. (2020). A multilabel classification approach to identify hurricane-induced infrastructure disruptions using social media data. Comput Aided Civ Inf. 35: 1387– 1402. <https://doi.org/10.1111/mice.12573>
- Rui, Yong & Carmona, Vicente & Pourvali, Mohsen & Xing, Yun & Yi, Wei-Wen & Ruan, Hui-Bin & Zhang, Yu. (2022). Knowledge Mining: A Cross-disciplinary Survey. Machine Intelligence Research. 1-26. 10.1007/s11633-022-1323-6.
- Sarker, I.H. Deep Learning: A Comprehensive Overview on Techniques, Taxonomy, Applications and Research Directions. SN COMPUT. SCI. 2, 420 (2021). <https://doi.org/10.1007/s42979-021-00815-1>
- Shirky, C. (2008). It's not information overload. It's filter failure. keynote at Web 2.0 Expo in New York. USA.
- Washington Cunha, Vítor Mangaravite, Christian Gomes, Sérgio Canuto, Elaine Resende, Cecilia Nascimento, Felipe Viegas, Celso França, Wellington Santos Martins, Jussara M. Almeida, Thierson Rosa, Leonardo Rocha, Marcos André Gonçalves, On the cost-effectiveness of neural and non-neural approaches and representations for text classification: A comprehensive comparative study, Information Processing & Management, Volume 58, Issue 3, 2021, 102481, ISSN 0306-4573, <https://doi.org/10.1016/j.ipm.2020.102481>.

DISINFECTION WITH VAPORIZED HYDROGEN PEROXIDE FLUID IN DIFFERENT ENVIRONMENTS AND ITS APPLICATIONS AND ADVANTAGES IN CRISIS MANAGEMENT

**Krista Rathammer, Lisa Winkelmayr, Alois Leidwein,
Sarah Lindinger, Theres Requat, Hermann Schildorfer,
Nikolaus Schmoll, Georg G. Duscher**

Austrian Agency for Health and Food Safety (AGES)
krista.rathammer@ages.at

Friedrich Bauer

TBB Bauer & Bauer GmbH
office@tbb-gmbh.at

Karl M. Hellemann

HOSAN®GmbH
office@hosan.at

Philippe Jäger, Davul Ljuhar

Braincon GmbH & Co KG
d.ljuhar@bct.co.at

Michael D. Mansfeld

ILV Kärnten, Veterinärmedizinische Untersuchungen
michael.MANSFELD@ktn.gv.at

DOI: 10-35011/IDIMT-2022-161

Keywords

Flexible disinfection, rapid laboratory disinfection, laboratory safety, crisis management, remote lab disinfection

Abstract

During a global pandemic, mitigating the impact of the disease and coordinating efforts to manage not only the medical but also the logistical and administrative aspects of such an all-encompassing phenomenon are of paramount importance. An extremely important but less publicised issue in this context is laboratory management and safety in analytical laboratories. In times of high capacity utilisation, as is the case during a pandemic or endemic outbreak of disease, other routine processes have to be abbreviated or are cancelled altogether due to lack of planning owing to the

rapid emergence of the outbreak. In order to achieve high level of cleanliness in laboratories of all shapes and sizes and with different requirements, a universal solution seems unimaginable. Our experiments show a promising, automated approach of disinfection of various spaces. Within a short timeframe of 1 h – 3 h it is possible to disinfect any desired room to achieve a laboratory grade hygiene status. This was proven by employing biological indicators validated for this procedure. The tested technology reduced the indicator germs by a concentration of the mathematical log 6 reduction. Achieving this high level of cleanliness is possible by assigning a single person to the task for the set-up at the scene. Steering and monitoring of the process can be done remotely. While the machine used in our experiments is not a completely new concept, our experiments in a real-life setting such as laboratories and clinics alike, show that the applied hydrogen peroxide vapour distributed by a specialized fogger, disinfects even hard to reach spots within closed-off spaces. This program can be performed while automated (PCR) machines are running and highly trained personnel can apply their expertise elsewhere. Moreover, while the program is running real-time data is available and the process can be remotely monitored and steered digitally. It is of major concern to ensure maintainability of infrastructure e.g. COVID labs, ambulances, laboratories or veterinary practitioners to ensure treatment of directly and indirectly related health issues within a crisis. We concentrated on evaluating the usability of the disinfection technology presented in real-life settings.

1. Introduction to the methods

The fogger used in these experiments was provided by Braincon GmbH & Co KG. It was developed to disinfect surfaces and airborne contaminants in clinics and hospitals, producing dry vapour hydrogen peroxide droplets of $\sim 0,3 \mu\text{m}$ in size without heating the fluid (Braincon GmbH). We used commercially available, validated biological indicators, containing different concentrations of viable of the standard microbe, as well as validated chemical indicators used for monitoring disinfection with H_2O_2 as controls for the process. These indicators were placed mainly on hard to reach spots or highly frequented areas within the rooms where the disinfection was performed. With the biological indicators we tested different concentrations, namely 10^4 , 10^5 and 10^6 viable, colony forming units or CFU, of *G. stearothermophilus* to see how powerful the disinfection we performed was. After the distribution of the indicators the doors and windows were sealed with duct tape and ventilation was turned off to prevent the vapour from escaping the assessed area. The disinfection program was adapted to the size of the room and the unique requirements i.e. relative air humidity (RAH) at the start. As a disinfectant 7.5 % hydrogen peroxide solution DCXF, was nebulized to achieve and maintain the desired RAH during the disinfection program of 3 h. In some cases with 50 ppm silver ions as an additive to the solution. After the disinfection protocol, the air ventilation was turned on and, if feasible (i.e. in the ambulance), doors and windows were opened to ensure air exchange and sufficient diffusion of hydrogen peroxide out of the disinfected room. To ensure safety the highly sensitive and portable Dräger X-am 5100 device was used to verify that the peroxide concentration had fallen under the maximum workplace level of 1.0 ppm before the respective areas were deemed safe and declared safe.

2. Validation

2.1. Empty Room

As a first step, the disinfection program was performed three times within a sealed cellar of approx. 38 m^3 to validate the fogger under comparable conditions. For this experiment various biological and chemical indicators were distributed on four different places within the room at the AGES

Mödling. The positions of the indicators were chosen to achieve a distance of approx. 2 m from the vaporizer while all seven different indicators could be placed at the same position at once. The following locations were selected to evaluate the peroxide distribution within the room: in a plastic tube sealed by 2 copper sponges, on the opposite side of the room and on the top of the ventilation shaft (10 cm below the ceiling, this was approx. 3 m from the vaporizer, for further information see 4. Materials and Supplementary). The fourth position, on the device itself, was added after the first experiment, because it was suspected that 90 % RAH could lead to condensation. In this case, the condensation would be most severe and most noticeable near the outlet of the vaporizer. The indicators inside the plastic tubes served as a negative control, since hydrogen peroxide is an oxidizing agent. Consequently, it reacts strongly with the copper ions in the sponges, ensuring that the vapour cannot reach the indicators inside.

Based on the practical experience of Braincon, 90 % of RAH was set as target value and the room was disinfected with DCXF solution over a span of 360 min. The DCXpro recorded RAH and temperature for further two hours after the nebulisation to measure the development of the humidity in the room and to compare the internal readout with the Porta Sense II device installed in the room. This was done to prove that the humidity curves measured by the DCX internal probe correlates with the ppm measurements of the Porta Sens II device. The humidity and the ppm measurements did match. The ppm-values peaked after fluid vaporization was finalized. This may be due to fluid dynamics within the room. 90 % RAH is feasible to perform a log 6 disinfection in a 38 m³ sealed cellar with no additional air ventilation. All tested biological indicators are applicable and can be used interchangeably.

2.2. Equipped room

After the room evaluation, the experiment was extended by assessing 23 positions of the biological and chemical indicators within and around office staples and miscellaneous objects of common use (i.e. drawer of a cupboard, in a folder between sheets of paper, HEPA filter, rubber boots, aluminium ventilation tube, etc.). The goal was to determine the accessibility of hydrogen peroxide fog to various locations in an equipped room. For the examination, a RAH of 80 %, 7.5 % hydrogen peroxide and an active disinfection time of 360 min was chosen. In this case, only one biological indicator and one chemical indicator were used to verify the reduction, and all indicators were placed approx. two meters from the vaporizer.

The gaseous hydrogen peroxide achieved a successful bacterial reduction within a two meter radius and was able to reach laterally open horizontal cavities such as sewer pipes or underneath the laptop. The disinfection in vertical cavities open at the top, however, was insufficient. Furthermore, the fog was able to access a coat pocket but not into the pile of clothes or narrow spaces such as filters and straw bales. The disinfection of closed drawers and behind cabinet doors was not successful. As described in the initial room disinfection experiment the indicators inside the plastic tube were used as negative control.

Results from evaluating an equipped room

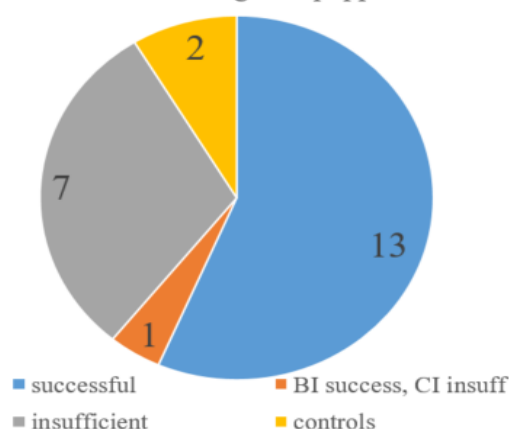


Figure 1 Results of the nebulization of the differentially equipped room showed a clear success, though some equipment was hard to decontaminate; see 4. Materials and Supplementary for more detailed results, BI= Biological indicator (Spore Strip *G. stearo*thermophilus ChemVapor), CI= C)

3. Real Environment Experiments

3.1. Dentist practice

Another proof of concept was the disinfection of a dentist practice in Linz, with the DCXplus in “boost mode” (continuous steam injection) for 120 min, then continued measuring of humidity and temperature for 60 min, before the biological indicators were taken out. In this experiment 50 ppm silver ions were added to the DCXF solution. In total four positions were monitored with biological indicators, to determine the disinfection power of the DCXplus.

Table 1 Overview of Apex Discs positions and results at the dentist practice(-): successful disinfection, (+): insufficient disinfection/growth

Position / CFU	10 ⁴	10 ⁵	10 ⁶		10 ⁴	10 ⁵	10 ⁶
Water fountain patient chair	-	-	-	Bench	-	-	+
utensil tableau	-	-	-	Suction device and tools	-	+	-

The insufficient disinfection of the bench and suction device could be due to the shorter vaporization time. Another issue could have been that the temperature in the room was much higher (~28°C) than the range of effective temperature for the DCXF fluid and dry vapour which lies between 15 and 22°C. In order to obtain more information swab tests at real locations and more real-life scenarios need to be assessed to see if temperature is really such a hindering factor.

3.2. Veterinary practice

The effectiveness of disinfection in real-life situations with the DCX technology was tested in an operational veterinarian practice. For the evaluation of the disinfection, biological indicators and swab tests were used to see if additionally optimization is required. The treatment room as well as the operation room were disinfected with DCXplus placed in the centre of the rooms and using 7.5 % hydrogen peroxide containing 50 ppm silver ions. The disinfection was performed with respect to the target humidity using the “boost mode” for 90 min. The samples were taken before (swab) and after completion (swab/biological indicators) of the disinfection process. The biological indicators were distributed across four different locations and evaluated after exposure time in two

laboratories. The operating room (OR) with an approx. volume of 37 m³ and the treatment room (TR) with a volume of approx. 46.8 m³ were both equipped with two biological indicators and the operating room was swabbed for microorganisms as well. Biological indicators (Apex Discs) showed a decimation of log 5, and in the TR a CFU reduction of log 6 could be reached on both positions. In the OR, however, a log 6 reduction could not be achieved. The bacterial analysis of the swabs displayed successful disinfection at all places.

Table 2 Results of the swab tests in the veterinary practice before and after disinfection with the DCXplus; (-): no microorganisms were found

Location of Swabbing	Time	Detected Microorganism	Pathogenicity
Handles overhead cupboard OR	Before	-	-
	After	-	-
Anaesthetic device	before	<i>Staphylococcus haemolyticus</i>	nosocomial pathogen, carrier of resistance genes (Takeuchi et al. 2005; Froggatt et al. 1989; Barros et al. 2012)
	after	-	-
Handles cupboard OR	before	<i>Acinetobacter lwoffii</i>	opportunistic pathogen, can cause nosocomial infections, carrier of resistance genes (Regalado, Martin, and Antony 2009)
	after	-	-
Keyboard x-ray PC	before	<i>Acinetobacter lwoffii</i>	opportunistic pathogen (see above)
	after	-	-

3.3. PCR Lab

Next a container laboratory with a total area of approximately 111 m² and a volume of approx. 265 m³ as well as its storage container with a size of 6.66 m² and a volume of 15.9 m³ was disinfected. Two DCXplus (located at opposite ends of the room) and one DCXpro (located at the centre) were positioned in the container lab. Only one DCXplus device was placed in the storage container. The PCR lab was disinfected with the same setting as the veterinary practice and the biological indicators were distributed on five positions within the laboratory. Additionally, two positions were chosen within the storage container. The disinfection program could be fully performed while automated (PCR) machines were running.

The results show a high efficiency of the DCX technology, indicating a promising application for PCR laboratory containers. A bacterial decimation of log 6 could be achieved, except for one indicator in the storage container, with which a log 5 reduction was attained.

3.4. Ambulance cleaning protocol comparison

Finally, two different approaches in cleaning protocols were compared in two almost identical ambulances. One was cleaned by hand by well trained staff via the established cleaning protocol while the other was submitted to the fumigation protocol of the DCXplus with 7.5 % hydrogen peroxide with 50 ppm silver ions in “boost mode”. A RAH of 88 % was achieved after 60 min of vaporization, although the first charge of biological indicators were taken out after 30 min and the main door was opened for approx. one min. The usual cleaning protocol took the two trained persons approx. 45 min each, meaning 90 min personnel hours in total. The used biological indicators were placed at five different locations in duplicates and removed after 30 and 60 min. In order to receive more data on existing contamination within the ambulances and the actual disinfection, the five locations where the biological indicators were placed and five additional

locations in both ambulances were swabbed before and after the disinfection process. All selected places for the swab tests are areas of contact for paramedics and patients which could be hazardous for both parties. The analysis of the indicators and swabs was again performed in the same laboratories as indicated in 3.2. Veterinary practice.

Table 3 Summary of findings of the swab analysis before and after disinfection by hand, * biological indicator at the same location, (+): remaining contamination after disinfection treatment; (-): non-pathogenic microorganisms, remaining after disinfection

Location of Sampling	Time	Detected Microorganism	Pathogenicity
Emergency bags*	before	<i>Micrococcus luteus</i>	Non-pathogenic, part of skin flora (Boldock et al. 2018)
	before	<i>Bacillus pumilus</i>	Food spoilage organism, rare cases of food poisoning (Drobniewski 1993)
	(+)after	<i>Staphylococcus hominis</i>	Opportunistic pathogen, nosocomial infections, part of skin flora (Kloos and Schleifer 1975), antibiotic resistance (Mendoza-Olazarán et al. 2015)
Handle recliner	before	<i>Staphylococcus epidermidis</i>	Opportunistic pathogen, nosocomial infections, part of skin and mucus membrane flora (A report from the NNIS System 2004)
	after	-	
Harness stretcher	before	<i>Staphylococcus epidermidis</i>	Opportunistic pathogen, see above
	after	-	
Headrest stretcher*	before	<i>Bacillus cereus</i>	Foodborne pathogen (Bottone 2010)
	(+)after	<i>Bacillus mycoides</i>	Foodborne pathogen, belongs to <i>B. cereus</i> group (Drobniewski 1993)
Rear patient chair seat*	before	<i>Micrococcus luteus</i>	Non-pathogenic (see above)
	after	-	
Seat belt (rear patient seat)	before	<i>Staphylococcus epidermidis</i>	Opportunistic pathogen, see above
	(+)after	<i>Staphylococcus hominis</i>	Opportunistic pathogen, see above
Tray/ledge entrance*	before	<i>Staphylococcus warneri</i>	Opportunistic pathogen, nosocomial infections, part of normal skin and mucus membrane flora (Becker, Heilmann, and Peters 2014)
	(-)after	<i>Bacillus subtilis</i>	Non-pathogenic (Earl Ashlee M. 2008)

Microorganisms could still be found in the swabs of the assessed areas after the conventional disinfection protocol. These were often even different species than before the disinfection which could be due to the large sampled areas, or perhaps due to the fact that through hand disinfection a smearing of microorganisms can occur. In one occasion the same can be seen after the DCXpro disinfection as described in Table 5. Since *Micrococcus luteus* is commonly found on human skin (Boldock et al. 2018), it is suspected that it was brought in when the biological indicators were taken out of the vehicle which was done before the swab testing. In this experiment the disinfection program achieved an up to log 5 disinfection at all locations after 30 min.

Table 4 Summary of findings of the swab analysis before and after disinfection with automated DCXpro program, * biological indicator at the same location, (-): non-pathogenic microorganisms, remaining after disinfection

Location of sampling	Time	Detected microorganism	Pathogenicity
emergency bags*	before	<i>Bacillus cereus</i>	Foodborne pathogen, see above
		<i>Bacillus megaterium</i>	Non-pathogenic, rare infection cases (Bocchi et al. 2020)
	after	-	
Handle recliner	before	<i>Bacillus cereus</i>	Foodborne pathogen, see above
	after	-	
harness stretcher	before	<i>Micrococcus luteus</i>	Non-pathogenic, see above
	after	-	
rear patient chair seat*	before	<i>Bacillus mycoides</i>	Foodborne pathogen, see above
		<i>Bacillus megaterium</i>	Non-pathogenic, see above
		<i>Staphylococcus haemolyticus</i>	Opportunistic pathogen, part of skin flora, nosocomial pathogen, carrier of resistance genes (Takeuchi et al. 2005) (Barros et al. 2012)
	after	-	
Tray/ledge entrance*	before	<i>Bacillus niacini</i>	Soil bacterium (Nagel and Andreesen 1991)
	before	<i>Corynebacterium glucuronolyticum</i>	Opportunistic pathogen, causes urogenital tract infections (Gherardi et al. 2015)
	(-)after	<i>Micrococcus luteus</i>	Non-pathogenic, see above

4. Materials and Supplementary



Figure 2 QR-Code linking to a PDF with supplementary information of all experiments for interested parties

5. Discussion

Our experiments show that disinfection protocols based on the DCXpro technology can keep valuable parts of infrastructure safe for both staff and patients. While more testing and fine tuning is needed we are confident that digitalisation and automation of disinfection protocols in critical infrastructure is a crucial part of effective crisis management.

As part of our investigation we could show that the intended reduction of log 6 was well achieved in most of the experiments performed under real environment conditions, though not in all. Although biological indicators are very good, validated measures of log reduction, we wanted to show the effect on true contamination in the tested areas and how the disinfection handles real life conditions. The effect of H₂O₂ on various species of bacteria is also necessary to be evaluated.

Hence, we defined several locations at the different evaluated settings and swabbed areas of interest before and after the treatment in addition to assessing the biological indicators. This helped to determine the bacteria occurring in these environments and also to define potential sources of human and animal infections. We are aware that these results are not as standardized as the biological indicators and their interpretation has to be done with caution. Nevertheless, these data are of great interest and represent important hints for further studies. Although in some cases the biological indicators showed a reduction lower than expected after the treatment in some spots (equipped room, dentist practice, and veterinary practice OR) the trend to a sufficient reduction (of at least log 5) is obvious. This becomes even more evident, when looking at the swab tests in the veterinary practice and the ambulance before and after treatment with H₂O₂. The comparison of the hand cleaning in the ambulances with the DCX technology showed that the disinfection is more time efficient and more thorough. Furthermore, from the five bacteria detected before disinfection only one was found after the disinfection program and the microbe in question is non-pathogenic. The disinfection by hand was also successful but only in 3 of the 7 found bacteria. While in the ambulance cleaned by hand, the swab test showed a greater distribution of bacteria species, the vehicle treated by the DCXplus featured more species of bacteria.

The disinfection procedure with DCX technology is not only faster and more efficient than conventional cleaning procedures, as proven by the real life examples of the veterinary clinic and the ambulance cleaning protocol comparison, but also less manual labour intensive. Furthermore the DCXpro is a validated and reproducible technology that can be easily monitored and controlled online. In the PCR lab it was shown that with little disruption during shift work schedule and high capacity workload, digital process management and control as well as online data viewing are tremendously advantageous in this regard.

6. References

- A report from the NNIS System. 2004. "National Nosocomial Infections Surveillance (NNIS) System Report, data summary from January 1992 through June 2004, issued October 2004." In American Journal of Infection Control, 470-85.
- Barros, E. M., H. Ceotto, M. C. Bastos, K. R. Dos Santos, and M. Giambiagi-Demarval. 2012. 'Staphylococcus haemolyticus as an important hospital pathogen and carrier of methicillin resistance genes', J Clin Microbiol, 50: 166-8.
- Becker, K., C. Heilmann, and G. Peters. 2014. 'Coagulase-negative staphylococci', Clin Microbiol Rev, 27: 870-926.
- Bocchi, M. B., L. Cianni, A. Perna, R. Vitiello, T. Greco, G. Maccauro, and C. Perisano. 2020. 'A rare case of Bacillus megaterium soft tissues infection', Acta Biomed, 91: e2020013.
- Boldock, E., B. G. J. Surewaard, D. Shamarina, M. Na, Y. Fei, A. Ali, A. Williams, E. J. G. Pollitt, P. Szkuta, P. Morris, T. K. Prajsnar, K. D. McCoy, T. Jin, D. H. Dockrell, J. A. G. van Strijp, P. Kubes, S. A. Renshaw, and S. J. Foster. 2018. 'Human skin commensals augment Staphylococcus aureus pathogenesis', Nat Microbiol, 3: 881-90.
- Bottone, E. J. 2010. 'Bacillus cereus, a volatile human pathogen', Clin Microbiol Rev, 23: 382-98.
- Braincon GmbH. "DCXpro - Der schlanke und mobile Profi für Ihre aerogene Raumdesinfektion." In.
- Drobniowski, F. A. 1993. 'Bacillus cereus and related species', Clin Microbiol Rev, 6: 324-38.
- Earl Ashlee M., Losick Richard Losick, Kolter Roberto 2008. 'Ecology and genomics of Bacillus subtilis', Trends Microbiol, 16: 269-75.
- Froggatt, J. W., J. L. Johnston, D. W. Galetto, and G. L. Archer. 1989. 'Antimicrobial resistance in nosocomial isolates of Staphylococcus haemolyticus', Antimicrob Agents Chemother, 33: 460-6.
- Gherardi, G., G. Di Bonaventura, A. Pompilio, and V. Savini. 2015. 'Corynebacterium glucuronolyticum causing genitourinary tract infection: Case report and review of the literature', IDCases, 2: 56-8.

- Kloos, Wesley E., and Karl H. Schleifer. 1975. 'Isolation and Characterization of Staphylococci from Human Skin II. Descriptions of Four New Species: *Staphylococcus warneri*, *Staphylococcus capitis*, *Staphylococcus hominis*, and *Staphylococcus simulans*1', *International Journal of Systematic and Evolutionary Microbiology*, 25: 62-79.
- Mendoza-Olazarán, S., R. Morfin-Otero, L. Villarreal-Trevino, E. Rodríguez-Noriega, J. Llaca-Díaz, A. Camacho-Ortiz, G. M. González, N. Casillas-Vega, and E. Garza-González. 2015. 'Antibiotic Susceptibility of Biofilm Cells and Molecular Characterisation of *Staphylococcus hominis* Isolates from Blood', *PLoS One*, 10: e0144684.
- Nagel, M., and J. R. Andreesen. 1991. '*Bacillus niacini* sp. nov. a Nicotinate-Metabolizing Mesophile Isolated from Soil', *International Journal of Systematic Bacteriology*, 41: 134-39.
- Regalado, N. G., G. Martín, and S. J. Antony. 2009. '*Acinetobacter lwoffii*: bacteremia associated with acute gastroenteritis', *Travel Med Infect Dis*, 7: 316-7.
- Takeuchi, F., S. Watanabe, T. Baba, H. Yuzawa, T. Ito, Y. Morimoto, M. Kuroda, L. Cui, M. Takahashi, A. Ankai, S. Baba, S. Fukui, J. C. Lee, and K. Hiramatsu. 2005. 'Whole-genome sequencing of *staphylococcus haemolyticus* uncovers the extreme plasticity of its genome and the evolution of human-colonizing staphylococcal species', *J Bacteriol*, 187: 7292-308.

SOCIAL MEDIA AUTHENTICITY AND TRANSPARENCY

CZECH MEDIA ACTIVITY ON FACEBOOK

Antonín Pavlíček

Department of System Analysis
Faculty of Informatics and Statistics
Prague University of Economics and Business
antonin.pavlicek@vse.cz

DOI: 10-35011/IDIMT-2022-173

Keywords

Facebook, Czech Media, Segmentation, Analysis

Abstract

Due to the increasing importance of social networking sites as sources of information, news media have created new channels on social networks, where they are reaching out to their readers by publishing news stories and links to articles. Readers can now react by commenting, sharing, or liking these posts. This research analyzed 8 most popular Czech online media, Aktuálně.cz, Blesk.cz, iDnes.cz, ČT24, Novinky.cz, PrimaFTV, Seznam Zprávy and TN.cz and their engagement on Facebook. By web scraping Facebook pages of selected media, we gained 16 725 comments under 479 posts and created a segmentation of readers based on their sex, location, and age. This research also provides interesting insights into Czech media on Facebook, supplemented by visualizations. Lastly, we created 12 hypotheses based on common generational and gender stereotypes and prejudices, out of which 9 were supported by our results.

1. Introduction

Most traditional media created their accounts on social media (Facebook, Twitter, or Instagram) to share their posts and articles with social media users to stay connected with their audiences. Facebook is still the most popular social network in Europe, but its purpose has changed over the years. Since TV, radio and print are losing popularity, especially among the young generation, Facebook is often becoming the primary source of information and news. The main goal of this research was to monitor audience behavior of 8 major Czech media outlets, based on the Facebook comments under article posts. We came up with 12 hypotheses based on common generational and gender stereotypes and prejudices from everyday life and the current pandemic and tried to confirm or reject them based on collected data.

Literature research have revealed eight studies related to our work. Thesis “Konstrukce účastníků politické komunikace v českých internetových periodických” analyzed two Czech events from 2008: Prague culture grant case and the signing of the framework agreement on the American radar on the territory of the Czech Republic case (Nejedlá, 2010). Another thesis called “Analýza nejlépe hodnocených příspěvků v diskuzích na českých internetových zpravodajských serverech” analyzed three Czech news online servers – idnes.cz, novinky.cz and aktualne.cz. The top-rated comment was chosen and analysed for: vulgarism, irony, humour or whether the author disagrees with the article (Šponer, 2017). Diploma thesis “Online žurnalistika a zpravodajské server” v ČR deals with

current trends of online journalism and their potential on news servers in the Czech Republic (Ireinová, 2009). Content analysis study “Social Media References in Newspapers: Facebook, Twitter and YouTube as sources in newspaper journalism” aims to examine the different appearances and functions of social media references in the news. (Paulusse & Harder, 2014) The study “Will Social Media Save Newspapers?” indicate a positive relationship among newspapers Facebook, Twitter, Web, and print readerships, social media subscribers continue to represent a small fraction of print and Web users (Ju et al., 2014). We also came across “MEDIA PROJEKT: 1. čtvrtletí 2020 a 2. Unie vydavatelů”, which focuses on Czech printed newspapers and their popularity (Unie vydavatelů, 2020). Another relevant analysis which we took into account was “Digital News Report 2018” by Reuters Institute and Oxford University. It concludes that the problems with fake news and the connection between media and politicians are still highly relevant (Reuters Institute for the Study of Journalism, 2018). Lastly, our work was inspired by Pew Research Center and their report “Americans Are Wary of the Role Social Media Sites Play in Delivering the News from 2019” (Shearer & Grieco, 2019).

1.1. Theoretical Concepts

- **Facebook as Source of News**

The initial mission of Facebook between 2004 and 2010 was different from the present (Observer.com, 2009). Today, Facebook’s mission is “to give people the power to build community and bring the world closer together.” (Facebook.com, 2020). Unlike traditional media, Facebook allows its users to discover, share and consume news publicly and/or comment on them.

- **Facebook as a source of news in the world**

Reuters Digital News Report 2018 conducted research and discovered that social media is mostly used as a gateway to news by the younger population (18-24), and the older population mostly sticks with traditional direct access. The following example discovered that the proportion that used social media as a source of news in the last week was 2018 highest in Brazil among the selected markets. Also, only 23% of respondents trust news in social media; more people still trust news in search Fields (Reuters Institute for the Study of Journalism, 2018). Pew Research Center, for example, conducted research in 2019; almost 90% of US adults think that social media companies have at least some control over the mix of news people see. More than 55% of respondents also declare that the role social media sites play in delivering the news on their sites results in a worse mix (Shearer & Grieco, 2019). Interestingly, 82% of respondents think that social media companies treat some news organizations differently than others (Shearer & Grieco, 2019). In 2018, Facebook's CEO said it would prioritize trustworthy news in its news feed, using community member surveys (Ingram, 2018).

- **Facebook as a source of news in Czech Republic**

Changes in the news consumption are also visible in the Czech environment. Researchers describe the situation in Czech Republic as: „Online media have continued to dominate as sources of news, while social media have gained further ground widening the distance from print.“ Also discovered that trust in news in the Czech Republic is worse than average across all markets. Only 17 % of respondents believe in News on social media, and only around 30 % believe in News overall or News in search (Reuters Institute for the Study of Journalism, 2018).

The enormous reach has a website Parlamentnilisty.cz, with their anti-EU and pro-Russian agenda. Other sites have limited reach, but all have their own Facebook pages.

2. Methodology

2.1. Selecting Media for the analysis

This paper used the Reuters Digital News Report to identify the most familiar Czech online media. Leading 16 Czech online media are: *Seznam.cz*, *iDnes.cz*, *Aktualne.cz*, *Novinky.cz*, *Czech Television news online*, *TN.cz*, *iPrima.cz*, *Bleska.cz*, *Denik.cz*, *Super.cz*, *iHned.cz*, *Lidovky.cz*, *Reflex.cz*, *DVTV.cz*, *Tyden.cz*, and *iRozhlas.cz* (Reuters Institute for the Study of Journalism, 2018). Since this research analyses media engagement on Facebook, we decided to compare the Reuters results with the following of the 8 chosen media on Facebook. There are eight selected media based on its background, reader, and Facebook profiles: *Seznam zprávy*, *iDNES.cz*, *Aktuálně.cz*, *Novinky.cz*, *Blesk*, *ČT24*, *Prima FTV*, *TN.cz*. The most followed medium online based on the Reuters report is Seznam.cz zprávy, whereas Seznam Zprávy Facebook page has the lowest number of likes and follows. On the other hand, ČT24 is the most followed and liked Facebook page out of all 8 media but it takes fifth place in the following of web portal. It is obvious that media's web following is different from their following on Facebook, one of the reasons for this difference is that social networks are used more by younger people who are interested in various media outlets.

2.2. Web Scrapping

We used the web scrapping method to extract data from Facebook. Though there is an obstacle related to slow-loading, the method still successfully scrapes the data. In terms of data, we collected around 170,000 records from Facebook users commenting on selected Czech media groups, consisting of first name, last name, sex, and age divided into categories, region, and Facebook fan batch. We downloaded around 2,000 records for each media for each of six media pages which makes 16,693 records. Also, age was divided into categories and analyzed based on profile photos.

2.3. Data Cleaning and Editing

Anonymization of the last names of each individual commenter was a huge undertaking. We used the in-built library hashlib to transform last names into individual MD5 hexadecimal hashes. This ensures that in case there are two comments from the same person, their last name is not human-readable.

2.4. Vulgarisms

We have written a function that uses regular expressions to look for vulgarisms in comments. The function would return number 1 if it found a match in the comment and 0 if there will be no match. We have included star signs “*” in the search, as some people try to censor insults with star signs.

2.5. Unification of the database

Since we were able to scrape a different number of comments under a different number of posts, it was important to unify the base of the data to proceed with the analysis. We took 2 approaches to do that. Firstly, we created a database with a minimal number of comments by each medium. The minimum number of comments was 1,861 for TN.cz. 8 media by 1,861 comments allowed us to work with 14,888 comments in total. The number of posts for a unified number of comments changed slightly. We also created a second database with the same number of posts for each medium; in our case, it was the minimal value of 27 posts by ČT24. Because some media, for example, iDnes or PrimaFTV have lower average of comments under 1 post, the quantity of comments dropped significantly, and we worked only with 7,589 comments.

All the visualizations of this research were created using the Microsoft Power BI database and a tool Lynt.cz for word frequency analysis.

3. Results

We have come up with interesting finding across all the media we analyzed, most surprising findings are:

- ČT24 has, in average, the most comments under 1 post, iDnes.cz or PrimaFTV have in average the least comments under 1 post.
- Seznam Zprávy and Aktuálně.cz have slightly more regular commentators, TN.cz and Blesk have fewer regular commentators.
- Women comment more on TN.cz and Blesk, men comment more on iDnes.cz and Aktuálně.cz.
- Blesk and iDnes have more middle aged readers, Aktuálně.cz, Seznam Zprávy, and TN are more popular among younger readers.
- Blesk has the most readers from Jihočeský region, Prague comments largely on Seznam Zprávy.
- Highest number of fans commented on ČT24, Aktuálně.cz and TN.cz had no comments from top fans.
- People read and are active on multiple media platforms at the same time; they don't stick to only one medium.
- PrimaFTV has the most vulgar comments (8,4%).
- Number of likes does not seem to influence the amount of comments.

Following are the results by individual media:

- In *Seznam Zprávy* we can see that most commentators are men (68,57 %) in the youngest group (age 18-30) that are from our capital city Prague. Seznam Zprávy is a very young medium created in May 2016, so we can expect bigger expansion and more readers and followers on social media.
- *iDnes.cz* also has more men commentators (70,9 %), but the biggest age category is middle age 30-50 years from Prague. What is interesting is that they have very little commentators in the oldest age group even though it is a medium owned by former Czech prime minister who gets mostly the votes of older people.
- *Aktuálně.cz* was created at the same time as iDnes.cz but has fewer posts and less commentators. The segmentation here is mostly men (70,56 %). Interesting is that most commentators are young people from 18 to 30 (521 commentators), and they are mostly from the Zlínský region, not Prague as we would expect from the size of these regions.
- *Novinky* has quite a similar segmentation to iDnes.cz. Most commentators are men, with 66,77 % in the middle age group from 30 to 50 years from again capital city Prague. Facebook page Novinky.cz was also created in 2009, only a few months after iDnes.cz, and even though they have less posts, they have more unique commentators than iDnes.cz.
- ČT24 Facebook page was also created in 2009 as Novinky.cz, Aktuálně.cz and iDnes.cz. They have only 20 posts but an impressive number of 1342 commentators for such a small

number of posts. Most of these commentators are again men (66,54 %). When it comes to location, the situation is the same as with most of the media, the highest number of commentators is from Prague.

- *TN.cz* Facebook page has more women commentators (57,62 %), which is not such domination as when it comes to other media with men, but it's still a significant amount. We could assume that it can be due to the content *TN.cz* has, but this page has similar posts to other media. *TN.cz* also has a lot of commentators, mostly young people from Prague.
- *Zpravodajství FTV Prima* or *Prima News* has an expected segmentation. The majority of commentators are men (53,16 %) from Prague. Age groups are almost balanced, slightly bigger is the middle age group. FTV Prima has a lot of posts, but the number of commentators is not that significant compared to other media.
- *Blesk.cz* is a medium commented mostly by women (66,71 %). We compare this to the fact that women like to gossip more than men and *Blesk.cz* is a tabloid that posts except for the local and foreign news about politics and economics and so also gossip about celebrities.

3.1. Hypotheses

All the hypotheses we created and tried to test are based on common generational and gender stereotypes and prejudices from everyday life and the current pandemic situation.

H1: Women are more interested in tabloids (they comment on Blesk more than men)

The hypothesis assumes women chatter more than males. We chose Blesk since it's the most popular tabloid medium we have. Several comments on the initial visualization support the hypothesis. Men make longer remarks, which can be linked to conventional masculinity and the drive to prove a point.

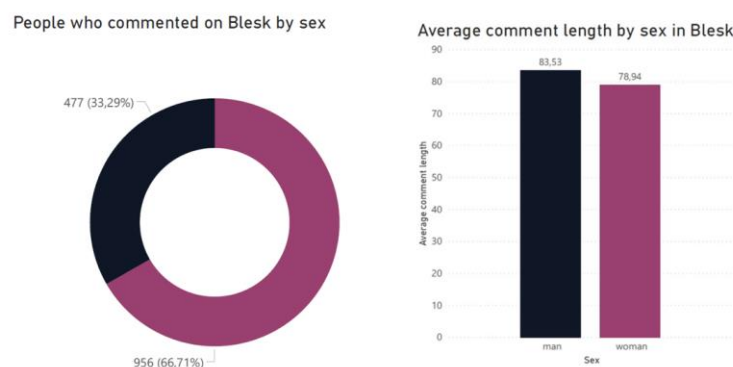


Figure 1: People who commented on Blesk by sex & Average comment length by sex in Blesk (Source: author)

H2: Do women talk more? Will their average length of comment be bigger than men's?

Our research shows that when it comes to media comments, women say more than men. Men's remarks are longer than women's. We assume testosterone affects men's temperament. We have witnessed a lot of insults and defenses of thoughts and ideas in non-aggregated data.

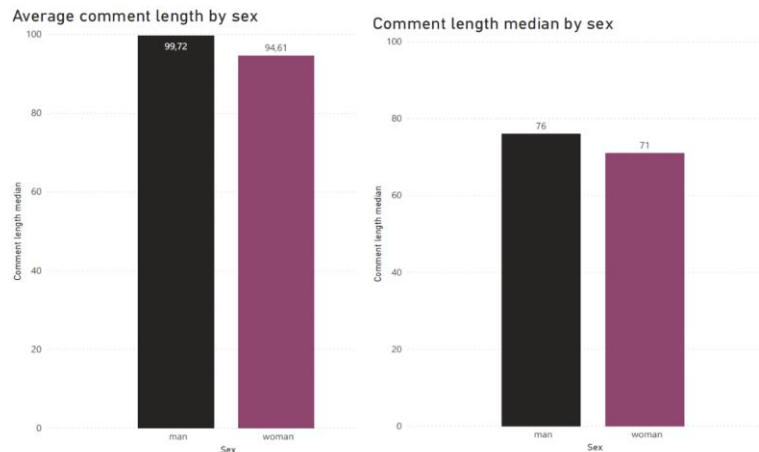


Figure 2: Average & median comment length by sex (Source: author)

H3: Women comment more, because they are more talkative

Some studies show women talk more than men; however, in Czech media, men have more comments (8.9K) than women. When comparing males vs. women in each media, we notice that women comment mostly on Blesk, likely because women appreciate gossip more than men. Men remark on Aktuálně.cz, iDnes.cz, and Seznam Zprávy, which cover foreign and domestic politics, current cases, etc.

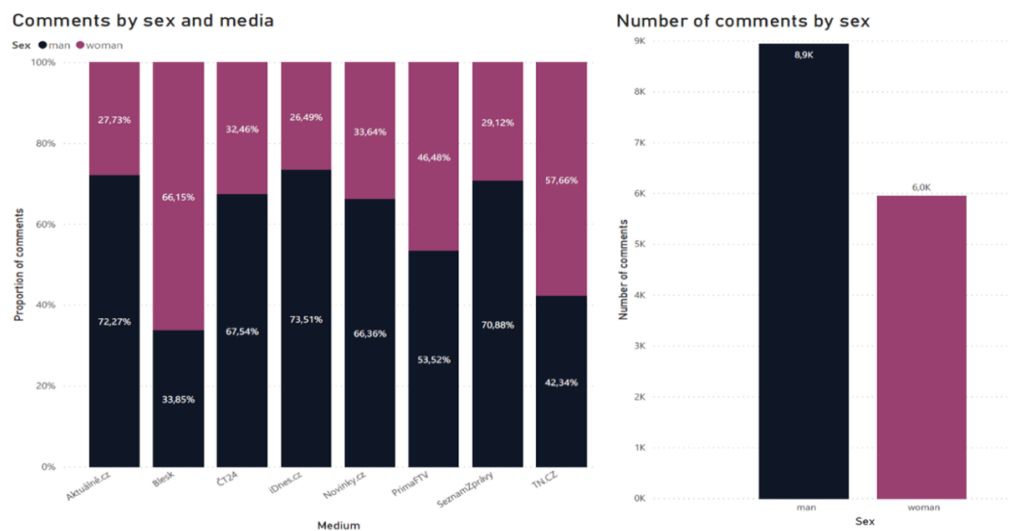


Figure 3: Comments by sex and media & Number of comments by sex (Source: author)

H4: Traditional media (Blesk, ČT24, PrimaFTV, TN) are more popular than online media (Seznam Zprávy, Aktuálně, iDnes, Novinky)

We call Blesk, ČT24, PrimaFTV, and TN.cz traditional due to their long existence across platforms (we are not focusing here only on FB or Internet, but we also took television and paper news into consideration).

This hypothesis was confirmed, “also traditional media” are more popular than “online only media”.

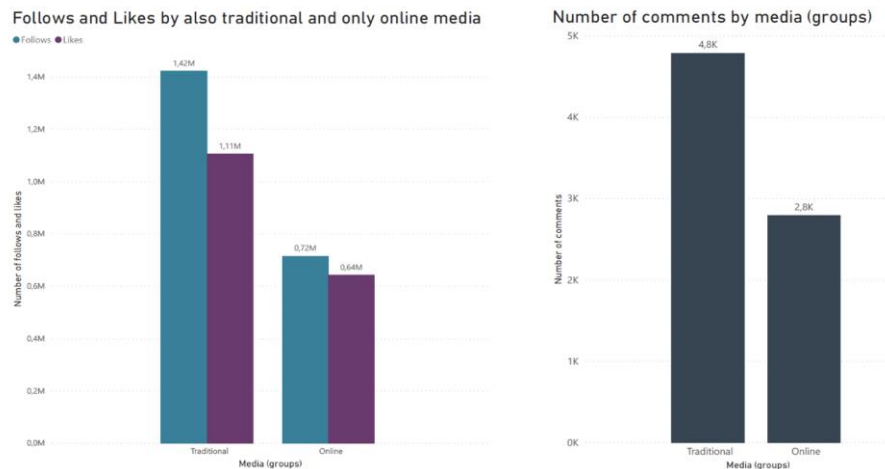


Figure 4: Follows and Likes by traditional and online only media & Number of comments by media (groups)
(Source: author)

H5: Young people from Prague mostly read Seznam Zprávy

Pražská kavárna (the Prague café) was named after a hypothesis about young people from Prague and metropolitan intellectuals. Seznam Zprávy has the largest representation among young people.

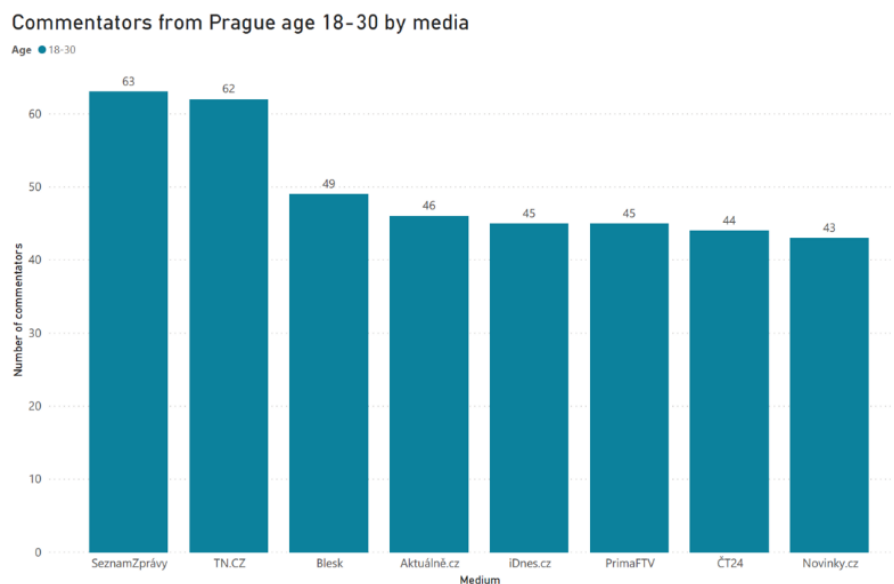


Figure 5: Commentators from Prague age 18-30 by media (Source: author)

H6: Young people read "online only media" more than older people, they read "traditional media" more

The number of unique commentators is highest in the age group of 30-50 years in traditional media. The age group 18-30 years has the most unique commentators in online media. The oldest age group always has the lowest number, which can be connected to older people not using the internet so much.

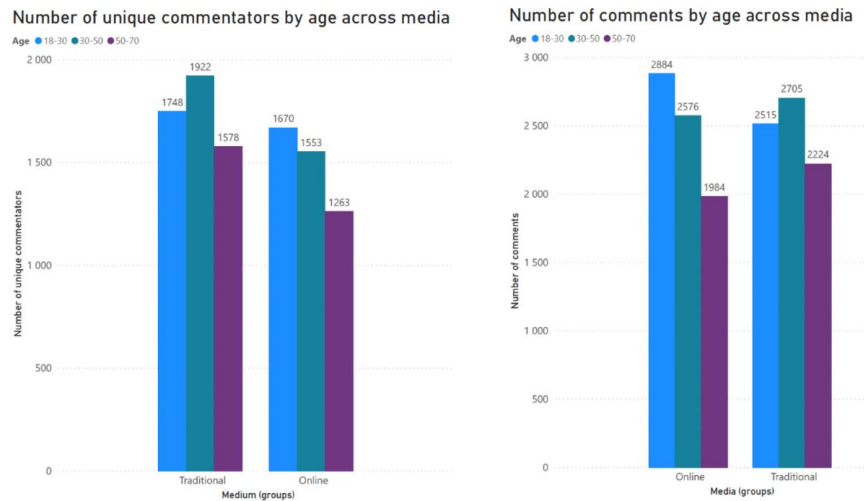


Figure 6: Number of unique commentators by age across media & Number of comments by age across media
(Source: author)

H7: Older people comment less

In this eighth hypothesis, we wanted to find out which age group comments the most on the articles. We assumed that people are not so used to commenting on everything or cannot do it in some cases. Our hypothesis that older people will comment the least has been confirmed.

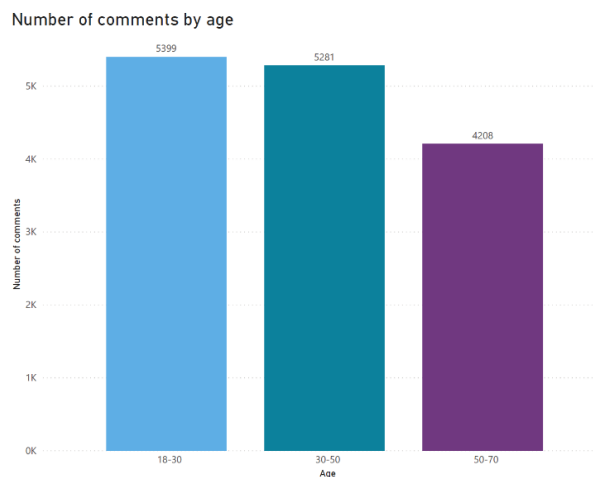


Figure 7: Number of comments by age (Source: author)

H8: Men use more vulgarisms than women

The hypothesis is based on the stereotype that men are more vulgar than women. Based on our results of using vulgar words in actual comments, this hypothesis is proven. Men have 5.86 % of vulgar comments and women only 3.75 %. But as we can see, both genders know how to be vulgar sometimes.

H9: Young people are more vulgar

This hypothesis is based on the idea that younger people are more prone to vulgar comments and that the older a person is, the calmer and more polite he or she becomes. The data of vulgar comments have proved that this is not the case at all.

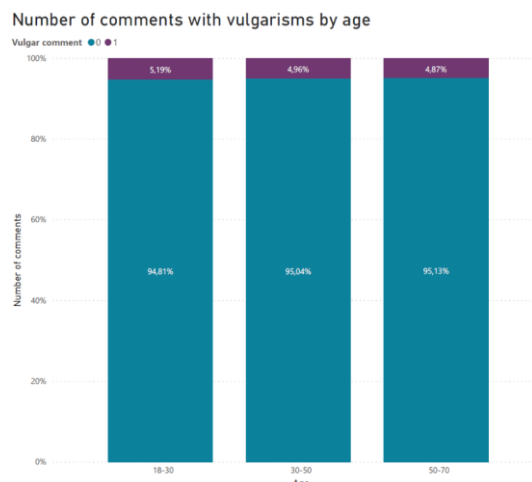


Figure 8: Number of comments with vulgarity by age (Source: author)

H10: People comment mostly about COVID and politics

The hypothesis was supported because most of the keywords are somehow connected to COVID and government, which means it is still very important for people to comment about it.

Table 1: Frequent keywords in comments

keyword	count	%	keyword	count	%	keyword	count	%
1 lidi	709	0.22%	12 obchody	109	0.03%	23 práce	128	0.04%
2 lidí	452	0.14%	13 soustrast	181	0.06%	24 práci	125	0.04%
3 covid	366	0.11%	14 den	177	0.06%	25 vlády	123	0.04%
4 děti	290	0.09%	15 rok	169	0.05%	26 roušky	122	0.04%
5 lidé	284	0.09%	16 lidem	163	0.05%	27 pravda	122	0.04%
6 vláda	284	0.09%	17 rodině	154	0.05%	28 školy	121	0.04%
7 let	274	0.09%	18 vánoce	151	0.05%	29 život	117	0.04%
8 člověk	248	0.08%	19 eu	136	0.04%	30 pes	111	0.03%
9 doma	242	0.08%	20 pení	135	0.04%	31 stav	110	0.03%
# stát	231	0.07%	21 zdraví	133	0.04%	32 opatření	109	0.03%
# peníze	220	0.07%	22 pravdu	129	0.04%	33 babiš	108	0.03%

The last hypothesis is connected to the previous one. But this time, we analyzed the keywords in the titles of the posts. The keywords connected to covid are for example covid, covidem, obchody, koronavirus, vycházení (going out/curfew) and zákaz (ban), pes (covid prevention system).

In 1st place, there is "je to" (it is), which is a very common phrase, so again we cannot really say the actual meaning of it. The 2nd place is "od pondělí" (from Monday), which refers to pandemic government actions from 20th November.

This hypothesis was also supported. It suggests that the media tend to write posts about anything connected with the current situation based on popular demand. (Table 3)

Table 2: Frequent keywords in media's post titles

keyword	count	%	keyword	count	%	keyword	count	%
1 blatný	18	0.35%	10 lidé	9	0.17%	19 vycházení	6	0.12%
2 lidí	15	0.29%	11 Česku	9	0.17%	20 Češi	6	0.12%
3 Česko	13	0.25%	12 vláda	8	0.15%	21 stovky	6	0.12%
4 covid	13	0.25%	13 tisíc	8	0.15%	22 video	6	0.12%
5 policie	11	0.21%	14 covidem	8	0.15%	23 zákaz	6	0.12%
6 pes	11	0.21%	15 obchody	8	0.15%	24 život	6	0.12%
7 milionů	10	0.19%	16 koronavirus	7	0.14%	25 ods	6	0.12%
8 pondělí	10	0.19%	17 děti	7	0.14%	26 lety	6	0.12%
9 vánoce	10	0.19%	18 let	7	0.14%			

Table 3: Frequent phrases in media's post titles

keyword	count	%	keyword	count	%	keyword	count	%
1 je to	8	0.15%	10 je v	4	0.08%	19 se s	3	0.06%
2 od pondělí	7	0.14%	11 se bojí	4	0.08%	20 bez diváků	3	0.06%
3 zákaz vycházení	6	0.12%	12 milionů korun	4	0.08%	21 míří do	3	0.06%
4 sledujete ŽIVĚ	6	0.12%	13 za týden	4	0.08%	22 na poplatníka	3	0.06%
5 na covid	6	0.12%	14 nouzový stav	3	0.06%	23 kvůli covidu	3	0.06%
6 jak se	6	0.12%	15 úmrtí s	3	0.06%	24 slevy na	3	0.06%
7 290 milionů	5	0.10%	16 až do	3	0.06%	25 do obchodů	3	0.06%
8 na vánoce	4	0.08%	17 do škol	3	0.06%	26 23 hodin	3	0.06%
9 daňový balíček	4	0.08%	18 zvýšení slevy	3	0.06%			

4. Limitations and further research

It would be possible to expand our work and add more informational value to our results. Technically, it would be appropriate to deal with the hashing of names differently. Currently, our solution is hashing only the last name of the person, so every person with the same last name also has the same hash. Because we did not create a unique identifier while acquiring the data, we created a unique identifier for each reader during the data processing, using a combination of their first name, last name, gender, age, and region. Creating a unique identifier using the link to their Facebook profile could be more relevant.

It could also be beneficial for the analysis to acquire more data, such as data on education or employment of the commentators. But because Facebook has tighten privacy rules and the Facebook profiles of commentators are mostly private, it is not easy to achieve. It could be maybe possible for the media themselves because of their insight into the Facebook page statistics. We think that analysis of the content of comments is a very interesting field, and we can get a lot of interesting information and get into the minds of people. The media could use the analysis to find out what their readers are most interested in or what their opinions are on different topics.

5. Conclusion

We were able to acquire over 16,700 comments under almost 500 posts from 8 selected Czech media Facebook pages. Using this data, we analyzed their reader base and its behavior in the comment section. We found out what media are mostly read by different age groups or people from different regions. Finally, we managed to confirm 8 out of 11 hypotheses, which were based on common stereotypes. We can say that some of the gender or age stereotypes are actually correct. Our results denied the hypothesis that women write longer comments because they are more talkative, Women comment more, or that young people read "online only media" more than older people preferring "traditional media".

6. Acknowledgement

This paper was processed with a contribution from the Prague University of Economics and Business, IG Agency, grant number VŠE IGS F4/13/2021, data were gathered and analyzed with the help of students in the course 4SA526 New Media.

7. References

- Aktuálně.cz. (2020). Mediakit. https://www.economia.cz/wp-content/uploads/2020/02/Aktualne_mediakit_CZ_2020.pdf.
- Aust, O. (2016). Seznam.cz rozjel vlastní Seznam Zprávy ve videu. <https://www.mediar.cz/seznam-cz-rozjel-vlastni-seznam-zpravy-ve-videu/>
- Ingram, D. (2018). Facebook to prioritize “trustworthy” news based on surveys. <https://uk.reuters.com/article/us-facebook-media/facebook-to-prioritize-trustworthy-news-based-on-surveys-idUKKBN1F82M2>
- Ireinová, H. (2009). Online žurnalistika a zpravodajské servery v ČR. Masarykova univerzita, Filozofická fakulta.
- Ju, A., Jeong, S. H., & Chyi, H. I. (2014). Will Social Media Save Newspapers? 1–17.
- Kurzy.cz - archived. (2014). <https://web.archive.org/web/20150213230027/http://www.kurzy.cz/netmonitor/201412>
- Lidovky.cz. (2016). Zpravodajský kanál ČT24 bude mít konkurenta. https://ceskapozice.lidovky.cz/tema/zpravodajsky-kanal-ct24-bude-mit-konkurenta.A170523_111940_pozice-tema_houd
- Nejedlá, T. (2010). Konstrukce účastníků politické komunikace v českých internetových periodících. Univerzita Karlova, Fakulta sociálních věd, Katedra mediálních studií.
- NetMonitor. (2020). OLA, Online data. <https://www.netmonitor.cz/online-data-ola>
- Novinky.cz. (2007). <https://www.novinky.cz/internet-a-pc/clanek/novinky-prekonaly-hranici-milionu-ctenaru-za-den-40146173>
- Observer.com. (2009). The Evolution of Facebook’s Mission Statement. <https://observer.com/2009/07/the-evolution-of-facebooks-mission-statement/>
- Paulussen, S. & Harder, R. A. Harder (2014) Social Media References in Newspapers, Journalism Practice, 8:5, 542-551, DOI: 10.1080/17512786.2014.894327
- Reuters Institute for the Study of Journalism. (2018). Digital News Report 2018.
- ČTK (2018). Seznam.cz spouští vlastní televizi. Vysílat bude od pátku v multiplexu ČRa. https://www.irozhlas.cz/kultura/televize/seznamcz-televize-seznam-cra-vysilani-internet_1801101144_elev
- SeznamZprávy. (2016). Kdo je kdo? <https://www.seznamzpravy.cz/clanek/redakce-seznam-33526>
- Shearer, E., & Grieco, E. (2019). Americans Are Wary of the Role Social Media Sites Play in Delivering the News. <https://www.journalism.org/2019/10/02/americans-are-wary-of-the-role-social-media-sites-play-in-delivering-the-news/>

- Šponer, J. (2017). Analýza nejlépe hodnocených příspěvků v diskuzích na českých internetových zpravodajských serverech. Univerzita Karlova, Fakulta sociálních věd, Katedra mediálních studií.
- Unger, J. (2019). Novým šéfredaktorem Seznam Zprávy se stal Jiří Kubík, přicházejí i Pergler či Kubica. <https://www.seznamzpravy.cz/clanek/novym-sefredaktorem-seznam-zpravy-se-stal-jiri-kubik-prichazeji-dalsi-jmena-83503>
- Unie vydavatelů. (2020). Media Projekt. http://www.unievydavatelů.cz/gallery/files/Zakl3_a4_Q2020.pdf
- Zive.cz. (2009). Novinky.cz mají nový design a zkročené diskuze. <https://www.zive.cz/bleskovky/novinkycz-maji-novy-design-a-zkrocene-diskuze-oziveno/sc-4-a-146076/default.aspx>

FAKE NEWS SUSCEPTIBILITY OF THE YOUNG GENERATION

Tomáš Sigmund, Jiří Korčák

Department of System Analysis
Faculty of Informatics and Statistics
Prague University of Economics and Business
sigmund@vse.cz, jiri.korcak@vse.cz

DOI: 10-35011/IDIMT-2022-185

Keywords

Fake news, human bias, logical fallacy, logical inconsistency, information literacy

Abstract

Fake news is becoming a big problem in current society and especially social networks are an environment where it spreads very quickly. Their users succumb to many biases and imperfections and are susceptible to news created with the intention to manipulate. We tested young generation of internet users with a questionnaire and compared their self-evaluation with a test of fake news susceptibility. The results are promising as the respondents show a high level of information literacy and are quite resistant to fake news. However, there are always possibilities for improvement. We also confirmed the existence of the third person effect.

1. Introduction

Social networks have been around for some time now and since their inception, they are space, where news and information spread. It has already been found in recent years that they can serve as a solution to crisis situations, for example in the events of disasters or other emergencies (Reuter & Kaufhold, 2018). Social networks are also a place where people meet, spend their free time, consume information, and make a living. Such an environment is an obvious place where a huge amount of information is exchanged and shared. As people are those who share this information, they are susceptible to many forms of problems which come from not facing information in rational sense.

1.1. Fake news

Fake news is a topical phrase which draws attention of many scholars and wide public. It is related to concepts like misinformation, disinformation hoax etc. and is used in politics which makes its precise definition very difficult (Sindermann et al., 2020). Using the definition of (Egelhofer & Lecheler, 2019) we may find three criteria of fake news: low facticity, intention to deceive and journalistic format. Fake news is often politicized because they often deal with political topics and are used in many campaigns.

The problem related to fake news is that readers are not able to identify them and recognize their difference from true news. We can support readers to pay attention to suspicious news, using

warnings, drawing attention to source credibility, supporting information literacy etc., but readers are responsible for themselves, too, and their abilities to discern fake news and true news differs.

1.2. Human bias

The cognitive dissonance theory teaches us that people try to avoid cognitive inconsistencies in their thinking (Festinger, 2001). According to this theory people will try to avoid and mark as fake news content that is in opposition to their attitude. In addition to that information compliant with one's attitude flows more fluently and is perceived more positively and accurately. To conclude people tend to overrate the truth of news that are consistent with their attitude and underrate the news that are inconsistent with it.

Analytical thinking is another factor which is often tested with the Cognitive Reflection Test (CRT) where some mathematical tasks must be solved which have a counterintuitive answer. So, CRT measures the use of analytical versus intuitive thinking (Frederick, 2005), (Evans & Frankish, 2009). In many studies, analytical thinking has been positively related with discernment of true and fake news (Bago et al., 2020), (Bronstein et al., 2019), (Pennycook & Rand, 2020). The more people think analytically the less accurate they consider fake news. Our CRT test consisted of three question with counterintuitive answers (1) A pen with a refill costs 110 CZK. The pen is 100 CZK more expensive than the refill. How much is the refill? (2) 5 seamstresses sew 5 shirts in 5 minutes. How long does it take 100 seamstresses to make 100 shirts? (3) Water lilies grow in the pond. Every day the area they cover doubles. They cover the entire pond in 48 days. How long will it take them to cover half the pond?)

1.3. Logical fallacies

Logical fallacies are violation of one of the basic principles of logic, which are based on inference rules that are inherent in general rationality (Bunnin & Yu, 2004). Such disturbances may be, for example affirming the consequent (If A Then B, B, therefore A) or denying the antecedent also called modus tollens (If A then B, Not A, therefore not B). People use these fallacies while argumenting things they trust and believe or want to persuade others to act as desired. There is a question whether this persuasion is done consciously or not. Lieto and Vernero (2013) in their research done on 150 websites show that people don't argument through logical fallacies consciously rather it is lack of attention to the form of argumentation.

In our questionnaire we used the so-called Linda problem which tests the conjunction fallacy known also as the Linda problem. It is based on the presupposition that the probability of two events occurring together is always less than or equal to the probability of either one occurring alone. We tested if our respondents are aware of this rule.

2. Material and Methods

Aim of this paper is to test young generation's susceptibility to fake news, their information literacy and analytical thinking. Our research is related to the cognitive reflection test which assesses individuals' ability to suppress an intuitive wrong answer and prefer the reflective and deliberative right answer. Many fake news misuse the biased way of thinking and respondents are researched with regard to their way of thinking (Bago et al., 2020), (Egelhofer & Lecheler, 2019), (Evans & Frankish, 2009).

We collected 119 answers in our online questionnaire distributed in April 2022 via mail and social networks. We sent an e-mail to first year Prague University of Economics and Business' students of Faculty of Finance and Accounting and to students of course Multimedia Semiotics taught at the

Faculty of Informatics and Statistics of the same university. Also, we posted the questionnaire into few leisure time groups on Facebook.com and Discord. Therefore, the respondents come from different age groups, education, gender etc. The respondents were dominantly young people (17-31 years of age). Their mean age was 21.8 years, $SD = 4.1$. 44% were females, 56% were male. Most of our respondents completed their secondary school education (75.6%), followed by completed bachelor degree (9.2%), basic education (5.9%) and master degree (5.0%). The rest of our respondents had other types of education (secondary school without final exam, higher vocational school).

Questionnaire was created with inspiration from paper by Kirchner and Reuter (2020) as they studied how different kinds of countermeasures against fake news are viewed by users of social networks. We used similar approach as they did when presenting post from social networks with different purpose. The questionnaire consisted of 3 parts, where in the first part the respondents were answering questions about their self-reported perception of information and relationship to accepting validity of information. Also, self-reported inclination to analytical or intuitive decision making was questioned. This first part of the questionnaire consisted of 17 questions. All of which were answered through 5-option Likert scale (1 meaning definitely yes and 5 meaning definitely no), except of one question where each respondent would choose out of possible answers, regarding type of information source.

For the second part we were testing respondents' ability to think analytically and statistically. This part consisted of 7 questions, 4 of them tested their ability to respond in compliance with mathematical and statistical knowledge, which is not inherent to thinking of people and stands against quick irrational intuitive thinking (Kahneman, 2012). For the other 3 questions we created fake Facebook.com posts and some minor adjustments to each of them. These posts were created to look like actual posts that any person with account on page Facebook.com can see on the website. For the creation of these posts we used on-line free generator on website Dizwa.com (*Generate Fake facebook post and chat online / Dizwa, b.r.*). We had to adjust the appearance of picture in the posts because if user on Facebook.com shares a post with URL link the look of the post (and picture) is different from classic post. For the appearance of these pictures, we used Adobe Photoshop. The Dizwa generator also allowed us to put comments to the post, which we differed for each question. We generated author of the post, the text, appearance, and comments in this way.



Figure 1. Generated Facebook post with warning (own research)

The author was named “Your random friend” and the text was created with intention to feel as if the “random friend” wants to warn others from danger that can threat anyone. First post was generated without comments and for the second and third we added comments that showed different kinds of argumentation against validity of the original post. The author of comments we generated was called “Unknown person” as it would suggest it can be anyone from author of the post social bubble, but not from the viewers social bubble. In the first comment the respond was scientifically correct with link to DOI of a scientific article. In second comment we used a fallacy

as it said that mum of the “Unknown person” is a biologist and therefore the original post is incorrect, also it stated that from experience the validity is false. Needless to say that the original post was a fake news about ticks in forests. The respondents had to self-report whether the post was believable and whether the comments influenced believability of the statement in the post. For these 3 questions we recorded answers again through 5-option Likert scale. Third part of questionnaire consisted of 5 demographic questions for descriptive reasons.



Figure 2. Post with scientific comment (own r.)



Figure 3. Post with comment with fallacy (own r.)

3. Results

In the following text, the answers to our questions will be analyzed.

In the first part of our questionnaire, we asked our respondents to self-evaluate their susceptibility to trust in fake news.

Table 1: Information literacy (own research)

Q1	M	SD
Do you have a high level of information literacy?	2.13	0.81

74% of respondents answered positively and 20% selected number three on the Likert scale. It proves our respondents have a high opinion on their information literacy.

Table 2: Information verification (own research)

Q2	M	SD
Do verify information you find in the online environment?	2.15	0.85

The answers to this question had similar statistical distribution, with 92% of respondents answering definitely yes, rather yes or between yes and no on the Likert scale. The correlation between Q1 and Q2 confirms the link between these two questions ($r_s=0.282$; $P=0.002$)

Table 3: Influence of others (own research)

Q3	M	SD
Do you make decisions based on others?	3.22	0.91

Here the distribution is placed between points 2-4 of the Likert scale which shows the young generation does consider others' opinions in their decision making. Unsurprisingly this question was negatively correlated with Q1 and Q2 ($r_s=-0.318$; $P=0.000$); ($r_s=-0.196$; $P=0.033$) and only closely insignificantly correlated with Q1 ($r_s=-0.177$; $P=0.054$).

Table 4: Message popularity (own research)

Q4	M	SD
Is it important in your decision about the credibility of a message on a social network how popular it is (how many likes it has)?	4.24	0.96

Here 80% of respondents answered rather no or definitely no which proves the number of likes is not important in the decision on credibility of a message. This question was negatively correlated with message verification (Q2) ($r_s=-0.233$; $P=0.011$) and positively with Q3 ($r_s=0.269$; $P=0.003$).

Table 5: Consistency with previous opinion (own research)

Q5	M	SD
In making your decision about the credibility of a report, is it important how consistent it is with your previous opinion?	3.08	1.02

In this question the distribution was similar to Q4 even though the two questions were not significantly correlated.

Table 6: News headline (own research)

Q6	M	SD
Do you decide the veracity of a report just by its headline?	4.29	1.07

Here 62% of respondents answered definitely no. The answers were negatively correlated with Q1 and Q2 ($r_s=-0.235$; $P=0.01$); ($r_s=-0.283$; $P=0.002$) and positively with Q4 ($r_s=0.186$; $P=0.043$).

Table 7: Type of thinking (own research)

Q7	M	SD
Do you think more analytically or intuitively?	2.61	0.90

Our respondents use a combination of both as the answers were located between points 2 and 4 of the scale of analytical and intuitive thinking, the extremes were very rare. This question was positively correlated with Q1, Q2 and ($r_s=0.308$; $P=0.001$); ($r_s=0.222$; $P=0.015$) and negatively with Q3 and Q4 ($r_s=-0.244$; $P=0.008$); ($r_s=-0.201$; $P=0.028$).

Table 8: Fake news susceptibility (own research)

Q8	M	SD
Is it easy for you to believe fake news?	3.87	0.85

The respondents are quite sure about their resistance against fake news. 75% of them think it is definitely not easy or rather not easy to believe fake news. This question was in accordance with our expectations negatively correlated with Q1 and Q7 ($r_s=-0.308$; $P=0.001$); ($r_s=-0.201$; $P=0.028$) and positively with Q3 and Q5 ($r_s=0.201$; $P=0.028$); ($r_s=0.227$; $P=0.013$).

In the second part of our questionnaire, we tested the respondents' resistance to fake news. Q9 tested the conjunction fallacy. In this question, only the answer definitely yes was correct.

Table 9: Conjunction fallacy (own research)

Q9	M	SD
Conjunction fallacy (Linda problem)	2.84	1.186

Only 20 respondents (17%) answered correctly. The rest answered more or less incorrectly. Points 2-4 on the Likert scale achieved around 20% each, point 5 6.7% of answers. It proves our respondents are susceptible to this type of fallacy. Unsurprisingly this question was negatively correlated with Q2 ($r_s=-0.194$; $P=0.034$).

Table 10: Facebook post trustworthiness (own research)

Q10	M	SD
Do you consider Figure 1 trustworthy?	3.7	1.01

Here, 63% of respondents does not definitely or rather consider it trustworthy. However, 14.3% consider it rather trustworthy which is alarming even though the number is not very high.

Table 11: Comment influence I (own research)

Q11	M	SD
Did the comment below the picture (Figure 2) affect the credibility of the claim?	2.6	1.16

Here 47% of respondents think the comment referring to scientific results rather affected the credibility of the news. That is not surprising considering the respondents' certitude about their information literacy.

Table 12: Comment influence II (own research)

Q12	M	SD
Did the comment below the picture (Figure 3) affect the credibility of the claim?	4.2	0.95

In this question 85% of respondents claim the comment rather or definitely didn't affect the credibility of the post. That is ok as it proves high level of information literacy.

In the following three questions we asked about the difference between preference of public media and the respondents and their friends' opinion. The respondents' preference was oriented towards public media which proves the respondents are not susceptible to biases like the ignorance of unpleasant news, limited and unprecise sample, precipitate conclusion, McNamara's fallacy etc.

Table 13: Public media in health issues (own research)

Q13	M	SD
When it comes to public health issues, such as coronavirus, do you trust your own experience and that of your friends, or do you trust the public media?	2.9	1.18

This answer is negatively correlated with Q1 about information literacy ($r_s = -0.218$; $P = 0.017$) with Q7 about analytical thinking ($r_s = -0.180$; $P = 0.05$). It is logical as trust in public media is in compliance with the principles of information literacy. It is also correlated with Q14 ($r_s = 0.591$; $P = 0.00$) and Q15 ($r_s = 0.404$; $P = 0.00$) and negatively with Q11 ($r_s = -0.212$; $P = 0.02$). The more people trust public media the more they trust science.

Table 14: Public media and world events (own research)

Q14	M	SD
When it comes to world events, do you trust your own experience and the experience of your friends, or do you trust the public media?	3.47	1.06

Table 15: Public media in political issues (own research)

Q15	M	SD
When it comes to political issues, do you trust your own experience and the experience of your friends, or do you trust the public media?	3.16	1.08

People tend to trust public media the most when it comes to world events or political issues. In health issues they rely on public media, too, but not so heavily. In health issues, 37% of respondents trust rather themselves or their friends. When it comes to world events or political issues this group consists of only 18% and 25% respectively. The correlation between Q14 and Q15 amounts to ($r_s = 0.404$; $P = 0.00$).

We also performed the cognitive reflection test (CRT) (Frederick, 2005). It consisted of three questions with counterintuitive answers. The respondents could achieved 1 point for the correct answer and 0 points for the wrong one. They could achieve 0-3 points in total.

Table 16: CRT test (own research)

Q16	M	SD
CRT	2.0	1.02

Table 17: CRT test results' distribution (own research)

Number of points	Frequency	Percent
0	13	10,9
1	23	19,3
2	33	27,7
3	50	42,0

Our respondents answered quite correctly. The most errors achieved the “pen” question. This question is negatively correlated with Q1 about information literacy ($r_s=-0.217$; $P=0.018$) and with analytical thinking (Q7) ($r_s=-0.242$; $P=0.01$).

4. Discussion

The level of information literacy was quite high as well as in the self-assessment as in our small test. Our young respondents know how to behave in the online environment, know their strengths and are not susceptible to fake news very much.

What requires further research is the low or non-existent significant correlations between some self-evaluative and testing questions. We expected more relations between the questions. Especially Q6 is very independent. In any case everything we found and confirmed was logical and supports relations found in other studies.

We also strongly confirmed the existence of third person effect with the young generation. The young people consider their abilities and resistance to fake news as better than the rest of the society. This should be considered in the education process to avoid seeming invulnerability of the respondents.

Limits of our research consist in the fact that the respondents are not rewarded for finishing the questionnaire, so they might have done it quickly, just to have it done. Also, some of the respondents might have already known the Linda problem and other presented tasks and so the results are not unbiased. The generated Facebook posts were created by our best knowledge of argumentation style in social network discussions, but for some respondents it might not seem that way. Finally, the chosen fake news might not have been as persuasive as other fake news on social networks.

5. Conclusion

The young generation has a high level of information literacy and is not susceptible to fake news even though there are still some reserves. They verify information, don't get confused by the title or number of likes, use analytical thinking, follow public media and don't get confused by comments under fake news. That is promising for the future.

On the other hand, there is a group of respondents that still doesn't have a sufficient level of information literacy. That can be proven by the results from the practical tests (Linda problem, CRT test). Even the Facebook post was not denied unanimously. The relationship between intuitive and analytical thinking requires further research to identify the proper place and use of both. People

should know where to apply the appropriate way of thinking which should be included into the information literacy education.

6. Acknowledgement

This paper was processed with a contribution from the Prague University of Economics and Business, IG Agency, OP VVV IGA/A, CZ.02.2.69/0.0/0.0/19_073/0016936, grant number 05/2021.

7. References

- Bago, B., Rand, D. G., & Pennycook, G. (2020). Fake news, fast and slow: Deliberation reduces belief in false (but not true) news headlines. *Journal of Experimental Psychology: General*, 149(8), 1608–1613. <https://doi.org/10.1037/xge0000729>
- Bronstein, M. V., Pennycook, G., Bear, A., Rand, D. G., & Cannon, T. D. (2019). Belief in fake news is associated with delusionality, dogmatism, religious fundamentalism, and reduced analytic thinking. *Journal of Applied Research in Memory and Cognition*, 8(1), 108–117. <https://doi.org/10.1037/h0101832>
- Bunnin, N., & Yu, J. (2004). *The Blackwell dictionary of Western philosophy*. Blackwell Pub.
- Egelhofer, J. L., & Lecheler, S. (2019). Fake news as a two-dimensional phenomenon: A framework and research agenda. *Annals of the International Communication Association*, 43(2), 97–116. <https://doi.org/10.1080/23808985.2019.1602782>
- Evans, J., & Frankish, K. (Ed.). (2009). *In two minds: Dual processes and beyond*. Oxford University Press. <https://doi.org/10.1093/acprof:oso/9780199230167.001.0001>
- Festinger, L. (2001). *A theory of cognitive dissonance* (Reissued by Stanford Univ. Press in 1962, renewed 1985 by author, [Nachdr.]). Stanford Univ. Press.
- Frederick, S. (2005). Cognitive Reflection and Decision Making. *Journal of Economic Perspectives*, 19(4), 25–42. <https://doi.org/10.1257/089533005775196732>
- Generate Fake facebook post and chat online | Dizwa. (b.r.). Získáno 29. duben 2022, z <https://dizwa.com/simulators/generate-facebook-status-post/>
- Kahneman, D. (2012). *Thinking, fast and slow*. Penguin Books.
- Kirchner, J., & Reuter, C. (2020). Countering Fake News: A Comparison of Possible Solutions Regarding User Acceptance and Effectiveness. *Proceedings of the ACM on Human-Computer Interaction*, 4(CSCW2), 1–27. <https://doi.org/10.1145/3415211>
- Lieto, A., & Vernerio, F. (2013). Unveiling the link between logical fallacies and web persuasion. *Proceedings of the 5th Annual ACM Web Science Conference*, 473–478. <https://doi.org/10.1145/2464464.2508564>
- Pennycook, G., & Rand, D. G. (2020). Who falls for fake news? The roles of bullshit receptivity, overclaiming, familiarity, and analytic thinking. *Journal of Personality*, 88(2), 185–200. <https://doi.org/10.1111/jopy.12476>
- Sindermann, C., Cooper, A., & Montag, C. (2020). A short review on susceptibility to falling for fake political news. *Current Opinion in Psychology*, 36, 44–48. <https://doi.org/10.1016/j.copsyc.2020.03.014>

SENTIMENT ANALYSIS ON SOCIAL NETWORKS IN CZECH AND SLOVAK (SYSTEMIC REVIEW)

Jana Syrovátková

Faculty of Informatics and Statistics
Prague University of Economics and Business
jana.syrovatkova@vse.cz

DOI: 10-35011/IDIMT-2022-193

Keywords

Systemic review, sentiment analysis, social networks, Czech language, Slovak language

Abstract

The text aims to analyze the possibilities and articles related to the sentiment analysis in the Czech or Slovak language. Main focus is to the articles related to the sentiment analysis on the social networks in the Czech or Slovak language. I use the methodology of systemic literature review with a focus on the Scopus and WOS databases and the occurrence of the term sentiment analysis, Czech and Slovak language and social networks in years 2017 to 2021. We found 600 articles related to sentiment analysis, social networks and Czech or Slovak language, where after detailed analysis 5 of them was perfectly relevant to the focus. Texts about using SA for analyzing social networks in Czech or Slovak language are described in the article. There were found and described tools using Machine Learning, Support Vector Machines, Random Forests, Logistic Regression, Multilayer Perception, Naive Bayes, Maximum Entropy, Lexicon based, using universal dictionary and using comparing and translations between Czech and English language. There were some special analysis using Twitter, Youtube and Facebook social networks. There are really few articles on the topic, but they can be found. It is certainly an opportunity for further research.

1. Introduction

Man has been using language since time immemorial. The language is a natural form of expression. From many of the sentences, it is possible to determine the positive or negative effect of the sentence on the audience, the positive or negative attitude of the speaker, or in general it is a positive or negative message.

With the development of book printing, people began to share their ideas in writing, and with coming of the Internet, they began to share them online. Whereas in the past it was necessary for respondents to see and talk to them for any survey, the possibilities of systematic data collection give us great opportunities to replace sociological surveys with a simple analysis of online data (Sedláček, 2020).

The simplicity and low cost of similar analyzes allows you to improve your business or make the right decisions. The main goal for the possibility of obtaining information from the data is to find out the speaker's opinion from the text (Kok, Frascinar, 2020).

1.1. Sentiment analysis

The goal of sentiment analysis is to determine a person's opinion, attitude or emotions about a product, service, organization, other people, topics. In addition to the term “sentiment analysis”, the terms “opinion mining”, “opinion extraction”, “sentiment mining” and “emotion analysis” are also used (Bing, 2012).

Sentiment can be positive or negative, but we can add bigger scale – neutral attitude, strong agreement, strong disagreement and others using ordered scale. It leads to the multi-class classification or to the regression problem (Berka, 2020).

Sentiment can also be used as a comparative opinion – “Coca-Cola tastes better than Pepsi.” It is possible to examine entire documents, specific sentences or the opinion of a specific person. (Bing, 2012).

The use of sentiment analysis can include the correct targeting of marketing campaigns, but also, for example, the recommendation of professional help in case of suspected depression. For example, it turns out that the survey of an individual's digital footprint is more accurate in determining the type of personality than the subject itself (Sedláček, 2020).

1.2. Computer processing of sentiment analysis

Machine learning tools are usually used for the first phase of computer processing of sentiment analysis, however, deeper concepts such as neural networks and deep learning can also be used (Cano, Morisio, 2018). For the task of computer processing, there are used classifiers, which help with sentiment analysis. Four basic classifiers are:

- Naive Bayes – most popular, computes posterior probability of a sentiment class,
- Maximum Entropy – post (document) is converted on vector and then this vector is used to calculate weights and determine the most likely label for a feature set,
- Support Vector Machines – for each post we calculate a multidimensional vector, then construe a hyperplane for separating a regions,
- Lexicon-based – the basic principle is to utilize the words which carry the sentiment, polarity is then deduced from quantity of words (Krchnavý, Simko, 2017)

The methods are usually combined. If we don't want to teach the computer everything from the beginning, then we need a dictionary of sentiment-bearing words to analyze sentiment. Examples of such words are words like good, great, bad, poor. In addition to individual words, comprehensive phrases can also be traced (Bing, 2012).

Many different dictionaries are now available, especially for the English language, from which one can draw for sentiment analysis, thus eliminating the manual marking of sentiment texts. The most popular are the Bing, Afinn and NRC dictionaries. The latter, the NRC, contains the most words and, in addition, contains not only "positive" and "negative" but a wide range of emotional options for sentiment analysis too. The authors Miazga and Hachaj (2019) compared these three dictionaries for four different types of lyrics – books, lyrics, reviews and posts on social networks. The NRC dictionary proved to be the best for all types of texts.

A complication of sentiment analysis is figurative speech. It includes sarcasm, irony, comparisons, metaphor, satire, exaggeration and humor. The analysis of similar texts is non-trivial either on computer-based. This analysis is on the borderline between natural language processing (NLP), information extraction and machine learning (Abulaish, 2020).

An extensive sarcasm detection analysis was published for the Czech language, published in 2014, with datasets freely available on the Internet and using machine learning (Ptáček, 2014).

1.3. Issues of sentiment analysis in the Czech and Slovak language

There are more than 7000 languages and only for few hundred of them exists computational linguistic resources such as machine-readable lexica, part-of-speech-taggers and dependency parsers. But for heritage of humankind and cultural diversification are even “small” languages important (Asgari, 2020).

The basic problem of all Slavic languages compared to English or German is the great freedom of word order and the high number of word forms. For example, Russian has up to 80 different forms of one verb, while English has 5 of these forms (Divjak et al., 2017). Dictionaries for Czech must be significantly more extensive than those for English. The problem can be partially eliminated by word stemming (Singh, 2017).

Very often is the problem solved using multilingual algorithms in which sentences are translated or as in Steinberger (2011) are sentiment annotations projected from one language to several others including Czech. Steinberger (2012) proposed a semi-automatic “triangulation” approach for sentiment dictionaries in more languages, including Czech (Habernal, 2014). An analysis based on Wikipedia and a comparison of Czech and English are processed by Svoboda (2019).

The initial research about sentiment analysis in the Czech language was published by Veselovská and Šindlerová (2012), which used a corpus of 410 news sentences. They used Naive Bayes classifier and classifier based on a lexicon generated from a data (Habernal, 2014).

First big analysis of Facebook posts in Czech language was made by Habernal (2014), which uses 10,000 random Facebook posts from nine pages. They have used preprocessing with n-grams, emoticons and other more complicated preprocessings. The accuracy of algorithm was around 66%.

Because dictionaries in the Czech language are significantly more extensive, it is also much more complicated to obtain a truly valid dictionary. They are either commercial, such as Acrea Text Mining, high-priced or smaller projects. One of these small projects is the ABSA (Aspect Sentiment Analysis) model by Hercig, Brychcig and Steinberger (2016), who trained the model and made it accessible. A year later, they used it to analyze comments on articles (Hercig, 2017). For Slovak language there is a commercial project Sentigrade (Krchnavy, 2017).

Accordingly, the aim of this systematic literature review is to find topics and tools which are used for sentiment analysis on social networks in the Czech or closely related Slovak language in the last 5 years. First, we identify the general words needed for research. We limit the focus based on an inclusion exclusion criteria. Second, we find the indexed articles about sentiment analysis related to the social networks and Czech or Slovak. Third we go through all find articles individually and identify the perfectly fit articles. In doing so, we structure the manuscript in such a way that provides reader (researchers and practitioners) with a clear information about a whole process of review. We are inspired by systemic review of Bhimani (2019).

Overall, this paper makes three contributions. First, it shows main problems with sentiment analysis in “small” languages. Second, it provides a structured analysis of previous scholarly work on the topic of sentiment analysis on social networks in two of this “small” languages, specifically Czech and Slovak. Finally, it provides propositions and future research directions, capturing the current state of research in the field and drawing attention to potential research opportunities for future.

2. Methods

The main research question was:

RQ1: What are the topics of sentiment analysis on social networks for indexed articles related to the Czech or Slovak language?

RQ2: Which automatized tools are used for sentiment analysis on social networks related to the Czech or Slovak language?

RQ3: How are validated automatized tools used for sentiment analysis in social networks in indexed articles related to the Czech or Slovak language?

2.1. Data collection

The bibliographic dataset which is used for this research has been collected from the Web of Science (WOS) and Scopus repositories on April 2022 using the keywords related to the sentiment analysis, Czech and Slovak language and social networks. This research limits the searching duration in between the years 2017 to 2022. By utilizing this search string, this work downloaded some publication information like title, abstract, keywords, source of journals, etc. in the form of a text file for next analysis.

We started with keywords sentiment analysis, then continue with Czech or Slovak and at the end we add keywords social network, social networks, Facebook, Twitter or Instagram. Initially, we searched for keywords anywhere in the title, abstract, or full text of articles. Due to big amount of articles on Scopus, we have limited search here for article keywords sentiment analysis and related to the social networks.

At the end the total of 48 papers from WOS and 105 papers from Scopus on sentiment analysis related to the social networks and Czech or Slovak language were retrieved.

2.2. Data analysis

Because Czech or Slovak can mean just the place of journal, conference or place of research, we started with deeply study of all those 153 papers. We have analyzed the papers abstracts, journal source, authors nationality, keywords. We excluded papers with clearly identified languages in which the analysis was done. In case we had suspicions, the text could be about Czech or Slovak language, for example, the authors were Czechs or Slovaks or it was multilingual analysis, we take whole text of the paper and identify the languages of the analysis.

In the articles perfectly fit to the topic we have identified the answers to the research questions.

3. Results

We do a systemic review of sentiment analysis in the Czech or Slovak language with data taken from WOS and Scopus databases with exact keywords. We try to find used tools for sentiment analysis and used topics, data sources and methods. We have found that it looks like there are only a few articles in that topics – but still there are the relevant articles.

We can see an upward trend in the amounts of articles about sentiment analysis and in the amounts of articles related to the sentiment analysis on social networks. Due to the small number of specific articles found, it is not possible to talk about a trend in articles specifically focused on the Czech or Slovak language.

3.1. WOS statistics

By using just search string sentiment analysis, we have found 12,991 papers between 2017 and 2021. There were 4,717 papers using search strings sentiment analysis and (((ALL=(Facebook)) OR ALL=(Twitter)) OR ALL=(social network)) OR ALL=(social networks)) OR ALL=(Instagram) – i.e. papers related to social networks and sentiment analysis. There were 134 papers using search strings sentiment analysis and (Czech OR Slovak). When we have combined all strings together, we get 48 results (see Table 1). Five of them perfectly fit to the topic of review.

Table 1 - Number of articles found in WOS

	2017	2018	2019	2020	2021	Total
sentiment analysis (SA)	1800	2329	2734	2919	3209	12991
SA and social networks	658	867	960	1061	1171	4717
SA and (Czech or Slovak)	25	30	30	33	16	134
SA and soc. netw. and lang.	12	10	7	13	6	48

3.2. Scopus statistics

By using just search string sentiment analysis, we have found 83,445 papers between 2017 and 2021. There were 46,777 papers using search strings sentiment analysis and (((ALL=(Facebook)) OR ALL=(Twitter)) OR ALL=(social network)) OR ALL=(social networks)) OR ALL=(Instagram) – i.e. papers related to social networks and sentiment analysis. There were 1,461 papers using search strings sentiment analysis and (Czech OR Slovak). When we have combined all strings together, we get 852 results. So we so we further limited the selection to the keywords Sentiment analysis and related to social networks. After it we get 105 results (see Table 1). Three of them perfectly fit to the topic of the review (was in WOS too).

Table 2 - Number of articles found in Scopus

	2017	2018	2019	2020	2021	total
sentiment analysis (SA)	10,267	12,869	16,232	19,112	24,965	83,445
SA and social networks	5,471	7,197	9,192	10,794	14,123	46,777
SA and (Czech or Slovak)	162	229	259	316	495	1,461
SA and social networks and language	99	132	148	188	285	852
limit to keyword SA	32	38	32	60	59	221
limit to keyword SA and soc. netw.	16	17	14	28	30	105

3.3. Detailed overview of the found multilingual articles

We have found six articles perfectly fit to the topic sentiment analysis on social networks in the Czech or Slovak language in last 5 years. Out of them, there were 3 multilingual using different ways of translating between languages and examining sentiment, one exactly about Czech language and one about Slovak language.

Graovac, Mladenović and Tanasijević (2019) worked with n-grams in conjunction with k Nearest Neighbourhood (kNN), Support Vector Machine (SVM) and Maximum Entropy (ME) algorithms. They have studied only polarity of the texts – if they are positive or negative. The aim of the paper was to determine if there is a unique type of features representing text documents, and if it can be valuable regardless of the language, so as to be successfully used by statistical ML classification techniques for solving SPD efficiently and avoiding previously mentioned challenges. They use 7 languages – Czech, English, French, Spanish, Arabic, Turkish and Serbian. In paper there is exactly and in detail explained the technique and theory of N-gram-based SPD techniques and its variants

kNN, SVM and ME. For experimental framework in the Czech language there was used a corpus CSFD by Habernal and Brychen consisting of 91,381 movie reviews with zero to six stars. They had accuracy over+ 80, for ME method it was 86%.

Very interesting is the work of Asgari (2020) which introduce universal sentiment lexica for 1000+ languages. They have sentiment lexicon in English and small, but massively parallel corpus – they have used Parallel Bible Corpus. As a method they used nearest candidate and SuperPivot method, which uses alignment graph. Then, for classification model they used logistic regression. The evaluation of the model was made using the data from Twitter, they had accuracy around 80% (manual lexicon had accuracy 87%).

The last multilingual work is Kocich (2017) in which they take 5.5 millions tweets in more than 100 languages from one day, then they translate it into English using Google Translate. At last they used AFINN-165 dictionary of sentiment. In this wordlist there is 3382 manually evaluated and ranked words on the scale from -5 to +5. Because the data came from many parts of the world, the authors eventually analyzed the percentage of negative and positive tweets in different regions of the world.

3.4. Detailed overview of the found articles about Czech or Slovak language

Cano (2019) focuses on researching the effectiveness of existing machine learning algorithms for analyzing the sentiment of Czech posts on Facebook. They used dataset from Habernal (2014) with ten thousand record manually independently revised by two annotators and in cases of disagreement there were two other annotators. Each post was positive, neutral, negative or bipolar (if they had both positive and negative sentiments). They have used user reviews out of Facebook too. In the article there are supervised algorithms Support Vector Machine, similar NuSVM, Random Forests, Logistic Regression, Multilayer Perception, Naive Bayes, Maximum Entropy. Accuracy for Facebook posts was between 60-70% (what is interesting is that user reviews had accuracy over 90%).

In Krchnavy, Simko (2017) the authors propose a method for sentiment analysis of social network posts on Facebook. The data contains 1588 from pages of clients of public relations company Seesame. They assume that one social network post (document) has assigned one sentiment value. In the article there are briefly described common used classifiers suitable for machine learning for a task of sentiment analysis, which the method is based on. It incorporates text pre-processing – emoticon normalization, diacritics reconstruction, lemmatization and negotiation handling. The accuracy of the method is around 80%, the best performing setup was with the method Maximum Entropy and with all parameters instead of negotiation handling (82%).

4. Conclusion and discussion

I have found 5 interesting articles with themes sentiment analysis, social networks and Czech or Slovak language. There are only a few articles with exact topic, but articles are interesting and show basic algorithms used, basic datasets used and a little about topics.

There were two main methods used – the first used English as a reference language and use translations into other languages. This method is very interesting due to possibility to have many languages and just one sentiment lexicon. Other possibility is to have special sentiment dictionary in specific languages – in the case of small languages, it turns out that both the type of document and the quality of the dictionary depend the result accuracy.

The main limitation of the study mainly on Scopus is that we have found huge amount of articles with the word Czech/Slovak, but it could be Czech/Slovak author or Czech/Slovak conference and then the articles was detected manually. For possibility of it, we have to limit the selection to keywords sentiment analysis and social networks relevant words. It may have happened that we have missed some articles. We have taken only last five years, but the topic is developing rapidly, so it can be expected that interesting older articles on the topic were mentioned in newer included works and therefore we have included them in the introduction.

There seem to be many ways to further work with sentiment analysis in the Czech or Slovak language. It certainly turns out that there are not many elaborated specific topics of sentiment analysis on Czech social networks and it is also possible to compare the algorithms used directly on the Czech and Slovak language and the sentiment dictionary.

5. Acknowledgement

This paper was processed with a contribution from the Prague University of Economics and Business, IG Agency, OP VVV IGA/A, CZ.02.2.69/0.0/0.0/19_073/0016936, grant number 05/2021.

6. References

- Abulaish, M., Kamal, A., Zaki., M. J. (2020). A Survey of Figurative Language and Its Computational Detection in Online Social Networks. *ACM Trans. Web* 14, 1, Article 3 (February 2020), 52 pages.
- Asgari, E., Braune, F., Roth, B., Ringlstetter, C., & Mofrad, M. R. K. (2020). UniSent: Universal adaptable sentiment lexica for 1000+ languages. Paper presented at the LREC 2020 - 12th International Conference on Language Resources and Evaluation, Conference Proceedings, 4113-4120.
- Babčanová, D., Hrablik, H., Caganova, D., Sujanova, J., Horňáková, N. (2019). Qualitative and quantitative analysis of social network data intended for brand management. *Wireless Networks*. 10.1007/s11276-019-02052-0.
- Berka, P. (2020). Sentiment analysis using rule-based and case-based reasoning. *J Intell Inf Syst* 55, 51–66. <https://doi.org/10.1007/s10844-019-00591-8>
- Bhimani, H., Mention, A.-L., Barlatier, P.-J. (2019) Social media and innovation: A systematic literature review and future research directions, *Technological Forecasting and Social Change*, Volume 144, Pages 251-269, ISSN 0040-1625, <https://doi.org/10.1016/j.techfore.2018.10.007>.
- Bing Liu. (2012). *Sentiment Analysis and Opinion Mining*, Synthesis Lectures on Human Language Technologies. Vol. 16.
- Cano, E and Bojar, O (2019). Sentiment Analysis of Czech Texts: An Algorithmic Survey. In *PROCEEDINGS OF THE 11TH INTERNATIONAL CONFERENCE ON AGENTS AND ARTIFICIAL INTELLIGENCE (ICAART)*, VOL 2 , pp.973-979
- Çano, E., Morisio, M. (2018). A deep learning architecture for sentiment analysis. In *Proceedings of the International Conference on Geoinformatics and Data Analysis (ICGDA '18)*. Association for Computing Machinery, New York, NY, USA, 122–126.
- Divjak, D., Sharoff, S., & Erjavec, T. (2017). Slavic Corpus and Computational Linguistics. *Journal of Slavic Linguistics*, 25(2), 171–200. <https://www.jstor.org/stable/26535064>
- Graovac, J., Mladenović, M., and Tanasijević, I. (2019) NgramSPD: Exploring Optimal N-gram Model for Sentiment Polarity Detection in Different Languages. *Journal: Intelligent Data Analysis*, vol. 23, no. 2, pp. 279-296. DOI: 10.3233/IDA-183879
- Habernal, I., Ptáček, T. Steinberger, J. (2014). Supervised sentiment analysis in Czech social media. *Inf. Proc. & Manag.*, 50(5), pp. 693-707.

- Hercig, T; Brychcin, T; Steinberger, J. (2016). Unsupervised Methods to Improve Aspect-Based Sentiment Analysis in Czech. In *COMPUTACION Y SISTEMAS 20* (3) , pp.365-375
- Hercig, T., Krejzl, P., Hourová, B., Steinberger, J., & Lenc, L. (2017). Detecting stance in czech news commentaries. Paper presented at the *CEUR Workshop Proceedings*, , 1885 176-180.
- Kocich, D. (2018). Multilingual Sentiment Mapping Using Twitter, Open Source Tools, and Dictionary Based Machine Translation Approach. In: Ivan, I., Horák, J., Inspektor, T. (eds) *Dynamics in GIScience. GIS OSTRAVA 2017. Lecture Notes in Geoinformation and Cartography*. Springer, Cham. https://doi.org/10.1007/978-3-319-61297-3_16
- Kok, Sophie, Frasincar, Flavius (2020). Using word embeddings for ontology-driven aspect-based sentiment analysis. In *Proceedings of the 35th Annual ACM Symposium on Applied Computing (SAC '20)*. Association for Computing Machinery, New York, NY, USA, 834–842.
- Krchnavy, R., Simko, M. (2017), Sentiment analysis of social network posts in Slovak language, 2017 12th International Workshop on Semantic and Social Media Adaptation and Personalization (SMAP), 2017, pp. 20-25, doi: 10.1109/SMAP.2017.8022661.
- Miazga, J., Hachaj, T. (2019). Evaluation of Most Popular Sentiment Lexicons Coverage on Various Datasets. In *Proceedings of the 2019 2nd International Conference on Sensors, Signal and Image Processing (SSIP 2019)*. Association for Computing Machinery, New York, NY, USA, 86–90.
- Ptáček, T., Habernal, I., Hong, J. (2014). Sarcasm Detection on Czech and English Twitter. In *Proceedings of COLING 2014, the 25th International Conference on Computational Linguistics: Technical Papers*, pages 213–223, Dublin, Ireland, August 23-29 2014.
- Sedláček, J. (2020). Digitální stopa: Konec empirické sociologie?, *Sociologický Casopis*, vol. 56, no. 4, pp. 471-490.
- Singh, J., & Gupta, V. (2017). An efficient corpus-based stemmer. *Cognitive Computation*, 9(5), 671-688. doi:10.1007/s12559-017-9479-z
- Steinberger, J., Ebrahim, M., Ehrmann, M., Hurriyetoglu, A., Kabadjov, M. A., Lenkova, P., et al (2012). Creating sentiment dictionaries via triangulation. *Decision Support Systems*, 53, 689–694.
- Steinberger, J., Lenkova, P., Kabadjov, M. A., Steinberger, R., & der Goot, E. V. (2011). Multilingual entity-centered sentiment analysis evaluated by parallel corpora. In *Proceedings of the 8th international conference on recent advances in natural language processing* (pp. 770–775).
- Svoboda, L., & Brychcin, T. (2019). Enriching word embeddings with global information and testing on highly inflected language. *Computacion y Sistemas*, 23(3), 773-783. doi:10.13053/CyS-23-3-3268
- Veselovská, K., Jr., & Šindlerová, J. (2012). Creating annotated resources for polarity classification in Czech. In *Proceedings of KONVENS 2012, ÖGAI* (pp. 296–304). *PATHOS 2012 workshop*.

TV CONTENT AUDIENCE PROFILE PREDICTION OPTIONS

Marie Kovářová, Miloš Maryška

Prague University of Economics and Business
Department of Information Technology
marie.kovarova@vse.cz, milos.maryska@vse.cz

DOI: 10-35011/IDIMT-2022-201

Keywords

Audience prediction, Fourier transform, analysis, time series

Abstract

TV audience prediction plays a key role in planning, decision making, buying or producing TV content. In the case of terrestrial (non-internet) broadcasting, the analysis and subsequent prediction can be particularly challenging than from data received online. This article describes possibilities of data analysis of terrestrial broadcasts within selected time series. Fourier transform is used in the data analysis to create a more accurate model with increased predictive ability especially in given data which show signs of high frequency data.

1. Introduction

TV channels (both private and public) benefit from predicting future audience numbers and getting the advertising right. In the case of private TV channels, the price of advertising slots is set according to the expected number of viewers of the programs. Public television has to fulfil the tasks for which it is publicly funded, i.e. to maximize the audience for its programs. In either case, it is important to predict future audiences in the context of future TV program development. A good prediction will enable both public and private broadcasters to make better decisions when planning the purchase or production of TV program content. It can influence organizational decisions about which content to publish and at what time.

Predicting the audience profile of TV content can be addressed by several possible approaches in two basic areas, which are audience prediction and content popularity prediction.

In the case of audience prediction, the most common statistical methods used are

- time series
- Bayesian statistics
- trend detection

In the case of content popularity prediction, the most used methods are:

- cumulative growth,
- temporal analysis

- evolutionary trend

Each of the areas is described and elaborated in detail. In the case of audience prediction based on time-series analysis and the benefits of its components e.g. trend, seasonality is addressed for example in (Nixon et al., 2019). Audience prediction based on Bayesian statistics is addressed for example in (Bavelloni et al., 2015). And trend detection is addressed in (Zhu et al., 2017) who used K-medoids.

In the case of predicting the popularity of web content, methods based on cumulative growth, temporal analysis or evolutionary trend are often used. In the case of cumulative growth (e.g., cumulative attention growth), the popularity of each TV program item is examined from the time of registered attention to the time of prediction. According to (Kaltenbrunner, et al., 2007), it has been suggested that, as a function of the time of publication, news stories follow a continuous growth pattern. A log-linear prediction model was proposed by (Szabo et al. 2010). According to (Zhu et al., 2017), this model outperformed the constant growth models under MSE. According to (Zhu et al., 2017) a different prediction approach was proposed by (Lee et al., 2012), where they used a survival analytical model to detect threads with comments. A subsequent contextual system architecture was proposed by (Wang et al., 2014).

Each of the above methods has its advantages and disadvantages, and always depends on the availability and type of data sources. Their goal is common namely, to predict the profile of a given audience for better advertising targeting. In this article are used data, which show patterns as in high frequency data. Author of this article needed to found optimal way of proper data analysis which can be used on the given data.

The aim of this article is to create statistical data model to analyze problematic data from the audience of terrestrial (not over internet) television broadcasting of a specific Czech television station and the possibilities of using the statistical methods described above in a more detailed analysis of the users of the selected television station.

All data processing and outputs presented in this article were done in Python 3 with its associated packages.

2. Methodology

The methodology is based on the standard requirements set for the field of statistics and the basic statistical methods that are analyzed and used to achieve the objective of this paper. The objective of the paper is to analyze the selected time series.

The validation is done on data from an unnamed company, which cannot be mentioned for data protection reasons, and is referred to as X. Company X collects data from terrestrial television broadcasts of a selected Czech television station. The data contains information about the users of the terrestrial television broadcast by means of so-called sessions. Each session represents a specific user and his behavior when switching the content of the TV broadcast. The user's behavior is represented in the data by several rows of sessions, e.g. if the user switched to other TV stations during commercials, he may appear in the data just as many times as he went back to the selected TV station. The data used are so-called panel data, which contain five categories:

- 4+ (whole TV population)
- 4+ HbbTV (the entire TV population that says they have addressable television)
- 15-54 (TV population from 15 to 54 years of age)
- 15-69 TV population from 15 to 69 years of age)

- 15-69 HbbTV (TV population from 15 to 69 years of age, that says they have addressable television)

The representation in the data of each category in thousands can be seen in Figure 1

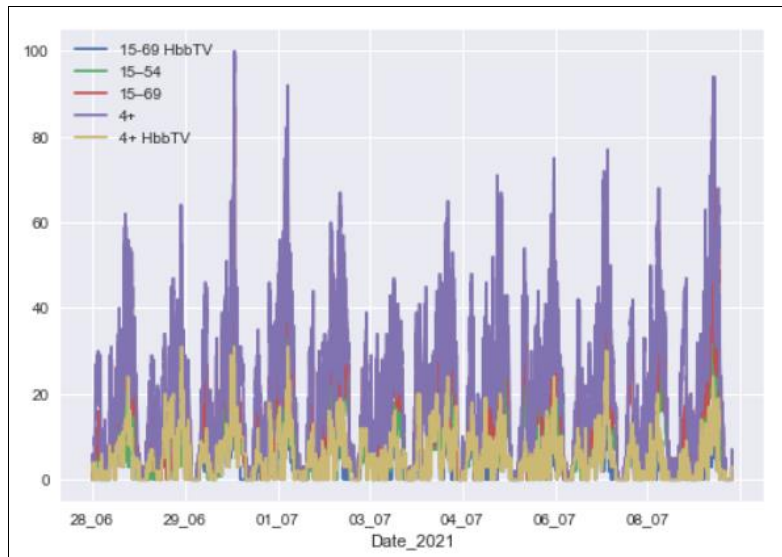


Figure 1 – Overview of the data

For the analysis was chosen the 4+ category, or the entire TV population within 12 days between the months of June and July 2021. The data set had more than 100 thousand rows for analysis. The data was provided by Company X for review only for the consecutive 12 days in the year 2021. The forecast should be generated by projecting the identified trend and seasonal cycles into the future without considering the unpredictable component.

Since the data are a short period of time, we can observe a strong trend component in the data after decomposing the time series, see. Figure 2. The left part of Figure 2 shows the decomposition by days. The right part of Figure 2 shows the decomposition by time of observation. In case we have a longer time series of TV audience prediction we can also use the time series prediction by (Nixon et al., 2019). The seasonal component within the longer time series would appear very prominent in terms of viewership during the summer months rather than the winter months.

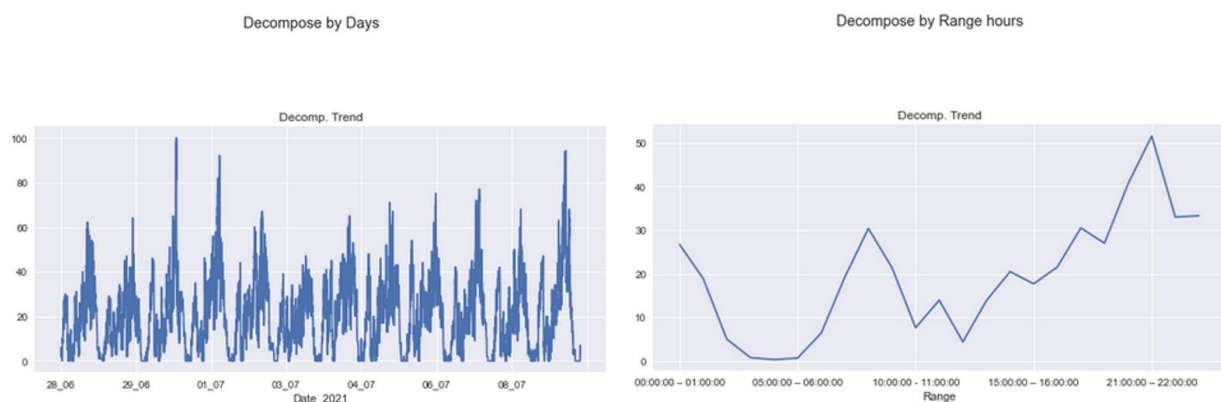


Figure 2 – Data decompose by time

Steps below were followed for the time series analysis:

- Identify the type of time series

- Applying an appropriate time series transformation
- Prediction
- Model checking

3. Time series analysis and discussion

From Figure 2 we can see that the time series is stationary in terms of trend, which is confirmed by the autocorrelation function (ACF) in Figure 3 (values are not near 0 and are with trend). Even though we have a short time interval, the time series is highly seasonal, so it will be non-stationary in terms of seasonality. The partial autocorrelation function (PACF) in Figure 4 confirms for us that only three lags are significant (higher than 0,05).

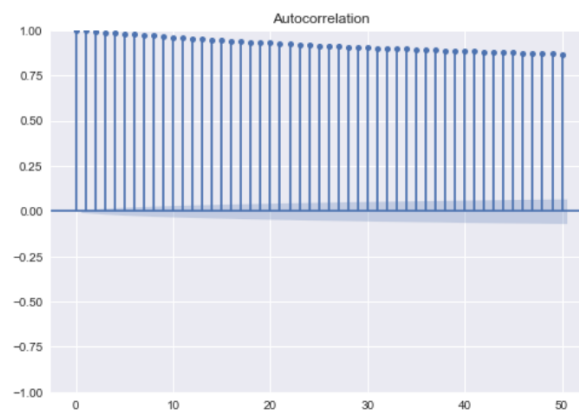


Figure 3 - ACF

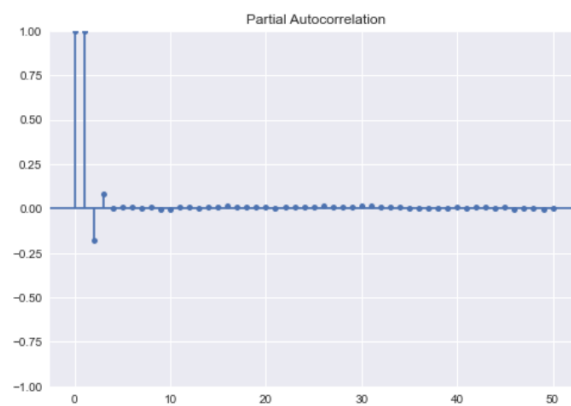


Figure 4 - PACF

For confirmation of the time series non-stationarity, the Augmented Dickey-Fuller (ADF) test was used with a threshold of 5%, where:

H0: The time series is non-stationary.

H1: non H0

The developed ADF test did not confirm at the 5 % significance level that the time series is non-stationary. The time series was found to be stationary in terms of trend but non-stationary in terms of seasonality. In terms of data that are high frequency, it will not be appropriate to use regression

models by using Box-Jenkinson methodology (Newbold, 1975). When applying a regression model, the quality of the prediction was very low:

Slope: $5.78\text{e-}06$, Intercept: 16.67
R-squared: $1.45\text{e-}02$

Figure 5 – Test R^2

Fourier transform (Nussbaumer, 1981) was used to analyze the seasonal component in the selected time series. The Fourier transform allows to transform the function of time and signal. It tells us what frequencies make up the signal and how strong they are. In this case, the signal is the count of viewings, where we can expect hourly or daily frequencies. The first week of data is plotted in Figure 6 on the right, where strong seasonality can be seen. Using the Fourier transform, we found the most dominant frequency. The inverse Fourier transform detects which frequencies correspond to them.

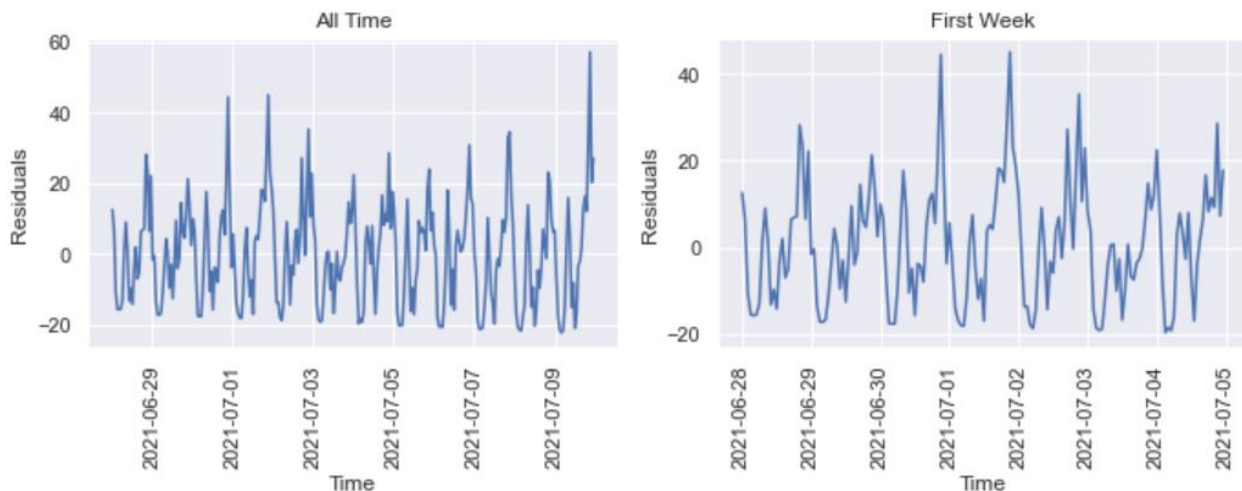


Figure 6 – Residuals by Time

In Figure 7 we see amplitude vs. frequency. Frequencies with the largest amplitude are indicative of seasonal patterns. Frequencies with low amplitude are noise.

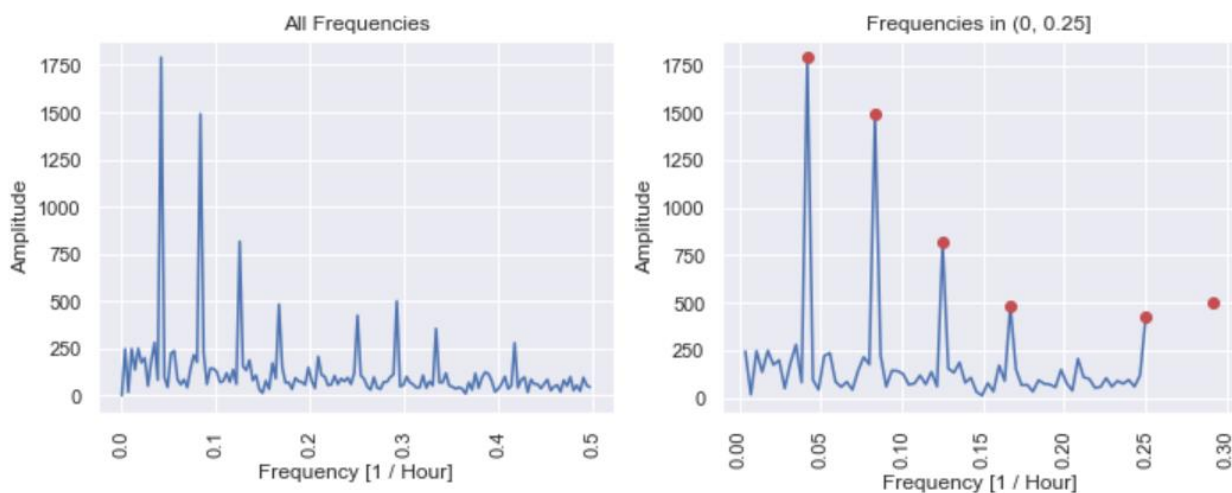


Figure 7 – Amplitude by Frequency

Details of the amplitudes in Figure 8 shows, that the frequency with the highest amplitudes when converted to hours shows a seasonal pattern on the hourly frequency. Specifically, 24h (1/0.042), 12h (1/0.083), 8h (1/0.125) etc... The first high frequencies show 24h, 12h and 8h high viewership that repeats. The other frequencies are difficult to put into context, but their low amplitudes are not very important, see. Figure 8.

	index	freq (1/hour)	amplitude	period (days)	fft
0	12	0.042	1,790.27	1.0	(631.9230737406792+1,675.033851690004j)
1	24	0.083	1,490.382	0.5	(-159.27586947081062+1,481.8467362293525j)
2	36	0.125	815.515	0.33	(690.1306264062086+434.4929274863251j)
5	84	0.292	499.946	0.14	(402.7679760852667-296.18286567669185j)
3	48	0.167	482.553	0.25	(-325.23488773917023-356.48223140124924j)
4	72	0.25	423.693	0.17	(286.792195594163-311.8755289274965j)

Figure 8 – Overview of the amplitude

From the above results, we know that there is hourly seasonality, but we do not know which hour has higher seasonality. The question is how to find it out? To find out which hour has higher seasonality, we can use the inverse Fourier transform. Figure 9 shows the filtered signal over the original signal for the first 5 days in the data.

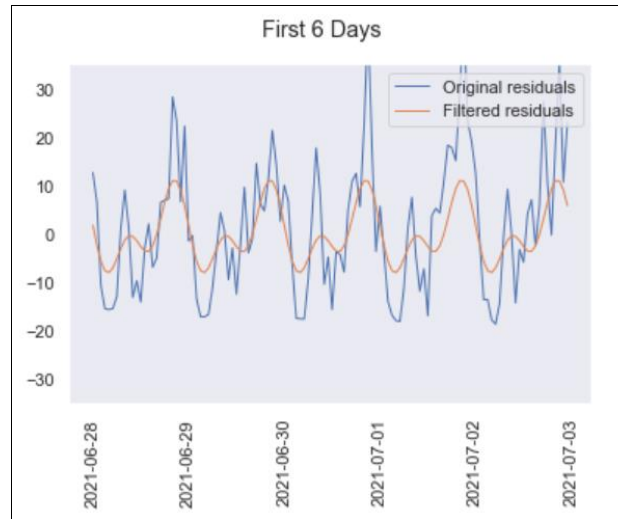


Figure 9 – Filtered signal

The newly created variables from the Fourier transform are then incorporated into the model. The result of the prediction and the original values can be seen in Figure 10. After checking the quality of the model, the R^2 came out to be around 65%. Which means that incorporating new variables using Fourier transform into these types of data, increases the prediction ability.

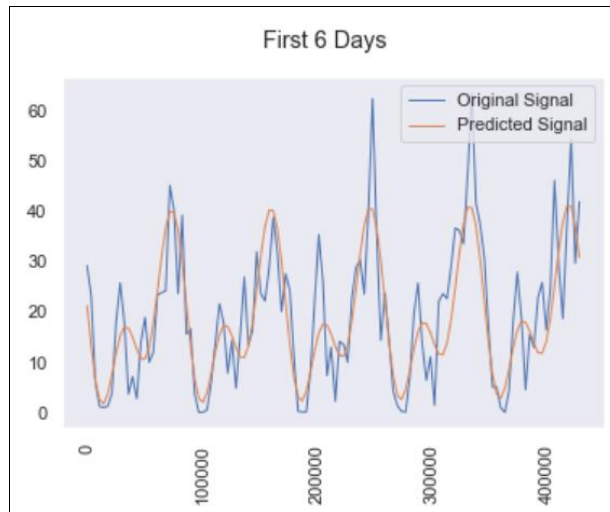


Figure 10 – Predicted Signal

4. Conclusion

The main aim of this article was creation of the statistical data model for finding the time patterns in data. The time patterns found can help this particular company better focus the TV content and advertising in the specific time slot and predict further TV viewer's behavior. The time patterns were found by using the Fourier transform. Within comparison of the classical regression approach with the given columns was the prediction result very low. But within the newly added columns using Fourier transformation had the prediction model better result, where R^2 was higher than in previous result - from 0.0145 to 0.65. The new variables created by Fourier transform have hereby increased the predictive ability of the model and had found the time patterns, which help the company to better understand the higher frequency data.

The next challenge of this TV viewers analysis will be to include additional information about television viewership using external data sources in order to find deeper behavior of the television viewer.

5. References

- Bavelloni, A., Piazzini, M., Raffini, M., Faenza, I., & Blalock, W. L. (2015). Prohibitin 2: At a communications crossroads. *IUBMB Life*, 67(4), 239–254. doi:10.1002/iub.1366
- FIGUEIREDO, Flavio, Jussara M. ALMEIDA, Marcos André GONÇALVES a Fabrício BENEVENUTO, 2016. TrendLearner: Early Prediction of Popularity Trends of User Generated Content. arXiv:1402.2351 [cs] [online]. [vid. 2021-04-18]. Accessible from: <http://arxiv.org/abs/1402.2351> arXiv: 1402.2351
- NUSSBAUMER, Henri J., 1981. The Fast Fourier Transform. In: Henri J. NUSSBAUMER, ed. Fast Fourier Transform and Convolution Algorithms [online]. Berlin, Heidelberg: Springer, Springer Series in Information Sciences, s. 80–111 [vid. 2022-04-28]. ISBN 978-3-662-00551-4. Accessible from: doi:10.1007/978-3-662-00551-4_4
- HAIR, Joseph. F. Multivariate data analysis. 2021. Amazon, 2020. ISBN 0138132631.
- KALTENBRUNNER, A., V. GÓMEZ a V. LÓPEZ, 2007. Description and Prediction of Slashdot Activity. In: 2007 Latin American Web Conference (LA-WEB 2007): 2007 Latin American Web Conference (LA-WEB 2007) [online]. s. 57–66. Accessible from: doi:10.1109/LA-Web.2007.21
- LEE, Jong Gun, Sue MOON a Kavé SALAMATIAN, 2012. Modeling and predicting the popularity of online contents with Cox proportional hazard regression model. *Neurocomputing* [online]. 76(1), Seventh International

Symposium on Neural Networks (ISNN 2010), 134–145. ISSN 0925-2312. Accessible from: doi:10.1016/j.neucom.2011.04.040

NIXON, Lyndon, Krzysztof CIESIELSKI a Basil PHILIPP, 2019. AI for Audience Prediction and Profiling to Power Innovative TV Content Recommendation Services. In: the 1st International Workshop: Proceedings of the 1st International Workshop on AI for Smart TV Content Production, Access and Delivery - AI4TV '19 [online]. Nice, France: ACM Press, s. 42–48 [vid. 2021-04-04]. ISBN 978-1-4503-6917-6. Accessible from: doi:10.1145/3347449.3357485

POSOLDOVA, Alexandra, Renata RYBAROVA a Alan Wee-Chung LIEW, 2015. Content Based Rating Prediction Recommendation System for HBB TV.

SZABO, Gabor a Bernardo A. HUBERMAN, 2010. Predicting the popularity of online content. Communications of the ACM [online]. 53(8), 80–88. ISSN 0001-0782. Accessible from: doi:10.1145/1787234.1787254

ZHU, Chengang, Guang CHENG a Kun WANG, 2017. Big Data Analytics for Program Popularity Prediction in Broadcast TV Industries. IEEE Access [online]. 5, 24593–24601. ISSN 2169-3536. Accessible from: doi:10.1109/ACCESS.2017.2767104

WANG, K., H. LU, L. SHU a J. J. P. C. RODRIGUES, 2014. A context-aware system architecture for leak point detection in the large-scale petrochemical industry. IEEE Communications Magazine [online]. 52(6), 62–69. ISSN 1558-1896. Accessible from: doi:10.1109/MCOM.2014.6829946

NEWBOLD, Paul, 1975. The Principles of the Box-Jenkins Approach. Journal of the Operational Research Society [online]. B.m.: Taylor & Francis, 26(2), 397–412. ISSN 0160-5682. Accessible from: doi:10.1057/jors.1975.88

SMART SUPPLY CHAIN

DEPENDENCY OF PUBLIC PROCURER ON SUPPLIER: DATA VIEW

Radoslav Delina, Gabriel Demeter, Anton Cornak

Faculty of Economics
Technical University of Kosice

radoslav.delina@tuke.sk, gabriel.demeter@tuke.sk, anton.cornak@tuke.sk.

DOI: 10-35011/IDIMT-2022-211

Keywords

Public procurement, dependency, supplier, risk

Abstract

Dependency in public and commercial procurement is considered as risk factor with several negative effects on procurement performance. Several studies or world of practice show 40% as risk threshold in commercial world. In the paper, we have analyzed data from Slovak public procurement from the view of dependency on supplier. Analysis shows that the relation between dependency and savings as possible negative effect is much more complex, although there are signals of negative trends. The paper motivates researcher to use data driven research to widen the gap in the research area to help decision makers in the field of spend management to improve their strategies based on data.

1. Introduction

Through last decades, the supply management increased the importance of risk management of their suppliers and entire supply chain. One of the important risk factors is lock-in or higher level of supplier dependency in buyer-supplier relationships (Schmitz, 2016, Mandt, 2018). There is a need to identify situations, where higher level of dependency may emerge and find strategies, how to avoid or reduce problems emerged due to inappropriate level of dependency.

The dependency is considered from two perspectives; first from existing dependency evolved from dominating relationships and relevant volume of contracts with one business partner or second, from some risk in procurement, which to this domination leads. On the other side, we must consider both sides of dependency; one from the side of procurer and the second from the side of supplier. Excessive dependency may lead to negative effects within negotiation phase and contractual conditions but also to the risk of unavailability of supplies.

Increasing level of business dependency may be determined by several factors – negative and positive. Within negative factors, we see the most significant problem of cartel or collusion agreements, low number of suppliers/applicants, lock-in situation, specific conditions for the participation in the tender and other. Although, dominant supplier may be leading from his position on the market regarding business and price strategy, loyalty efficiency or innovation level.

Although, building high quality relationship with suppliers within win-win strategy is being priority of current activities of procurers in commercial but also public procurement in many procuring

situations, the possibility of dealing with higher number of potential suppliers opens the opportunities of supplier portfolio diversifications and reduce risk from lock-in or high dependency level with negative effects. As each business depends on seamless flow of products and services in supply chain, disrupting of the flow from the reason of sudden capacity restriction, financial complications, problems of quality or natural disaster may lead the company into economic problems without suitable supplier portfolio diversification. In the public procurement area, there are also other factors as some reduced efforts of supplier to keep quality of products and services, market and competitive price achievement and increasing suspicions on collusion or conflicts emergence. As already mentioned, there are also strategies with positive impact as innovation partnerships or better synchronization of planning and information exchange (Krause et al., 2000; Prahinski and Benton, 2004; Wagner and Hoegl, 2006, Krause et al., 2007). As many authors are focusing on supplier development and its effect on buyers' performance (Carr and Kaynak, 2007; Krause et al., 2000, 2007; Li et al., 2007), its effect on suppliers' performance has been understudied.

In public procurement, the dependency on one supplier is being considered as very sensitive issue and often from negative aspect, where in some countries like U.K., there is the possibility to reconsider the approach against value for money and move more on the cooperation with higher number of suppliers.

There are two main drivers of government or public sector dependence on their supplier. Firstly, the supplier may be motivated by existing demand from the side of contracting authority in such a way, that it leads to higher failure risk of its capacity or financial difficulties. On the other hand, there is a strong incentive for supplier to take advantage of its dominant position, which can be built in various ways to influence the efficiency of the public resource management and to discourage other applicants.

Excessive dependence can be influenced by several factors such as, a lack of willingness from the side of applicants in the tender, a lack of competition in the market, or when costs of changing the supplier is too high.

Failure of identifying and over-solving these issues can have adverse effects, including risks of unsuccessful completion of the contract, reduced competition and innovation in the market.

There are several strategies aiming to reduce the risk of overdependence. The main strategies are considered to reduce barriers for supplier to enter the public sector market, or development of a portfolio of suppliers.

From a legal point of view, concerning the public procurement market, there is a case law in EU countries which suggests that firms may be excluded from a tender, if the scope of the procurement activity exceeds the ceiling set by national law. The Court of Justice has ruled that this could be a useful indicator of the economic and financial situation of a bidder, which is one of the legitimate criteria for assessing their selection.

There is no such ceiling in national law of Slovakia. Nevertheless, it would be legally possible to take into account the impact of e.g. the supplier's existing obligations, the financial and technical capacity to meet the tender conditions, the supplier's success in suspicious tenders, or the level of high dominance. In this context, selection procedures related to the reduction of the negative impact of excessive dependency, or comparing terms of contracts in similar procurements, could be used.

Before addressing the excessive dependence, contracting authorities should consider whether a restriction would be compatible with ensuring the value for money, or with encouraging suppliers to innovate and meet the requirements in a different way.

The level of over-dependence at which a firm can be considered to be excessively dependent and can vary by various factors such as the significance of the business relationship and the length of the contract. For these reasons some government guidelines in the EU no longer include a rule that suppliers should not be called upon, in the case of their turnover on a single contract dependency exceeding 40% level. Contracting authorities should also be aware of the risk of adverse impact of political or public interest in case of ambiguity of procedure/outcome or when there is an imbalance between rationality of the purchase and public/political perceptions.

There is a legitimate question to be asked related to the level of dependency in the public procurement. This issue is addressing, whether there is only one firm that has the capability to meet all the requirements and how data-driven procurement can help procurers answer this question.

However, in some cases where excessive dependency is an issue, the supplier will still be able to meet the minimum selection criteria and score well in the evaluation phase of the contract. Such a supplier will usually have plenty of resources and options to meet the criteria at a given time, despite not having met the criteria before the contract was published.

When there is a motivation to prevent or suppress the excessive dependence, a concept of how the procurement is structured becomes more important matter in contrast to the evaluation of applicants and their bids. The structuring of procurement should address issues of encouraging and motivating the participation of SMEs, non-profit (voluntary and community) sectors and social enterprises, also should help to improve the innovation value of suppliers.

2. Research on dependency level in public procurement

2.1. Data description

For the purpose of our analyses, we have used dataset based on open data from Slovak public procurement repositories. As data from several contracts reveals errors or anomalies, we have cancelled all contractual data from business relations between specific public organization and specific supplier. For filtering anomalies in savings, we have used IQR approach.

Finally, we have used almost 100 thousand contracts with 48 023 unique business relations, where 3261 business relations were with more than four contracts. As we want to analyze dependencies, it is necessary to calculate aggregated statistic for each business relation between one concrete public procurer and one concrete supplier. Basic parameters calculated and used were:

DependencyCA – dependency of public procurer on specific supplier on the base of total volume of contracts with this supplier

DependencyCO – dependency of supplier on specific public procurer on the base of total volume of contracts for this procurer

SavingI – saving calculated within specific contract

COCA_contracts_count – number of contracts between public procurer and supplier in specific time of contract

COCA_saving_mean – aggregated statistic of average savings achieved from previous contractual history of specific public procurer and supplier

Cpv2 – category of products or services according to the classification of Common Procurement Vocabulary

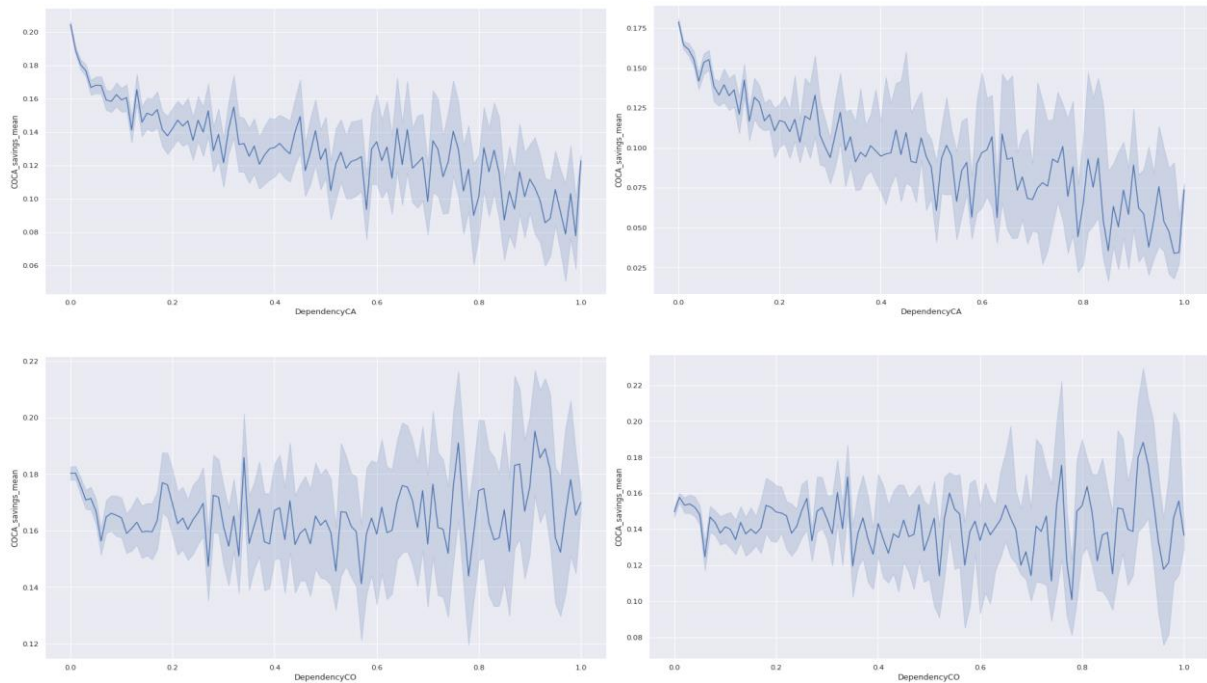
Table 1 Descriptive Statistics of data sample

	N	Minimum	Maximum	Mean	Std. Deviation
DependencyCA	96650	,00	1,00	,1695	,29707
Saving1	96653	-,45	,68	,1669	,16387
COCA_contracts_count	96653	1,00	324,00	6,0118	17,32293
Valid N (listwise)	96650				

2.2. Research results

For our analyses we have used descriptive statistics and visualization and Kruskal-Wallis test of variance. According to mentioned literature and many official documents for public procurement, the high level of dependency is considered as negative effect on final contractual performance. Several commercial companies are still using 40% threshold as a risk indicator for high dependency with negative effect as some holy grail in spend management. That's why we have analyzed average and median value of average savings from contractual history between procurer and supplier according to different level of Dependency which was after calculation rounded on 1%.

According to the following figure, we have compared dependency of public procurer (DependencyCA) with dependency of supplier (DependencyCO).

**Figure 1 Average savings from contractual relation based on different dependency level and subject**

As we see, although there is visible volatility, in general, the increasing dependency of public procurer on a supplier has negative effect (trend) on average savings achieved from historical contracts. As mean is higher than median, we see that we have more contracts with lower savings and some contracts with high savings are increasing this average saving, but both show negative trend by increasing dependency on supplier. Increasing volatility in higher level of dependence may be explained by higher dimensionality of the problem, where several other factors can determine the behavior of this indicator as volume of contracts, lengths of relationship, type of market segment (cpv), any non-standard behavior of procurer or suppliers etc.

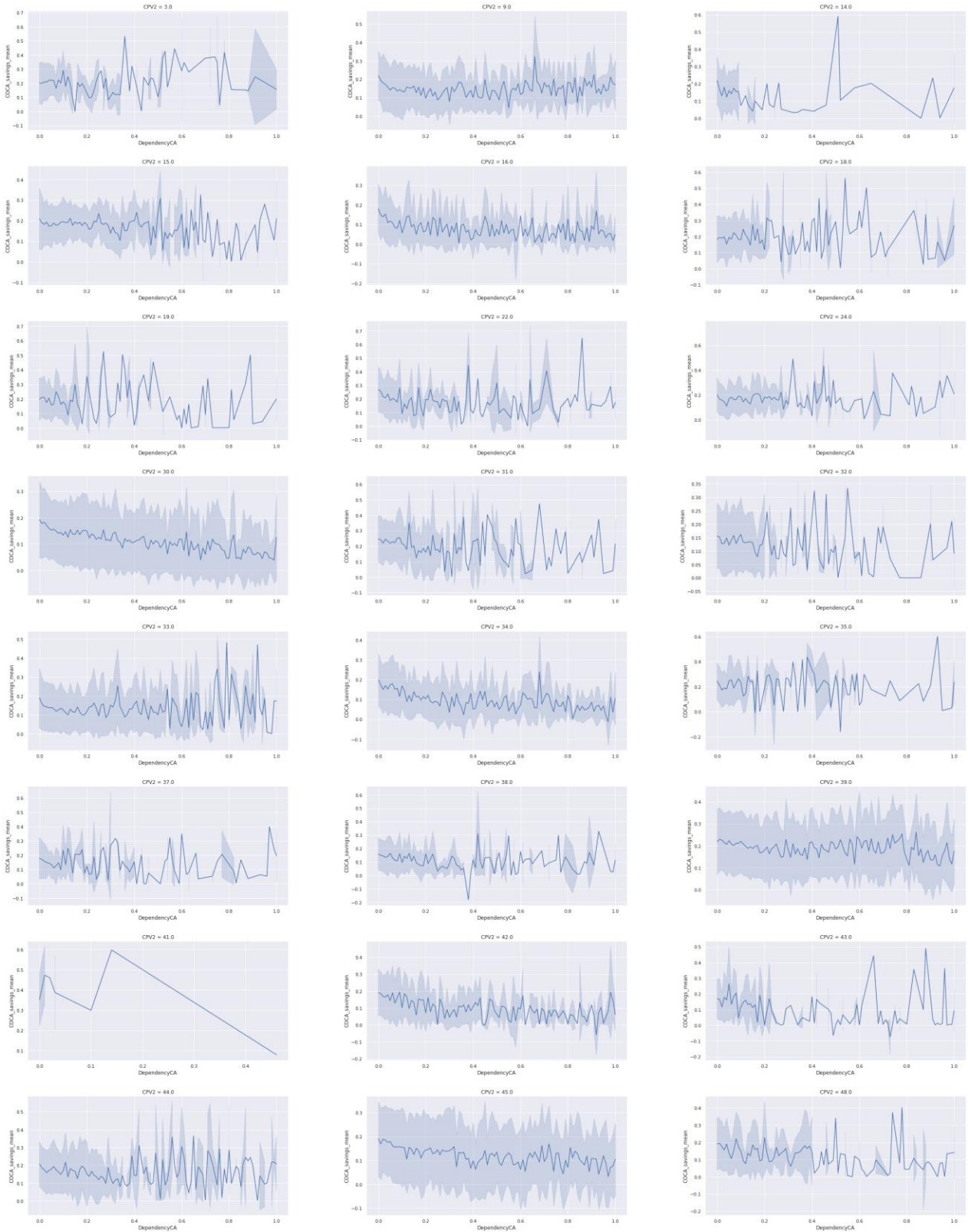


Figure 2 Average aggregated savings based on different dependency level across CPVs

The dependency of supplier on public procurer doesn't reflect similar trend. We can say that supplier who relies on small number of procurers doesn't decrease or significantly increase their savings although, in general there are much more higher savings in higher levels of DependencyCO as in opposite direction of dependency.

One of the main differences of supplier behavior or contractual specifics is a market segment or category of product or service procured by public organization. For comparison of relations between dependencyCA and savings achieved within contracts we are presenting variability of dependencyCA across different CPVs. As we see, different market segments have different behavior of this indicator what means, that dependency behavior may be determined significantly by the category of product where different market situations, structures, competition of product characteristics may explain this variability of savings development.

When we are analyzing dependency levels, generally the world of practice are talking about different levels of percentage the most often 20% intervals. That's why we would like to analyze, if there is a significant difference between 20% intervals across dependency values in savings achieved within specific contracts realized in the situation of these different dependency of supplier. In next figure, we present categorized values of DependencyCA, where each category represents interval with 20% width from 0 to 100% of dependency. On the left side, the graph represents all contracts and relationships. On the right side, we have excluded those relationships with history less than five contracts to present more stable business relationships.

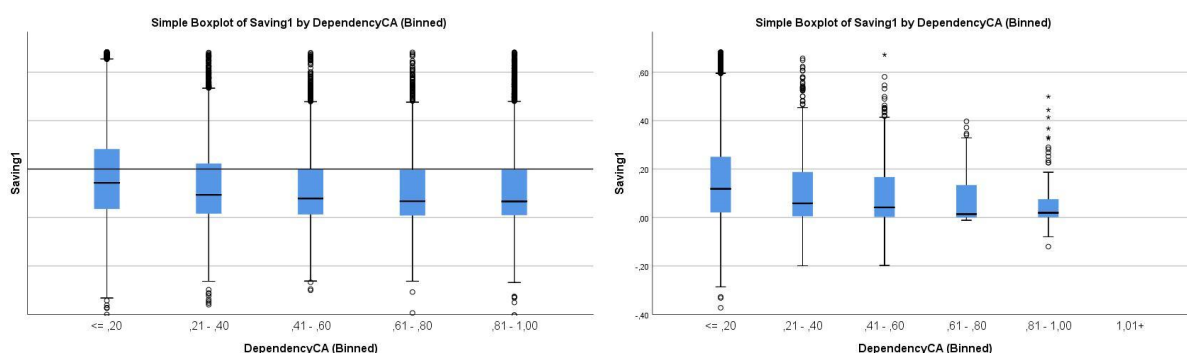


Figure 3 Categorized dependency and achieved savings

Table 2 Pairwise Comparisons of DependencyCA (Binned)

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.a
,81 - 1,00-.61 - ,80	686,574	815,307	,842	,400	1,000
,61 - ,80-.41 - ,60	1415,829	742,374	1,907	,056	,565
,41 - ,60-.21 - ,40	458,899	414,292	1,108	,268	1,000
,21 - ,40-<= ,20	1847,693	210,538	8,776	,000	,000

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

As we see, there is a clear declining trend, more in more stable relationships what is tested also by following table with Kruskal Wallis test of variance. From adjusted significance values we see, that there is a significant difference in achieved savings between lowest neighboring intervals and 40-60 vs 80-100. Two highest intervals of DependencyCA, 40-60 vs 60-80 and 20-40 vs 40-60 seems according to tests that they are from the same distribution. Although, according to standard significance, there is also some threshold on theoretical 40% level.

3. Conclusion

Dependency of procurer in our case public procurer as dominant position of supplier is considered by authors mostly from negative aspect of increasing business risk leading often in lock-in or low performance procurement results. We have analyzed data from Slovak public procurement mainly by descriptive statistics to present simple view on relation between dependency and achieved

savings in public procurement with the motivation to increase research efforts in that area. Validation on data will provide opportunities for new data services in the field of decision support for procurers and spend management. Although, data are often suffering by low quality or very high complexity of problem.

As it is visible from our analyses, there is some evidence for claiming that higher dependency on supplier can have quite negative effect on savings achieved from negotiations, high complexity due to different market segments or other determinants call for wider research in this area. Although, the high dependency can lead to lower savings, in different situation there is quite higher volatility of savings achieved directly in each contract but also in aggregated average savings from previous contracts of public procurer. In general, there are still some advices to reduce related risks by increasing number of non-standard (new) suppliers. On the other hand, we must accept also natural dependency reflected by strong competitive position, good prices, flexibility or other determinants. Data and related multidimensional research methods may contribute to better understanding dependency from both sides to improve efficiency of decision making not only in public procurement.

4. Acknowledgement

The paper is written with support of APVV within the project No APVV-20-06089 “The research of behavioral patterns on big data within public and commercial procurement with negative impact on efficiency of procurement processes”

5. References

- Carr, A. S., & Kaynak, H. (2007). Communication methods, information sharing, supplier development and performance: An empirical study of their relationships. *International Journal of Operations & Production Management*.
- Handfield, R. B., Krause, D. R., Scannell, T. V., & Monczka, R. M. (2006). Avoid the pitfalls in supplier development. *Supply chains and total product systems: A reader*, 58, 25-44.
- Prahinski, C., & Benton, W. C. (2004). Supplier evaluations: communication strategies to improve supplier performance. *Journal of operations management*, 22(1), 39-62.
- Krause, D. R., Handfield, R. B., & Tyler, B. B. (2007). The relationships between supplier development, commitment, social capital accumulation and performance improvement. *Journal of operations management*, 25(2), 528-545.
- Li, W., Humphreys, P. K., Yeung, A. C., & Cheng, T. E. (2007). The impact of specific supplier development efforts on buyer competitive advantage: an empirical model. *International Journal of Production Economics*, 106(1), 230-247.
- European Court of Justice (ECJ) ruling in Bellini (C27/86)
- Mandt, T. (2018). Dependence in Buyer-Supplier Relationships – Present State and Future Perspectives. In: *Dependence in Buyer-Supplier Relationships*. Edition KWV. Springer Gabler, Wiesbaden. https://doi.org/10.1007/978-3-658-24252-7_2
- Schmitz, T., Schweiger, B., & Daft, J. (2016). The emergence of dependence and lock-in effects in buyer–supplier relationships—A buyer perspective. *Industrial Marketing Management*, 55, 22-34.

ANALYSIS OF PUBLIC PROCUREMENT SAVINGS IN V4

Michal Tkáč

Department of Corporate Financial Management
The Faculty of Business Economics with seat in Košice
The University of Economics in Bratislava
michal.tkac1@euba.sk

Michal Tkáč

Department of Quantitative Methods
The Faculty of Business Economics with seat in Košice
The University of Economics in Bratislava
michal.tkac@euba.sk

DOI: 10-35011/IDIMT-2022-219

Keywords

Public procurement, CPV, savings, Slovakia, Hungary, Czech Republic, Poland, V4

Abstract

The countries use public procurement to acquire sources for their institutions. These mechanisms aim to secure the lowest prices for products and services in most cases while meeting all the requirements. The performance of such a mechanism can be measured by savings defined as the difference between estimated prices and winning bids. This paper analyses the public procurement environment of four different countries known as the Visegrad Group by comparing the distribution of such savings. By comparing savings from more than a million contracts in twelve years, we use boxplot analysis and statistical tests to describe differences in the performance of the public procurement environment between countries. Moreover, we also analyse how the distribution of savings changes for EU-funded public procurement contracts and contracts procured by an electronic auction mechanism.

1. Introduction

Public procurement can be determined as the “overall process of acquiring goods, civil works and services, which includes all functions from the identification of needs, selection and solicitation of sources, preparation and award of contract, and all phases of contract administration through the end of a services’ contract or the useful life of an asset” (UNDP, 2010 Patrucco et. al, 2017). The countries, governments, and public administrations use public procurement as a key mechanism to obtain resources for their institution. The two main approaches frequently used to evaluate bids are the lowest bid price criterion and multi-criteria evaluation. The first type is preferred in Eastern European countries and the second type in Western countries. (Ochrana and Hrnčířová, 2015). Concretely work of Nemec, Mikušová Meričková and Grega (2014) showed that Slovakia, the Czech Republic and Poland represent the countries with the significantly higher portions (around

80% per country) of public procurement competitions which use lower price bids as evaluation criteria. Such criteria aim to secure the best (lowest) price while meeting the requirements set by the procurer. Because in the market economy the price is based on supply and demand, savings as a difference between the estimated price defined by the procurer (which can be understood as a price determined by demand) and the winning bid (which can be understood as the lowest price determined by supply), could be seen as an essential performance indicator for measurement efficiency of public procurement contracts. To improve this efficiency, the key characteristics of public procurement processes, request for tenders as well as closed procurement contracts have to be studied, analysed and compared with benchmarks (such as countries with similar socio-economic backgrounds). (García Rodríguez et al. 2019). This paper tries to provide such an analysis.

2. Methodology

The research in this paper focuses on the analysis of public procurement in the Visegrad Group (V4). It will primarily investigate procurement savings across different countries of V4 and different parameters of procurements. It can be divided into two parts. Firstly, we study differences in the distribution of procurements' savings in V4 countries. This is done through the boxplot analysis and statistical tests. Also, year-by-year changes in savings from 2009 to 2020 are investigated. The second part of the research compares differences in savings based on three parameters of procurements. The first parameter is the type of supply. It determines whether the procured items are works, supplies, or services. The other two parameters are binary and define whether the procurements were EU funded or whether the electronic auction was used as a procurement mechanism. The study is based on real procurement contracts realised in four countries (V4) during the 12 years. The data were acquired from countries' datasets published in opentender.eu portal. This portal collects data from 33 jurisdictions including EU member states. The initial dataset covering data from the Czech Republic (CZ), Hungary (HU), Poland (PL) and Slovakia (SK) has more than 6 million cases. According to the methodology of data collecting, for each of surveyed countries the opentender.eu platform collects data from TED and the national procurement database. For more information, see Hruby et al. (2018). The initial database was reduced to the research sample based on a few rules. In the first reduction, we deleted all cases that were not actual contracts. Then we delete all cases which do not have the estimated value of the contract and the value of the winning bid. These two variables were essential for the determination of savings from procurement. For the purpose of this study, savings from public procurement contracts represent the difference between the estimated value and the winning bid as a percentage of the estimated value. Due to the data discrepancy, we have also deleted all cases which procure more than one lot. The final step in the creation of the research sample was the elimination of outliers. This was done using the boxplot methodology. We estimated the second (Q2) and third (Q3) quartiles and created an interquartile range (IQR) for the whole sample. Savings higher than $Q3 + 1,5 * IQR$ or lower than $Q2 - 1,5 * IQR$ were considered outliers. The final sample has 1 083 153 cases. The distribution of savings in the research sample ranges from -45% to 58% with an average of 4,8%.

3. The research

As was mentioned in the previous part, research in this paper analyses the performance of the public procurement environment in four different EU countries. The research sample includes real procurements contracts from countries of Visegrad Group and it is covering 12 years period from 2009 to 2020. The performance is measured by variable savings, which represent a percentage

difference between the winning price and the estimated price of the contract. The motivation for this approach is to describe the differences in the distribution of savings from public procurement between countries. To characterize the distribution of public procurement's savings for each country, we use boxplot analysis, which is presented in Figure 1.

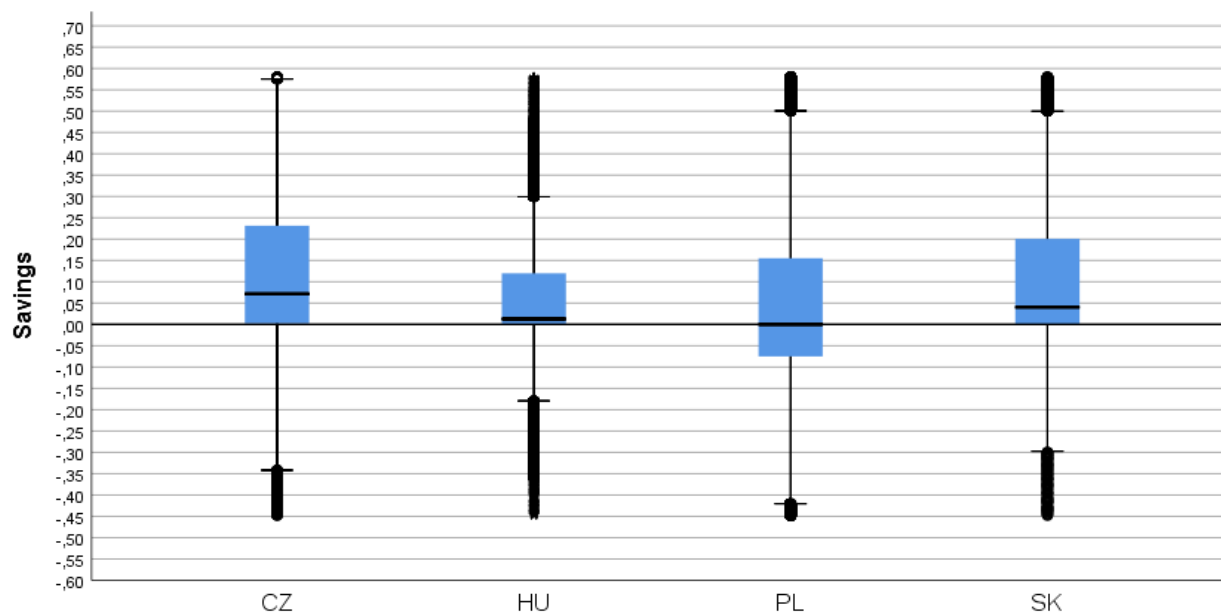


Figure 1: Boxplot analysis of the distribution of public procurement savings of V4 countries

As can be seen in Figure 1, there are differences in distributions of savings from one country to another. The lowest median of savings was found in Poland. The median value of procurement savings was zero. A slightly higher median value of 1% was found in Hungarian data. The median value of public procurement savings found in the Slovakian dataset was 4%. The highest median value was 7% and it was found in the Czechian dataset. The boxplot analysis also showed that apart from Poland in all other countries no more than 25% of contracts in the dataset have negative or zero savings. In the case of Poland quarter of contracts in the dataset have savings lower than -8%, which means that 25% of contracts have a winning price more than 8% higher than was estimated by the procurer. Moreover, zero median means that half of the analyzed contracts have negative or zero savings. The positions of the boxes in boxplots suggest that the highest savings can be found in Slovak and Czech datasets. The results showed that a quarter of analyzed contracts achieved more than 23% (in the case of the Czech Republic) and more than 20% (in the case of Slovakia) savings per contract.

To confirm that differences between savings are statistically significant, we used the Kruskal-Wallis test which on the significance level of $\alpha = 5\%$ tests the null hypothesis The distribution of Savings is the same across categories of Country. The results of the test are presented in Table 1.

Table 1: The results of the statistical test comparing distributions of V4's countries' savings

Hypothesis Test Summary				
	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Savings is the same across categories of Country.	Independent-Samples Kruskal-Wallis Test	,000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is 05.

The results of the Kruskal-Wallis test presented in Table 2, suggest that at significance level $\alpha = 5\%$ we can reject the null hypothesis of the same distribution of saving from Public procurement

contracts across different countries of V4. Moreover, the pairwise comparison showed that the null hypothesis of the same distribution of Savings was rejected at significance level $\alpha = 5\%$, for any pair of countries.

The next part of the research provides a more detailed analysis of the public procurement environment of the Visegrad group by focusing on year by year comparison of the distribution of savings. The boxplot analysis of such a comparison is presented in Figure 2. The motivation behind this investigation is to determine whether the distribution of savings in surveyed countries changes through the years.

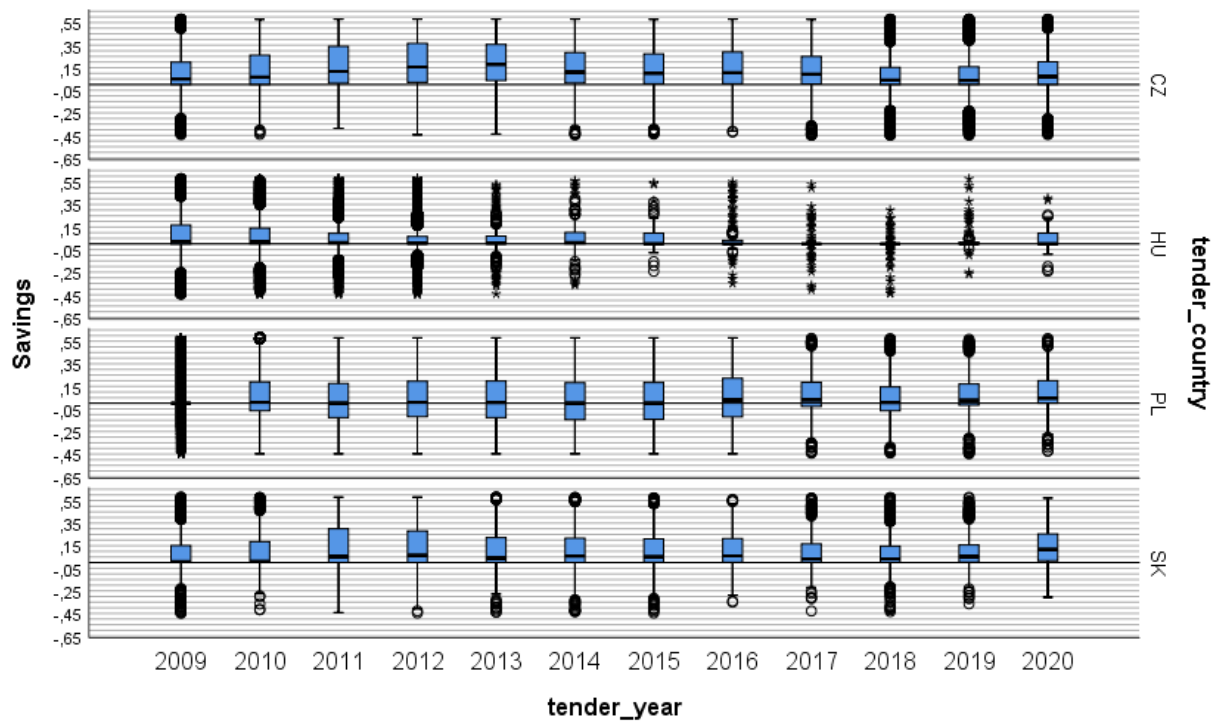


Figure 2: Boxplot analysis of yearly distributions of V4 countries' savings

As can be seen in Figure 2, the variability of the savings from public procurement is significantly changing over the 12 years. The boxplot analysis suggests that the highest variability of savings can be found in the six years from 2010 to 2016 for all surveyed countries. Moreover, it is very hard, to recognize any trend country-wise, because the medians of savings increase, decline, or stay the same from one year to another in random order. On the other hand, boxplots of savings showed that in the last two years (2019-2020) proportion of contracts with negative savings was less than 25% finally for all four countries. It should be also noted that during the year of lockdowns median savings from public procurement in Slovakia increased by more than 100%. During the 11 years before 2020, the median of savings in Slovakia does not overcome 6% but in 2020 median was 12%. Similar results can be found in Poland. Before 2020 the highest median of savings was 3%. The median of savings in 2020 was 5%. The differences between the savings in 2020 and savings in the previous years are not so significant for the other two countries.

The next step in the research was the analysis of savings based on the supply type. The motivation for this kind of investigation is to determine whether distributions of savings change significantly based on the country of public procurement. The results, in the form of boxplot analysis, can be found in Figure 3.

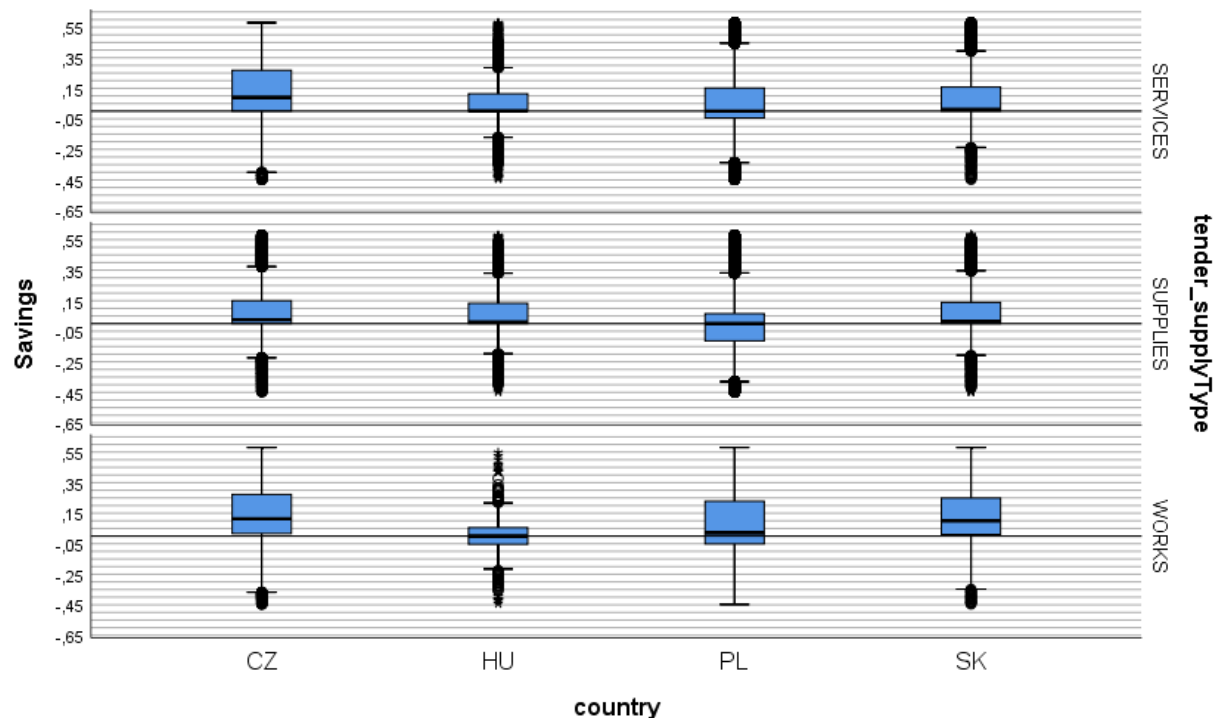


Figure 3: Boxplot analysis of savings based on country and supply type

The boxplot analysis presented in Figure 3, showed differences in the distribution of savings between countries. The statistical significance of differences was also confirmed by the independent sample Kruskal-Wallis Tests, which at a significance level of 5% reject the null hypothesis that the distributions of Savings are the same across categories of Country for all the types of supply, services, supplies, and works. All the tested hypotheses have p-values $<0,001$. Pairwise comparisons of the countries showed that for supplies and works statistical differences in distributions of savings were not confirmed in Slovakian and Czech data, because the null hypothesis in these cases could not be rejected at a 5% significance level (p-values $>0,05$). Another type of analysis consists of testing the differences in distributions of savings between types of supply for each country alone. The null hypothesis stating that the distribution of savings is the same across categories of supply type was rejected at a 5% level of significance (p-values $<0,001$) for each of the four tested countries. Detailed, pairwise comparisons of supply types showed that in the cases of Slovakia and Hungary the statistically significant differences cannot be confirmed for pair services and supplies because the null hypothesis in these cases could not be rejected at a 5% significance level (p-values $>0,05$).

The fourth type of analysis compares savings from public procurements contracts which were EU funded with savings from the contracts that were not. The motivation for this kind of research was to determine public procurement contracts that are funded from EU funds tend to have a different distribution of savings that public procurement contracts that are not. Boxplot analysis is presented in Figure 4.

The positions of boxplots and medians in Figure 4 suggest that the situation with parameters describing whether the contract is EU-funded is unique for each country. Czech Republic data shows that the distribution of savings from public procurement contracts does not seem to be different for EU-funded contracts and contracts that are not EU funded. This is also confirmed by the statistical test presented in Table 2.

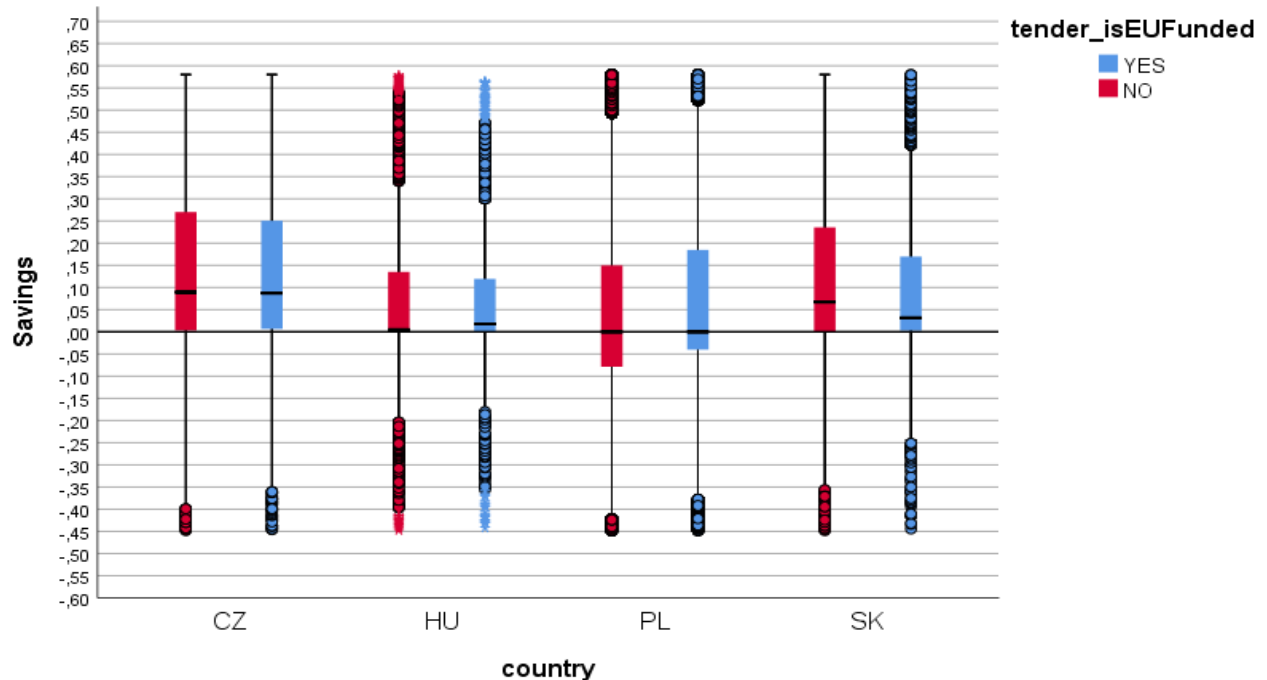


Figure 4: Boxplot analysis of savings based on country and source of funding

Based on the same table, it can be assumed that, for all other countries, the differences in savings between previously described groups of contracts are statistically significant at a 5% significance level. The position of median showed that in term of Slovakia, EU-funded public procurement contracts tend to have lower savings and the variability of savings is also smaller than it is in contracts which are not funded by the EU. In Hungary, EU-funded public procurement contracts seem to have higher savings than contracts that are not funded by the EU. In terms of Poland, the position of boxplots shows that public procurement contracts which are not funded by the EU seem to have a higher ratio of savings that are negative than the contracts that are funded by the EU.

Table 2: The results of the statistical test comparing distributions of V4's countries' savings based on the source of funding

Hypotheses Test Summary				
	Null Hypothesis	Test	Sig.	Decision
CZ	The distribution of Savings is the same across categories of tender_isEUFunded.	Independent-Samples Mann-Whitney U Test	0,792	Retain the null hypothesis.
HU	The distribution of Savings is the same across categories of tender_isEUFunded.	Independent-Samples Mann-Whitney U Test	0,001	Reject the null hypothesis.
PL	The distribution of Savings is the same across categories of tender_isEUFunded.	Independent-Samples Mann-Whitney U Test	0	Reject the null hypothesis.
SK	The distribution of Savings is the same across categories of tender_isEUFunded.	Independent-Samples Mann-Whitney U Test	0	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is 05.

The last part of the research is analysing differences in savings from public procurement based on the use of electronic auctions as a procurement mechanism. The motivation behind this type of research is to determine whether the use of electronic auctions has an impact on savings from public procurement contracts. The boxplot analysis of the distribution of savings is presented in Figure 5.

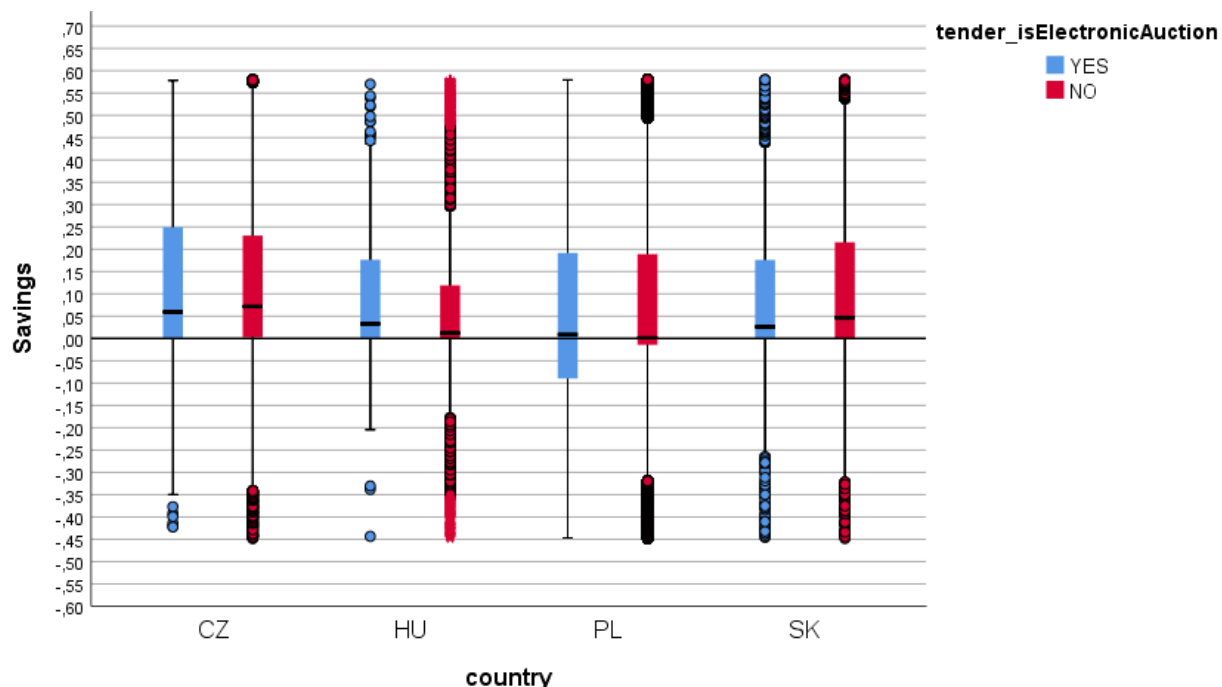


Figure 5: Boxplot analysis of savings based on country and type of procurement mechanism

The results presented in Figure 5 show that the use electronic of auctions does not have the same uniform impact on the distribution of savings from public procurement contracts. First of all, it should be noted that based on the results of hypotheses testing presented in Table 3, there are statistically significant differences (at a significance level of 5%) in the distribution of savings between the public procurement contracts that use electronic auction mechanism and public procurement contracts that do not use it. The position of the mean suggests that in the case of Slovakia and the Czech Republic savings from public procurement contracts procured by electronic auction seem to be lower than savings from public procurement contracts which do not use this mechanism. In Hungary and Poland, the situation is the opposite and procurement with the use of electronic auction seems to provide higher savings. The data also showed that the majority of public procurement contracts, which have negative savings were procured using an electronic auction mechanism.

Table 3: The results of the statistical test comparing distributions of V4's countries' savings based on the type of procurement mechanism

Hypotheses Test Summary				
	Null Hypothesis	Test	Sig.	Decision
CZ	The distribution of Savings is the same across categories of tender_isElectronicAuction.	Independent-Samples Mann-Whitney U Test	0,045	Reject the null hypothesis.
HU	The distribution of Savings is the same across categories of tender_isElectronicAuction.	Independent-Samples Mann-Whitney U Test	0,004	Reject the null hypothesis.
PL	The distribution of Savings is the same across categories of tender_isElectronicAuction.	Independent-Samples Mann-Whitney U Test	0	Reject the null hypothesis.
SK	The distribution of Savings is the same across categories of tender_isElectronicAuction.	Independent-Samples Mann-Whitney U Test	0	Reject the null hypothesis.
Asymptotic significances are displayed. The significance level is 05.				

4. Conclusion

The research in this paper is based on an analysis of real procurements contracts from four countries of Visegrad Group. By comparing savings from more than a million contracts in twelve years, we use boxplot analysis and statistical tests to describe differences in performance of the public procurement environment between countries of the Visegrad Group. Results showed that there are statistically significant differences in the distribution of savings from one country to another. The highest savings can be found in the Czech Republic, the lowest in Poland. Besides Poland, all other three countries, have according to our data, a proportion of contracts with negative savings lower than 25%. The comparison of distributions of savings from one year to another seems to be random do not show any trend for all reviewed countries. In terms of the type of supply, analyses showed significant differences in distribution savings across countries for all types of supplies. On the other hand, the test did not confirm significant differences in savings between the Czech and Slovak datasets when comparing types of supply such as supplies and works. From the perspectives of countries, in the Hungarian and the Slovakian dataset we could not find statistically significant differences between the distribution of savings among supply-type services and supply-type supplies. The research also provides some ambiguous results, regarding the impact of the use of electronic auction mechanisms on savings from public procurement contracts. The impact seems to differ from one country to another.

5. Acknowledgement

The paper is written with the support of APVV within project No APVV-20-06089 “The research of behavioral patterns on big data within public and commercial procurement with negative impact on efficiency of procurement processes”

6. References

- García Rodríguez, Manuel J., et al. Public procurement announcements in Spain: regulations, data analysis, and award price estimator using machine learning. Complexity, 2019, 2019.
- Hrubý, Jan, Pošepný, Tomáš, Krafka, Jakub, Toth, Bence, Skuhrovec, Jiří The Digital Whistleblower: Fiscal Transparency, Risk Assessment and the Impact of Good Governance Policies Assessed Work Package: 2 - Data Collection and Cleaning, 2018 Available at: <http://digiwhist.eu/wp-content/uploads/2018/03/D2.8-revised-version-FINAL.pdf>
- Nemec, Juraj; Mikušová Meričková, Beáta; Grega, Matúš. Contracting, outsourcing, procurement: selected factors limiting their success in the CEE region. 2014.
- Ochrana, František; Hrnčířová, Kristýna. Does the lowest bid price evaluation criterion make for a more efficient public procurement selection criterion? (Case of the Czech Republic). NISPAcee Journal of Public Administration and Policy, 2015, 8.1: 41-59.
- Patrucco, Andrea Stefano; Luzzini, Davide; Ronchi, Stefano. Research perspectives on public procurement: Content analysis of 14 years of publications in the journal of public procurement. Journal of Public Procurement, 2017.
- UNDP (2010). Public Procurement Capacity Development Guide. New York: United Nations Development Programme.

COMPARISON OF ELECTRONIC INVOICING ADOPTION BEFORE AND AFTER COVID-19 PANDEMICS IN EUROPEAN UNION

Michal Tkáč, Jakub Sieber

The University of Economics in Bratislava
michal.tkac1@euba.sk, jakub.sieber@euba.sk

DOI: 10-35011/IDIMT-2022-227

Keywords

e-invoicing, eCommerce, digitization, SMART administration

Abstract

This paper presents the results of electronic invoicing adoption and eCommerce turnovers in European Union enterprises between the years 2018 and 2020. Given the changes in e-invoicing adoption at national levels, the possible drivers of change are examined. As key explanatory variables are analyzed two sets of predictors. The first set is describing the overall embrace of ICT, digital skills, and innovations. The second set contains predictors describing the effects of changes related to the digitalization of enterprises. The results of the paper showed that enterprises from EU countries using e-invoicing on a smaller scale before 2018 are nowadays implementing more. Results showed that countries where at least one-third of enterprises are using e-invoicing also experienced higher growth in e-commerce turnovers, and cross-border sales, and the variability of eCommerce turnovers are lower in countries, where is a higher rate of e-invoicing adoption.

1. Introduction

Digitization of business processes as well as providing government services through various online platforms remains one of the pillars of the European Union (EU) strategy. Implementation and adoption of electronic invoicing (e-invoicing) is one part of the EU's long-term strategy to achieve faster payments, decrease storage expenses, and minimize the dependence on physical delivery. According to (Cepparulo & Zanfei, 2019) e-services, such as e-invoicing fall under the umbrella term "eGovernment," and have received far less attention than services that respond more directly to users' requirements, such as eHealth, transportation/info mobility, and eProcurement. This implies a weak awareness of the current and potential impact of new technology on the delivery of commonly used services affecting businesses' daily lives.

Large organizations have been automating their invoicing processes for the past two decades to benefit from the cost reductions, time savings, and efficiency that electronic invoicing can give. In the event of widespread adoption, these benefits might have a significant impact on the European economy as a whole (Veselá & Radiměský, 2014). E-invoicing may also be more appealing to businesses with a high volume of invoices (Hernandez-Ortega, 2012). In a measure of productivity, unmeasured business heterogeneity, such as variations in manufacturing technology and staff abilities, becomes obvious (Bartelsman & Doms, 2000). This indicates that those that can efficiently utilize their production capacity are more likely to issue e-invoices. Furthermore,

enterprises with expertise in e-invoicing, special client needs, and established ICT infrastructures (connection to high-speed internet) are expected to participate more actively. In line with the growing concern about ICT dissemination in the public sector, a great number of empirical studies have used a range of approaches to create evidence for the growth of new digitalized public services (Arduini & Zanfei, 2014; Wirtz & Daiser, 2018). Nonetheless, cross-national, and intra-national comparative studies face significant data restrictions and are generally reliant on surveys and benchmarking analyses. Companies are striving to automate their financial operations, and electronic invoicing and payment systems have been sluggish to catch on, even though they provide speed, transparency, and cost benefits (Berez et al., 2007).

In order to enhance the attainment of the Europe 2020 Strategy in the Digital Agenda, the European Commission agreed to make e-invoicing essential for the public sector in the event of public procurement. Electronic invoicing is rapidly becoming the main method of data sharing. Companies that wish to be competitive must be prepared for the global market's inevitable evolution. According to the European Commission, the main advantages of implementing e-invoicing for enterprises are: decreased printing and shipping expenses; faster recovery of money from clients by minimizing the time an invoice or payment is in the mail; electronic invoices can be immediately routed into a company's payment and accounting systems, allowing for faster and less expensive processing; storage expenses are reduced; costs of training and system development decreased.

E-invoicing, on the other hand, presents challenges such as e-invoicing can be created in a variety of forms and according to a variety of standards. This obstructs the easy transfer of an e-invoice from one location to another, preventing the full benefits and cost savings of e-invoicing because of differences in national standards governing the legal, financial, and administrative validity and acceptability of e-invoices. This makes their usage in cross-border transactions inside the EU challenging since many potential users are concerned about e-invoicing systems' security and the possibility of fraud misrepresentation. According to conceptual assessments, using e-invoices is directly helpful to businesses since it boosts their productivity, lowers their expenses, and makes them less geographically reliant (Koch, 2016). E-invoicing is inextricably tied to supply chain activities across the procure-to-pay and order-to-cash lifecycles, therefore it makes logical to include it in the procurement context (Taylor, 2013).

2. Methodology

Several ICTs features are classified not just as innovations but also as general-purpose technologies, even though complementing applications that integrate a firm's internal operations with the commercial system (such as e-invoicing and eCommerce) are more hazily conceptualized in the literature. There is no overarching theoretical foundation for e-invoices. E-invoicing might be viewed through the lens of the diffusion of innovations notion (Penttinen, 2008), which holds that development occurs in phases (Rogers, 2010). As a theoretical starting point, Hernandez-Ortega (2012) adopts a combination of the Innovation and Technology Acceptance models (Davis, 1989). If e-invoicing systems are considered technical advances, they will evolve in stages until widespread adoption is achieved. Due to the consequences of the COVID-19 pandemics breakout and various lockdowns, social distancing, and measurements, the whole society had to change the way they approach different activities, not only enterprises. In the presented paper we refer to a state (company's environment) capacity to embrace an ICT innovation, as an intensity (or use) of e-invoicing as a percentage of companies that adapt to e-invoicing and the amount to which they do so (similarly to OECD, 2004). Changes in behavior, economic structure, or performance as a result of use are referred to as impact or effect, in this paper we measure mentioned effect as a percentage of eCommerce sales turnovers.

In this paper, we examine the change in the adoption of e-invoicing in EU member states, excluding Great Britain. The analysis is conducted by assessing two snapshots of time. The first and base period is in 2018 – referred to as a pre-COVID-19 state of examined indicator. The comparison is done against the state in 2020, which is referred to as a period when the whole Europe (World) economy was highly influenced by COVID-19 pandemics. Besides mentioned dependent variable there is also an observed set of predictors (see *Tab. 1*), which are sorted into two components (C1 and C2). C1 describes the ability of an economy (company's environment) to embrace ICT innovations. C2 contains a set of predictors describing the effect of changes in behavior related to the digitalization of enterprises. *The main research question (RQ)* of the proposed paper is to analyze and claim if there statistically significant change in the adoption of e-invoicing (EIA) and change in eCommerce turnovers (eCT) within EU member states. *The second RQ* is what component is showing greater association with EIA and eCT. *The third RQ* is to determine the trend within EU countries of EIA if countries with lower overall EIA are implementing e-invoicing at a different scale about the eCommerce turnover of enterprises in the common EU market.

2.1. Methods used and data description

For a description of changes between observed periods, there is used Wilcoxon signed-rank test for related samples for statistical significance of observed changes in EIA and eCT. Next, we use features of exploratory data analysis such as boxplot analysis and correlation heat map. There are two primary data sources for this paper: i) Eurostat Database and ii) European Innovation Scoreboard Database. Obtained data are describing two periods' observations, starting in 2018 as a pre-COVID-19 baseline and are compared to values in 2020 as post-COVID-19 changes. Table 1 below describes examined variables.

Table 1 Description of analyzed variables

Variable	Description	Component
EIA	Adoption of electronic invoices by enterprises	dependent variable
eCT	Percentage of enterprises turnovers coming from eCommerce sales	
ICTs	Employed ICT specialists - ISCO-08 classification	C1
ICTg	Individuals with a degree in ICT	
ICTu	Rate of ICT adoption according to European Innovation Scoreboard	
BDS	Individuals with 'basic' or 'above basic' digital skills	
BSS	Individuals with 'basic' or 'above basic' software skills	
EIT	Enterprises that provided training in ICT to their personnel	
FiveG	The amount of spectrum assigned and ready for 5G use	
R&D	Digitization research financed in total per inhabitant	
MDS	Number of mobile data subscriptions per 100 people	
SCB	SMEs that carried out electronic sales to other EU countries	C2
SMEon	SMEs selling online	
FourG	Populated areas with coverage by 4G	
EIS	European Innovation Score of digitalization adoption	
CCS	Enterprises purchasing at least one cloud computing services	
BDU	Enterprises analyzing big data from any data source	

3. Results

Bellow on *Figure 1*, it is possible to observe the aggregate rate of EIA in EU countries as reported by the end of 2020. Looking at individual EU member states, the biggest EIA is observed in Finland reaching almost 80% of all enterprises, followed by Slovenia (62%), and Denmark (55%). The countries from Visegrad 4 region are reporting EIA at the level of around 15% of all enterprises. *Tab. 2* shows the results of the Wilcoxon signed-rank test for our sample regarding the change of EIA. The Wilcoxon signed-rank test was carried out for related samples of observed variables in two time periods to statistically test the significance of the change in EIA and eCT.

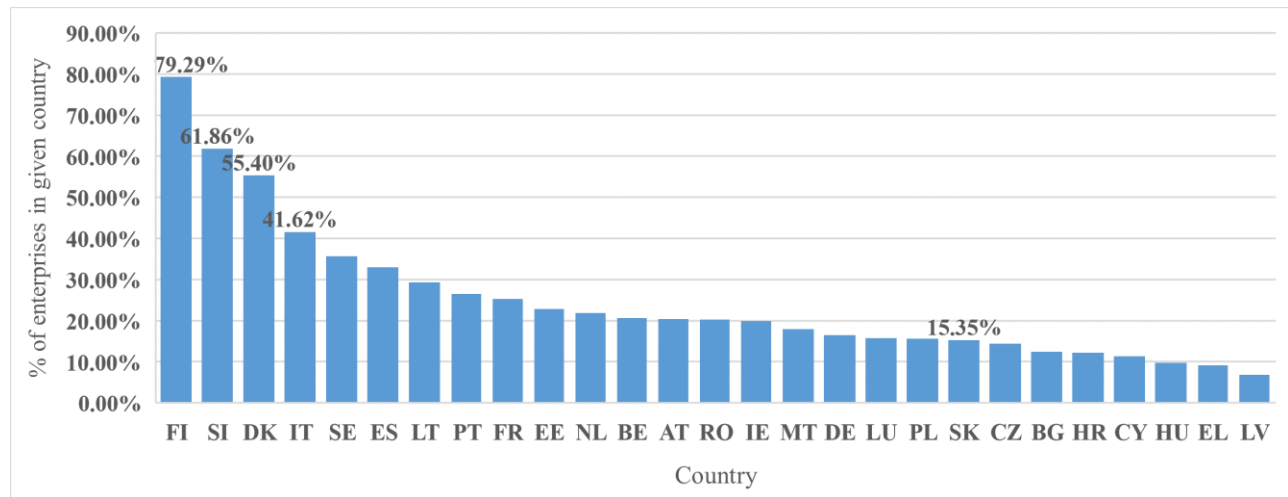


Figure 1 Percentage of EIA by enterprises in EU countries

Table 1 Wilcoxon signed-rank test for related samples of e-invoices adoption and eCommerce turnovers

	Null Hypothesis	Test	Sig.	Decision
1	The median of differences between EIA18 and EIA20 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,850	Retain the null hypothesis.
1	The median of differences between eCT18 and eCT20 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,031	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is ,05.

According to Wilcoxon's signed-rank test in *Tab 2*. We might retain the null hypothesis as the median of differences between the EIA in 2018 and 2020 is not statistically significant. In the case of eCT we can reject the null hypothesis as the median of differences between the observed values in 2018 and 2020 is statistically significant. Therefore, it might be claimed that changes in eCommerce turnovers were not influenced by implementing electronic invoices. In *Figure 2* below is a histogram of the observed changes in eCT. It is possible to claim that the most frequent change in eCT was in the range of 0 to 2%. In general, the positive change in the eCT of the EU enterprises was observed in 18 member countries, while 9 countries experienced a decrease in their enterprise's eCommerce turnovers. Despite the fact, that COVID-19 restrictions were considered to favor electronic sales, according to the results it might be claimed that enterprises in one-third of EU member states experienced a decrease in their eCommerce turnovers during the pandemic (*Figure 2*).

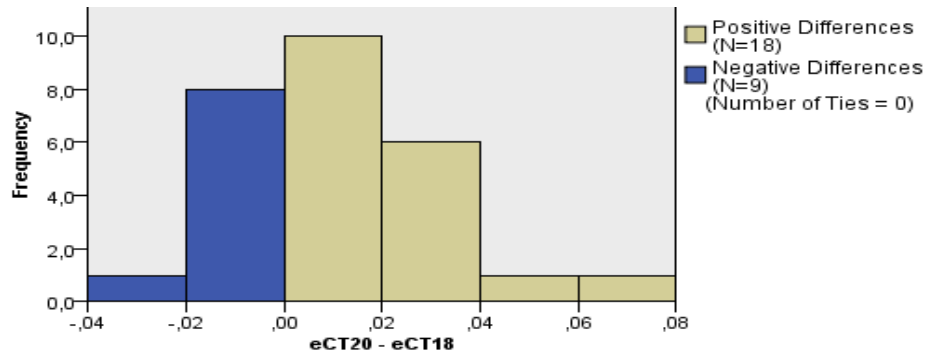


Figure 2 Histogram of eCT changes between the years 2018 and 2020

Figure 3 below illustrates the changes in EIA and eCT in enterprises between the years 2018 and 2020 within the EU member states. The presented scatter plot is in line with the Wilcoxon signed-rank test results. It is observable that changes in the vertical dimension of EIA are not as visible as the horizontal assigned to eCT. The biggest gainers of eCT are enterprises in Ireland, the Czech Republic, Denmark, and Sweden.

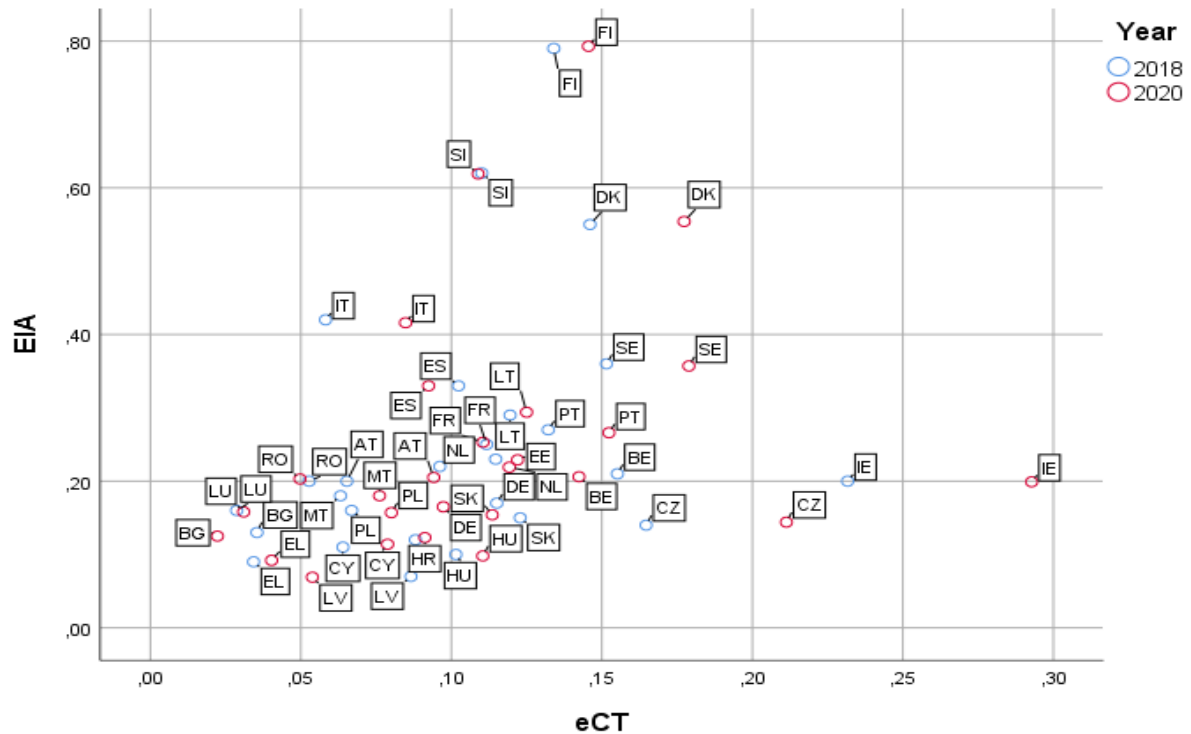


Figure 3 Scatter plot of EIA and eCT changes within EU member states between the years 2018 and 2020

While analyzing the relationship between eCT and EIA (Figure 4), according to the analysis between the years 2018 and 2020, the greatest change was observed in countries with EIA greater than 33%. The median value of eCT change in countries with an EIA rate greater than 33% was 1.9%, while in countries with EIA less than 10% it was 0.5%. The boxplot in Figure 5 shows the change in cross-border sales to the percentage of enterprises using e-invoices. Median positive changes in cross-border sales to other EU countries were observed in countries with EIA ranging higher than 10% overall.

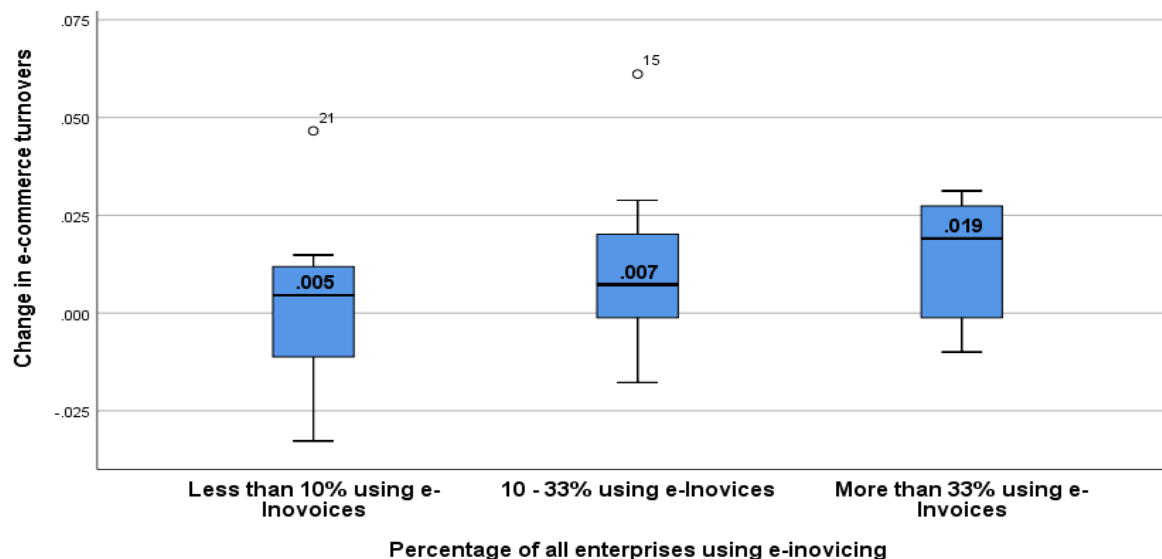


Figure 4 Boxplot of change in eCommerce to the percentage of enterprises using e-invoicing

However, as it can be seen in *Figure 5* the countries with EIA higher than 33% have experienced a slower increase in cross borders sales, with a median change around +0.5%, while the countries in the range of 10-33% experienced median growth by +0.8%. Both presented boxplots in *Figure 4* and *Figure 5* suggest lower variability of eCT in countries, where is the degree of EIA more than 33%.

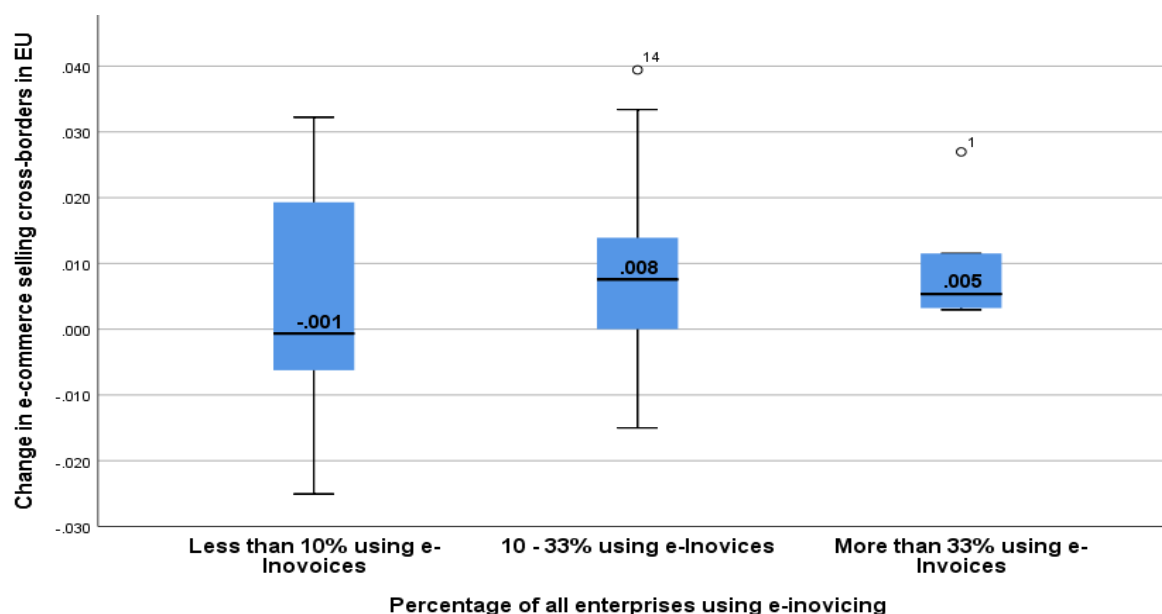


Figure 5 Boxplot of change in cross border sales to the percentage of enterprises using e-invoices

Following *Tab. 3* includes only statistically significant Spearman's Rho correlation coefficients, as the first column describes tested correlation with eCT and set of predictors, while the fourth column shows the correlation of predictors with EIA. Correlations are divided by the observed year. While observing correlations of eCT, it is possible to claim, that correlation with ICTs and SMEon has increased by the highest value. In general, the results in *Tab.3* show an increase in both components of predictors. From *Tab.3* it can be observed that the EIS score shows significant relation to both eCT and EIA, suggesting that the status of a "digital innovator" is not closely related to EIA.

Table 3 Correlation table of chosen predictors with dependent variables in the years 2018 and 2020, * - correlation is significant at 0.05 level, ** - correlation is significant at 0.01 level.

eCT	2018	2020	EIA	2018	2020
EIA	.42*	.5**	eCT	.42*	.5**
ICTs	.383*	.564**	ICTs	.476*	.522**
ICTu	.492**	.511**	ICTu	.412*	.424*
BDS	.466*	.555**	BDS	-	.473*
BSS	.452*	.506**			
EIT	.433*	.516**	R&D	.452*	.426*
SCB	.521**	.622	SMEon	.484*	.441*
SMEon	.584**	.832**			
EIS	.487**	.541**	EIS	.587**	.649**

Results presented in *Tab. 3* also show that eCT was strongly correlated with small and medium enterprises selling online, increasing from .584 to .832 in 2020, suggesting the association and share of eCommerce turnovers of SMEs to aggregate national turnover of enterprises resulting from selling online.

4. Conclusion

In the presented paper we examined the changes in e-invoicing adoption and eCommerce turnover within 27 EU member states. When analyzing the changes in dependent variables between the years 2018 and 2020 and the changes in two sets of predictors – C1 standing for embracing ICT innovations, and C2 standing for the effect of changes in the behavior of enterprises as the national economy transform into digitalization. However, Wilcoxon's test showed that changes in examined variables are statistically significant only in terms of eCT. As presented in 3, there is observed a significant change in eCommerce turnovers, but that is not led by the higher implementation of e-invoicing in EU member countries.

When comparing the effects of digital transformation at national levels (C2) there is evidence that in countries, where was overall EIA rate was over 10%, the increase of eCommerce turnover was higher than 0.5%. The median value of change in countries with EIA rates in the range from 10 to 33 percent was +0.7%. In the countries with an overall EIA rate higher than 33%, there is observed the most significant growth of eCommerce turnovers, with a median value of change of +1.9% (*Figure 4*). In Aboutommerce, there is also observed similar behavior of positive correlation between the increase in enterprises selling online (at least 1% of turnover is coming from electronic sales) and an increase in EIA. The mentioned effect is also influenced by the COVID-19 pandemic and its consequences of lockdowns and social distancing, as the businesses were forced to implement online services to sustain their operability and competitiveness. Results presented in *Figure 4* and *Figure 5* suggest an association of higher eCT for enterprises with a higher degree of EIA, also connected with smaller variability of eCT. The correlation table (*Tab. 3*) is showing positive associations of examined predictors from C1 to EIA during the COVID-19 pandemics, however, when comparing correlation coefficients with the period before COVID-19, the associations are showing stronger relations, with exception of SMEon and R&D. The role of SMEs in national turnover from eCommerce has experienced the most significant increase.

Further research should be more focused on national legal frameworks, directives governing sales, and administrative validity and acceptability of e-invoicing, especially in the online environment of EU countries, which may show higher importance than general indicators of the digital environment. On the other hand, the EIA rate showed a positive association with eCommerce and

the enterprise's online sales during the selected period. An interesting fact is that EIA growth is not showing a positive association with the growth of cross-border sales among EU countries, which is not in line with goals the EU has set for inclusive and connected markets of all its member states.

5. Acknowledgement

The paper was written with the support of VEGA 1/0873/21 The socio-economic potential of data sharing as a tool to support smart supply chain management.

6. References

- Arduini, D., & Zanfei, A. (2014). An overview of scholarly research on public e-services? A meta-analysis of the literature. *Telecommunications Policy*, 38, 476-495.
- Bartelsman, Eric, J., & Mark Doms. (2000). "Understanding Productivity: Lessons from Longitudinal Microdata." *Journal of Economic Literature*, 38 (3): 569-594.
- Berez, S., & Sheth, A. (2007). Break the paper jam in B2B payments. *Harvard Business Review*, 85(11), 28.
- Cepparulo, A. & Zanfei, A. (2019). "The diffusion of public eServices in European cities," Working Papers 1904, University of Urbino Carlo Bo, Department of Economics, Society & Politics - Scientific Committee - L. Stefanini & G. Travaglini, revised 2019.
- Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, 13(3), 319-340.
- European Commission. 2021. Internal Market, Industry, Entrepreneurship, and SMEs: e-invoicing. Retrieved from: http://ec.europa.eu/growth/single-market/public-procurement/digital-procurement/e-invoicing_en
- Eurostat. (2017). Digital economy and society statistics – enterprises. Retrieved from: http://ec.europa.eu/eurostat/statistics-explained/index.php?title=Digital_economy_and_society_statistics_-_enterprises#Access_and_use_of_the_internet
- Hernandez-Ortega, B., Jimenez-Martinez, J. (2013). Performance of e-invoicing in Spanish firms. *Inf Syst E-Bus Manage* 11, 457-480.
- Koch, B. (2016). E-invoicing/E-billing. *Digitisation & Automation*, Will.
- Mirabella, N., Rigamonti, L., & Scalbi, S. (2013). Life cycle assessment of Information and Communication Technology application: a case study of dematerialization in the Italian Public Administration. *Journal of cleaner production*, 44, 115-122.
- OECD. (2004). In: Pilat, D. (Ed.), *The Economic Impact of ICT, Measurement, Evidence, and Implications* (Paris). Retrieved from: <http://www.oecd.org/sti/theeconomicimpactofictmeasurementevidenceandimplications.htm>
- Penttinen, E. (2008). *Electronic invoicing initiatives in Finland and in the European Union: Taking the steps towards the real-time economy*. Helsinki: Helsinki School of Economics.
- Rogers, E. M. (2010). *Diffusion of innovations*. Simon and Schuster.
- Taylor. (2013). E-invoicing target for EU Directive. *Credit Management*, 7. Retrieved from: <http://www.accaglobal.com/content/dam/acca/global/PDF-technical/other-PDFs/Electronic-invoicing-the-next-steps-towards-digital-government-2014.pdf>
- Veselá, L., & Radiměský, M. (2014). The development of electronic document exchange. Enterprise and the Competitive Environment 2014 conference, ECE 2014, 6-7 March 2014, Brno, Czech Republic. *Procedia Economics and Finance* 12 (2014) 743 – 751.
- Wirtz, B. W., & Daiser, P. (2018). A meta-analysis of empirical e-government research and its future research implications. *International Review of Administrative Sciences*, 84(1), 144-163.

SELECTED VIEWS ON EATING HABITS AND LIFESTYLE CHANGES OF CONSUMERS DURING THE COVID-19 PANDEMIC THROUGH THE OPTICS OF SUPPLY CHAINS

František Pollák

Faculty of Business Management
University of Economics in Bratislava
Faculty of Corporate Strategy
Institute of Technology and Business in České Budějovice.
frantisek.pollak@euba.sk.

Peter Markovič, Róbert Világi

Faculty of Business Management
University of Economics in Bratislava
peter.markovic@euba.sk.

DOI: 10-35011/IDIMT-2022-235

Keywords

pandemic, supply chain, food delivery, e-commerce, low carbon economy, reputation

Abstract

The global pandemic has changed the habits of both sides of the market. The study maps selected changes in the lifestyle of Czechs and Slovaks. Specifically, it focuses on examining changes in the eating habits of customers who have been under the pressure of social distancing and re-closure of the mortar and brick businesses forced to move their interactions dominantly into the virtual world. The concept of food delivery has taken on a new dimension in these conditions, which in combination with companies and services operating based on a shared economy has created completely unique and ideal situation for the renaissance of this sector. The theoretical overview combined with the empirical analysis of the online reputation of the main players in the food delivery industry in the monitored markets compared to the leaders of the industry from the United States created a starting point for the following comprehensive research of the reputation of companies operating in a shared and low carbon economy.

1. Introduction

Food in human life is not just a necessary supplement to fats, sugar and proteins. Food rituals have played an important role in the lives of individuals or groups since the early days of society. Sharing the time during which food is consumed, or sharing food as such, helped to form basic social units in the early stages of society's development. Rituals associated with the procurement, preparation or consumption of food are among the oldest preserved and documented evidence of

conscious human activity. It is therefore no surprise that this area of human life has undergone a major stress test in the early days of the global COVID-19 pandemic. Social distancing combined with a slowing economy of mortar and brick should have prevented the massive spread of the disease. Almost from evening to morning, the traditional operations closed and both sides of the market faced a seemingly insurmountable situation. As always in history, the market has managed to adapt. At the time of the physical separation, the delivery companies provided a solution to the problem of proximity. The food delivery area was not left out. The restaurants were thus given the opportunity to provide their services without the need for the customer's physical presence in their operations. The presented study maps the initial market conditions, which are described through the analysis of the state of knowledge in the issue, as the real state of the market through the eyes of a model customer. From the point of view of the realized empirical part of the study, we map the market response in the form of polarity of search results of specific market subjects through the google search platform by a simple analysis of sentiment. The market is represented by the main players in the industry in the Czech Republic and Slovakia, where we compare the results with respect to the measured characteristics of the market leaders operating in the United States. The main motivation for the elaboration of the study is the compilation of a basic knowledge base for further comprehensive research of the issue. From the point of view of the construction of the study, the introduction moves smoothly into the analysis of the state of knowledge. This is followed by the methodological part of the study, which presents the object of research, as well as the described starting apparatus for data acquisition and processing. The presentation of the research results is complemented by a discussion and conclusion, which concludes the study by defining areas for further research.

2. Analysis of the state of knowledge

The initial precondition for carrying out the study is the existence of significant changes in consumer behavior caused by external factors. Gao et al. (2020) examined the impact of COVID-19 on online food purchases. In his study, he found that the proportion of confirmed COVID-19 cases increased the proportion of online food purchases. However, this behavior was more likely among young people living in large cities. At the same time, it is possible to monitor the lower perceived risk of online purchases for these customers. Lv et al. (2020) argue that e-commerce has become the first choice for customers in the context of the global economic downturn caused by COVID-19. Many marketers have decided to launch promotional activities through some social media platforms. Sheth (2020) states that consumer habits have been disrupted by the COVID-19 pandemic, which has resulted in repeated closures and the introduction of a social distancing policy. Consumers thus learned improvisation and new habits. As consumers could not go to the store, the store came to their home. Wang et al. (2020) described a situation in which consumer behavior related to food supply is driven by a subjective perception of risk and a set of multiple motivations. In most cases, larger food stocks are created by high-income consumers, university-educated people and women, while consumers' willingness to pay for fresh food stocks is determined by income. Barska and Wojciechowska-Solis (2020) state that in the context of the constant development of consumer awareness of sustainable development, sustainable development has spread to food markets. For consumers, food decisions are increasingly becoming an opportunity to showcase their specific value system. Local food is gaining popularity, which consumers perceive as healthier, unprocessed and less preservative. It also requires the use of fewer natural resources, leading to a lower ecological footprint. Li and Hallsworth (2020) state that the outbreak of the COVID-19 pandemic in China has caused significant levels of change in consumer behavior, with farmers' markets losing most of their customers, while small local independent retailers have seen the highest levels of resilience. Hambalíková (2020) states that in terms of changing the shopping

behavior of Czechs on the Internet in terms of online food sales, in the beginning of the pandemic, increases in turnover of companies providing services in this sector grew by hundreds of percent. This category was expected to continue to grow due to the limited movement of people. It is therefore not uncommon for the food supply industry to have experienced ideal business conditions at the beginning of the pandemic. The element of shared economy has been complemented by an element of low-carbon modes of transport, which has brought the service offering even closer to trends in increasingly sophisticated customer preferences. At this point, it is possible to move on to the second of the dominant but fully complementary aspects of the issue. This is an aspect of digitization and the reputation of entities in the online environment. The online environment, especially if it is an environment that allows or supports online shopping, has its own specifics. Ayaburi and Trek (2020) state that privacy protection fundamentally determines consumer confidence. Buhalis et al. (2020) state that internal variables have a greater impact on consumers than external variables. Karampela et al. (2020) argue that brand interactivity has a positive effect on strengthening the B2C level of trust, which increases its perceived quality through its presence in the online environment. Shao et al. (2019) state that reputation is an important prerequisite for the establishment or strengthening of customer confidence, while Lv et al. (2020) point to the fact that the main motivation for buying on low-reputation e-commerce platforms is a discount on the price. Therefore, if we assume the optimization of economic indicators towards higher efficiency of spending resources, a positive reputation is a determining factor in market success. The issue of reputation in terms of trust building has been examined in both domestic and international conditions (Delina, Tkáč, 2010; Delina 2014; Dorčák, Pollák, Szabo, 2014). Regarding the phenomenon of digitization in general, we find a theoretical framework in studies examining the issue in its holistic form (Maryška, Doucek, Kunstova, 2012; Zgodavova et al., 2020). From the point of view of the initial theoretical framework for the issue of marketing communication, we build on our own studies carried out in the previous decade (Štefko, Dorčák, Pollák, 2011; Dorčák, Štrach, Pollák, 2015; Soviar et al., 2019). We are intensively investigating the phenomenon of changes in consumer behavior affected by the COVID-19 pandemic in a comprehensive study that confirms the onset of new trends (Pollák et al., 2022). By summarizing the presented knowledge, it is possible to confirm the high topicality of the issue, as well as its validity for deeper empirical research. The first phase of such research is a standard review of basic qualitative indicators. In this case, these are qualitative indicators in the form of the level of online reputation of selected industry representatives in two selected and one reference market. The results of the analysis will provide us with a realistic view of the establishment of entities in emerging markets, especially in comparison with the reference market, in which the examined sector has a realistically developed nature. From the analyzed state of knowledge, the chosen method of simple sentiment analysis is offered as an accessible and reliable research tool for the initial examination of the issue. After summarizing the knowledge from the theoretical analysis, it is possible to proceed to the empirical part of the presented study.

3. Objectives and methods

The study maps selected changes in the lifestyle of Czechs and Slovaks. Specifically, it focuses on examining changes in the eating habits of customers who have been under the pressure of social distancing and re-closure of the mortar and brick businesses forced to move their interactions dominantly into the virtual world.

The main goal of the study is to compile a basic knowledge base for further comprehensive research in the field. This goal can be decomposed into two complementary levels, namely (i) to examine the current situation on the basis of the available literature, (ii) to carry out an empirical

qualitative study to identify the specifics of local emerging markets with respect to the reference market with a highly developed nature.

The object of the research are business entities operating on the basis of a shared economy, whose object of business is defined predominantly by the delivery of food from third parties. These are therefore service businesses that do not provide food preparation directly, thus serving as a logistical element between the producer and the consumer. From the market point of view, we distinguish between two local and one reference market, while we select five representatives in each market. As far as the Czech market is concerned, the food delivery industry is represented by the following companies: (i) Dáme jídlo; (ii) OneMenu.cz; (iii) Wolt; (iv) Bolt Food and (v) Gastry. The Slovak market is represented by the following companies: (i) foodpanda; (ii) Wolt; (iii) Bolt Food; (iv) Bistro.sk and (v) dones.to. The reference developed market, in this case the global market from the point of view of a model customer from the United States, is represented by the main players in the industry based on the order of the tomsguide portal (Corpuz, Woo, 2022). The main players in this order are: (i) Grubhub; (ii) DoorDash; (iii) Seamless; (iv) Uber Eats and (v) Instacart. The empirical analysis itself is based on a simple sentiment analysis (Dorčák, Pollák, Szabo, 2014), where each of the subjects is tested on the basis of the nature / polarity of the results of searching for its own name. The first ten search results are taken into account. Only search results of an organic nature are taken into account, paid references were excluded from quantification. The authenticity of the results is optimized through the chosen market location in the search engine settings so that the results are relevant to the market in which the test subject operates. At the same time, the analysis is performed in an anonymous mode so that the search results are not distorted by personalizing them based on the browser's history. Specific search results are scored based on the following table:

Table 1: Sentiment of results / position of results; Source: (Liu, 2012 In: Dorčák, et al., 2014).

Sentiment/ Position of the result	1	2	3	4	5	6	7	8	9	10
Positive sentiment +	20	19	18	17	16	15	14	13	12	11
Own Website X	10	9	8	7	6	5	4	3	2	1
Neutral sentiment ±	2	2	2	2	2	2	2	2	2	2
Negative sentiment -	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11

The results quantified in points are then calculated for each of the subjects tested, with the sum of points representing the overall level of online reputation for a particular entity. In order to better visualize the results, in the next step, the point score is converted to percentages. Where we start from the assumption that each of the subjects can get a maximum of 155 points, which represents 100% in percentage terms. Thus, one point is equivalent to approximately 0.645%. The entire dataset of tested subjects thus gives us an order based on the reputation level of the tested file. The first subject in the order takes on the role of a benchmark representative, against which the whole set is qualitatively compared. In our case, the file is divided both on the basis of the order of subjects and on the basis of geographical selection. For comparison, we get a total of 3 data matrices. As far as data processing is concerned, this is done using the MS Excel spreadsheet in the MS Office suite. The findings are visualized through an overview table and hystogram in order to better interpret the context. Homogeneity of results is ensured through the ranking of entities, where each of the three files is ranked on the basis of the overall level of online reputation. In comparison, we do not compare the subjects themselves, as the dataset does not work with the same selection, in contrast, we compare the level of reputation of the subjects in the first to fifth place in the order for each of the three geographical matrices. The data collection itself took place at the beginning of

April 2022, so the results of the analysis take into account the state of pandemic suppression and the gradual lifting of anti-pandemic measures. The data thus synthesize the broadest nature of the pandemic, throughout its duration.

4. Results and discussion

Empirical analysis produced results in the form of basic reputation scores for the three monitored markets, the scores are shown in the following table:

Table 2: Basic reputation scores

Rank ČR	Subject/ Result sentiment	SA score (%)	Rank SR	Subject/ Result sentiment	SA score (%)	Rank Global	Subject/ Result sentiment	SA score (%)
1.	Wolt	87.08	1.	foodpanda	80.63	1.	Grubhub	87.72
2.	Bolt Food	57.41	2.	Bistro.sk	78.05	2.	DoorDash	87.08
3.	OneMenu.cz	47.73	3.	Bolt Food	72.24	3.	Uber Eats	87.08
4.	Dáma jídlo	46.44	4.	Wolt	49.67	4.	Instacart	87.08
5.	Gastry	27.74	5.	done.to	37.41	5.	Seamless	51.60

Czech market: Market leader (i) Dáma Jídlo records significant positive sentiments in the first positions. Wikipedia is followed by social networks. However, these search results are followed by a negative ranking on mapy.cz and firmy.cz, ie pages with a high Page Rank. Other search results again include social media and controlled publicity. We therefore record the features of targeted optimized e-communication. However, it is still developmental in nature. As far as the (ii) OneMenu is concerned, we find similar characteristics as in the previous case. (iii) Wolt is benefiting from the parent company's comprehensive infrastructure on the Czech online market. Great work with the media (social networks, reviews) is also visible. As for (iv) Bolt Food, the Czech market benefits mainly from the parent company's infrastructure, but compared to Wolt, it is significantly less optimized. On the first page of the search, there are dominant variations of the company's own website. Nevertheless, we observe that the existence of a global infrastructure (even with relatively weak optimization) guarantees a better position in the online market compared to local entities, which show signs of significantly higher targeted optimization of their e-marketing communication. The strength of Page Rank of global sites helps to displace domains that brought negative sentiments in the case of local entities. The last of the Czech entities – (v) Grastry - synthesizes the locality and non-existence of the supporting infrastructure. In this case, it is a very unfortunate combination that exposes the entity to a potential significant reputational threat.

Slovak market: As far as the Slovak online market is concerned, the first of the analyzed companies, namely (i) foodpanda, benefits from extensive infrastructure and relatively strong optimization. Again, we see an example of how e-communication works in a holistically managed ecosystem. (ii) Wolt took a chance on a better result relatively weak optimization of the first five search results, which are represented by mutations of their own domain, the state could be attributed to the developmental nature of the entity establishing itself in the local market, but compared to the Czech Republic this is a significant difference. We are also encountering a relatively unfavorable overall evaluation of the subject on the social network Facebook for the first time as part of our measurement. (iii) Bolt is also benefiting from the infrastructure on the Slovak online market, but it is possible to observe that its optimization of e-communication on the first 10 pages in Google search is, similarly to the Czech market, of a considerable development nature. (iv) Bistro.sk, as a local entity, shows signs of good establishment on the online market, but it lacks the existence of a global infrastructure for a better position among the evaluated entities. (v) Dones.to shows signs of ongoing optimization, as in previous cases of local entities, its overall position is

complicated mainly by the lack of global infrastructure. This is documented in particular by the relatively negative evaluations of their own applications for the iOS and Android platforms.

Global market: (i) Grubhub presents excellent work in optimizing e-communication in search engines in the global market. We have seen this phenomenon several times in recent years, especially when it comes to a global company and its global profile without localization on the national market. We note that the best players in the industry have homework in their market in the form of simple online reputation optimization met on the A mark. The differences occur only in more sophisticated parameters, which require a targeted and systematic approach to reputation optimization. However, we do not follow them in a simple sentiment analysis. (ii) DoorDash uses the same optimization scheme almost identically, as evidenced by the almost identical evaluation. It is evident that there is a clear macro that Internet marketers use as a standard in managing the reputation of entities in the online environment. (iii) Seamless as the third of the rated entities obviously uses the same formula for reputation management as the previous two competitors, but in this particular case the entity encounters a relatively non-standard proper name, where search results are confusing in almost a third of occurrences. This fact reduces the maximum optimization effort by about one third of the full reputation potential. (iv) Uber Eats confirms the assumption of the existence of the optimization scheme from the previous two cases, which corresponds to a relatively similar reputation score. The last tested entity, (v) Instacart, closes the rating with almost the same score as its global competitors. This trend is particularly noticeable in comparison with the reference emerging markets, the following figure shows it in relation to three separate measurements as follows:

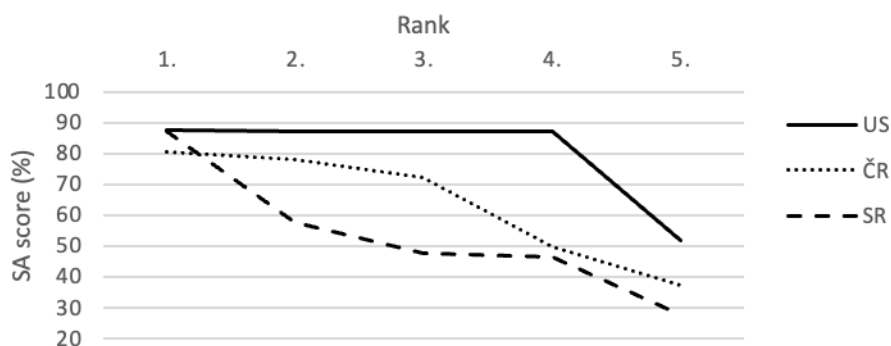


Figure 1: Basic reputation indicators - developing vs. developed markets.

Based on the discussed findings, it is possible to proceed to conclusion.

5. Conclusion

The issue of changes in eating habits during a pandemic is extremely complex, in the presented study we focused on fulfilling two decomposed goals. The first decomposed goal was to examine the issue in terms of studies that mapped the onset of the pandemic in its early days. It was at this time that trends emerged that created a new norm from the pandemic (Pollák et al., 2022). As far as diet as such is concerned, this has been largely marked by the onset of social distancing and self-isolation. Fresh food has become the domain of restaurants, as they have worked in the B2B supply chains, despite the pandemic, without major problems. According to Sheth (2020) customers could not come to the store, so the store came to their home. In the case of restaurants, food delivery was often the only way to remain operational. Thus, the change in consumer habits has occurred mainly in terms of location. This opportunity was used by companies whose main business is to provide

services related to food delivery. At this point, we come to the second with decomposed goals, namely the issue of trust and reputation, which is so characteristic of the online environment. By a simple analysis of sentiment, we examined the main players in the Czech and Slovak markets, which they then compared with the main global players from the United States. The findings were relatively expected, the developmental nature of the market, in comparison with the developed market, proved to be a crucial determinant in terms of the level of reputation in the online environment. Businesses operating in the local market but with global infrastructures are in a much easier position to protect their reputation. Even if they are exposed to reputational risks caused by the open nature of the Internet, they can defend themselves quite easily. In contrast, local businesses, without this infrastructure, have to make a much higher effort just to stay in the online environment. In the case of market turbulences (such as more difficult conditions and market nervousness caused by a pandemic), they are often at the mercy of chance. In terms of developed markets, major players have adopted a relatively simple portfolio of procedures for managing key aspects of their online reputation. In this case, it is relatively difficult, though not impossible, to jeopardize the entity's reputation in the short term.

As for the limitations of the presented study, they consist mainly of the qualitative nature of the data. The relatively narrow research object, represented by five representatives for each of the monitored markets in combination with one-time data collection made according to strictly limited methodology (Dočák et al., 2014), can be considered a certain limitation. These limitations will be removed in later phases of the research. In terms of prospects for further research, the analysis identified several areas. In the first place, this is an area of stabilizing dietary trends at the time of the pandemic, especially in terms of the growth of the food delivery sector as such. Furthermore, it is a prospect of catching up in terms of approaches to online reputation management. As developed markets are relatively saturated from the point of view of the main players in the industry in terms of managing their online reputation. The catching-up of these trends from the position of emerging markets creates room for continuous examination of the examples of good practice and the possibilities of their application in local conditions. The management of companies' intangible assets is becoming key to the elementary survival of these business units in an increasingly digital market.

6. Acknowledgment

This article is one of the partial outputs of the currently solved research grant VEGA no. 1/0140/21. This research was funded by the Institute of Technology and Business in České Budějovice, grant number IVSUPS005.

7. References

- Ayaburi, E.W., Treku, D.N. (2020). Effect of penitence on social media trust and privacy concerns: The case of Facebook. *International Journal of Information Management*, 50, pp. 171-181.
- Barska, A., Wojciechowska-Solis, J., (2020). E-Consumers and Local Food Products: A Perspective for Developing Online Shopping for Local Goods in Poland. *Sustainability*, 12 (12): 4958.
- Buhalis, D., Parra Lopez, E., Martinez-Gonzalez, J.A. (2020). Influence of young consumers' external and internal variables on their e-loyalty to tourism sites. *Journal of Destination Marketing & Management*, 15: 100409.
- Corpuz, J., Woo, K. (2022). Best food delivery services in 2022: Grubhub vs Uber Eats vs Doordash. Retrieved from <https://www.tomsguide.com/best-picks/best-food-delivery-services>
- Delina, R. (2014). Transparency in Electronic Business Negotiations – Evidence Based Analysis. *Quality Innovation Prosperity*, Volume 8, pp. 79 – 89.

- Delina, R., Tkáč, M., (2010). Trust Building Mechanisms for Electronic Business Networks and Their Relation to eSkills, *World Academy of Science, Engineering and Technology* 6 (71), pp. 380-390.
- Dorčák, P., Pollák, F. and Szabo, S. (2014). Analysis of the Possibilities of Improving an Online Reputation of Public Institutions. In: P. Doucek, G. Ch. and V. Oškrdal, *IDIMT-2014: Networking Societies - Cooperation and Conflict: 22nd Interdisciplinary Information Management Talks*. Poděbrady, Czech Republic, 10-12 September 2014. Linz: Trauner Verlag, pp. 275–282.
- Dorčák, P., Štrach, P., Pollák, F. (2015) Analytical view of the perception of selected innovative approaches in marketing communications. *Quality Innovation Prosperity*, 19(1), pp. 74-84.
- Gao, X., Shi, X., Guo, H., Liu, Y. (2020). To buy or not buy food online: The impact of the COVID-19 epidemic on the adoption of e-commerce in China. *PLoS ONE*, 15(8): e0237900.
- Hambalíková, K., (2020). Jak koronavirus změnil nákupní chování Čechů na internetu? Retrieved from <https://www.gopay.com/blog/jak-koronavirus-zmenil-nakupnichovani-cechu-na-internetu/>.
- Li, J., Hallsworth, A.G., Coca-Stefaniak, J.A. (2020). Changing Grocery Shopping Behaviours Among Chinese Consumers At The Outset Of The COVID-19 Outbreak, 111 (3), pp. 574-583.
- Liu, B. (2012). *Sentiment Analysis and Opinion Mining* Chicago, IL, USA: Morgan & Claypool Publishers.
- Lv, J., Wang, Z., Huang, Y., Wang, T., Wang, Y. (2020). How Can E-Commerce Businesses Implement Discount Strategies through Social Media? *Sustainability*, 12, 7459.
- Maryška, M., Doucek, P., Kunstova, R. (2012). The Importance of ICT Sector and ICT university education for the economic development. 3rd international conference on new horizons in education – INTE 2012. Vol. 55, pp. 1060-1068.
- Pollák, F., Markovič, P., Vavrek, R. and Konečný M. (2022). Return to the New Normal: Empirical Analysis of Changes in E-Consumer Behavior during the COVID-19 Pandemic. *Behavioral Sciences*, 12(3):85.
- Shao, Z., Zhang, L., Li, X. et al., (2019). Antecedents of trust and continuance intention in mobile payment platforms: The moderating effect of gender. *Electronic Commerce Research and Applications*, 33: 100823.
- Sheth, J., (2020). Impact of Covid-19 on consumer behavior: Will the old habits return or die? *Journal of Business Research*, 117, pp. 280-283.
- Soviar, J., Holubčík, M., Vodák, J., Rechtorík, M., Pollák, F. (2019). The Presentation of Automotive Brands in the On-Line Environment—The Perspective of KIA, Peugeot, Toyota and VW in the Slovak Republic. *Sustainability*, 11(7):2132.
- Štefko, R., Dorčák, P., Pollák, F. (2011). Shopping on the internet from the point of view of customers. *Polish Journal of Management Studies*, 4(2), pp. 214–222.
- Wang, P.W., Lu, W.H., Ko, N.Y., Chen, Y.L., Li, D.J., Chang, Y.P., Yen, C.F. (2020). COVID-19-Related Information Sources and the Relationship With Confidence in People Coping with COVID-19: Facebook Survey Study in Taiwan. *Journal of Medical Internet Research*, 22(6): e20021.
- Zgodavova, K., Bober, P., Majstorovic, V., Monkova, K., Santos, G., Juhaszova, D. (2020). Innovative Methods for Small Mixed Batches Production System Improvement: The Case of a Bakery Machine Manufacturer. *Sustainability*, 12(15):6266.

IDENTIFYING THE CHALLENGES IN E-PROCUREMENT STANDARDIZATION

Dana Paľová, Martin Vejačka

Department of Applied Mathematics and Business Informatics
Faculty of Economics, Technical University of Košice
dana.palova@tuke.sk, martin.vejacka@tuke.sk

DOI: 10-35011/IDIMT-2022-243

Keywords

Procurement, Standardization, Product and services classification systems

Abstract

Procurement and its electronic version play important role in a global economy. Involving e-Procurement processes has the potential to reduce costs, make spending more transparent, increase productivity, eliminate paperwork, increase transactions' speed, standardize purchasing process and reduce errors within the ordering process. For enabling the implementation and the use of e-Procurement, it is necessary to standardize procurement processes as well as the classification of procured products and services and to develop models that ensure the interoperability among different currently available product classification systems. This contribution provides an overview of problems connected to procurement processes and their standardization. Furthermore, the review of generally used product and service classification standards is presented, and the current challenges that e-procurement faces are identified. Finally, the available or possible approaches for solving the challenges are shortly mentioned.

1. Introduction

Procurement is an important tool for the business, via which a company could find reliable suppliers of needed goods and services and helps a company to minimize its cost. Among the main problems in the procurement, that were identified by Wu and Liang (2017) belongs the lack of relevant standards for the procurement, which influence the purchase quality and efficiency; less emphasis on information construction, which affects the fairness and transparency of procurement; unstandardized tendering and bidding system and unsound evaluation and supervision mechanisms, that makes the regulation difficulty.

The possibilities of global trading (both private and public procurement), and access to products that are marked by inconsistent ways create an inhomogeneous environment in which some of the following phenomena arise.

The lack of implementation of standards for procurement is influencing efficiency and purchase quality in procurement processes. Multiple cases of purchases of poor-quality products for an above-average price often undermine trust in the efficiency of procurement as a whole. This phenomenon thus contributes to the views that mainly governments (or public procurement in general) often purchase the expensive rather than the right. Due to the large and growing extent of public procurement, the lack of standards for procurement directly affects the effectiveness of all

procurement links, including the procurement process, procedure, management, etc. Lack of standardization also allows awarding of a manipulated award in procurement using conditions of the procurement process tailored specifically for one of the bidders (Wu & Liang, 2017). Solid standards for procurement might decrease the abundance of such cases.

Unstandardized tendering and bidding decrease the fairness of procurement. Open tenders are the main way of purchasing in procurement, which helps to fair play. It also promotes the development of a market economy, features transparent expenditure for purchase costs, and helps avoid corruption in funds used to a certain extent. Alvarez-Rodríguez et al. (2014) adduced that incomplete and unstandardized practices in procurement tendering and bidding system (e. g. less strict prequalification of suppliers, tendering information asymmetry between procurer and suppliers, bidding without guarantee, and unreasonable bid evaluation), negatively influence fairness in purchases and disturb the order of the market.

Low emphasis on information construction reduces transparency and procurement fairness. Information asymmetry in the process of procurement causes problems leading to more queries and complaints during the procurement process. Without standardization in information construction for procurement information resources do not work efficiently wasting material, financial and human resources (Wu & Liang, 2017).

Unsound evaluation and supervision mechanism increases the difficulty of regulation and decreases the transparency of the procurement process. Procured services are often hardly quantized and their quality cannot be judged by a definite evaluation standard. Therefore, it is not easy to accurately evaluate the efficiency of financial funds usage in procurement. Moreover, the provision of services is scattered, and not executed in a practice, causing difficulties against regulation. Therefore, the evaluation of the performance of procurement should reflect the evaluation of the efficiency of purchase behavior and evaluation of effect (Wu & Liang, 2017).

These identified phenomena suggest that standardization in the field of procurement should be implemented to an even larger extent. The main goal of standardization is to enable procurement public, transparent, standardized in operation, honest and high-efficient. According to Leukel and Maniatopoulos (2005), a key instrument for standardization by achieving a common product understanding in business-to-business and business-to-government e-commerce is classification by standard product classification schemes (standard PCS). Over time international organizations, institutions, and national authorities conceived requirements for the standardization of public and private procurement processes.

The World Trade Organization in 1979 (on the platform of the General Agreement on Tariffs and Trade at the time) incorporated government procurement into the process of trade and investment liberalization and composed the Government Procurement Agreement (GPA). It specified procurement executor, object, form, purpose and the scope of application of procurement amount. Furthermore, it identified the requirements of technical specifications for procurement that should comply with current international standards or other countries' technical regulations and generally recognized national standards (Wu & Liang, 2017).

In the USA, government procurement is standardized by legislation and the regulatory system based on the Federal Acquisition Regulation and the Buy American Act. US procurement regulatory system consists of more than 4,000 laws and bylaws directly or indirectly related to government procurement. These laws specify government procurement flow, products, and services and that suppliers' qualifications must be in line with corresponding standards. Some American government departments have also entrusted American National Standards Institute (ANSI) and other relevant standardization organizations with formulating a series of standards for government procurement (e. g. the Federal Procurement Classification, ANSI/EIA 623:1994 Procurement Quality of Solid-State Components by Government Contractors and ANSI/ASTM E1626

Part1:2002 Standard Guide for Including Government Procurement Requirements in ASTM Documents, etc.) (Wu & Liang, 2017).

The United Kingdom has specified a series of standards for government procurement since 1968 (for example: BS 2316 Pts. 1:1968 Specification for Radio-frequency Cables, Part I: General Requirements and Tests, BS 2316 Pts. 2:1968 Specification for Radio-frequency Cables, Part II: British Government Services Requirements). Later, the British Government and the British Standards Institute (BSI) issued a memorandum, ensuring that all government departments will no longer formulate any standard but use national standards of the United Kingdom formulated by BSI, particularly specifying that the laws involving government procurement should quote BSI standards (Wu & Liang, 2017).

European Union established sound legal systems for public procurement and clarified that the technical specifications required in government procurement can be international standards, EU standards, or national standards of member states. The EU also formulated the Common Procurement Vocabulary (CPV), to classify the procurement objects and describe them with digital codes. In 2004, the European Commission released the Green Procurement manual and established the procurement information database. In 2008, the most recent version of the Common Procurement Vocabulary (CPV) was adopted by European Commission Regulation No. 213/2008 at last. As stated by Alvarez-Rodríguez et al. (2014), the efforts to introduce a unified approach are present in the field of procurement for decades starting in the 1990s to make public procurement more transparent and efficient. The main principle is to use standardized codes to identify unambiguously the description in notices of the subject matter of contracts, statistical obligations, and the definition of their scope more easily.

The standardization of terms and used vocabulary within the process of procurement can, according to Schooner and Matsuda (2021), accelerate its progress in both public and private sectors or even help to enable the electronic procurement process. However, McCue and Roman (2012) identified that unsuitability of software platforms, organizational resistance, lack of strategic systems' integration, and failure to involve public procurement professionals in the design of e-procurement systems are primary obstacles to effectively implementing digital procurement.

The introduction of standardization in the procurement process in the form of the use of CPV makes it possible to carry out procurement and evaluate its effectiveness and sustainability across various areas, such as ICT hardware (Welz & Stuermer, 2020), medicine (Kastanioti et al., 2013), food industry (Lawless & Cville, 2013), etc. Using established terminology also allows preparation of the ground for the digitization of procurement processes.

2. Product Classification Systems

Procurement represents the key area for the application of e-commerce, and it needs to be supported by appropriate tools and techniques. During the previous decades, lot of different techniques, tools and systems were designed. It resulted in different-leveled challenges of the standardization of the workable e-commerce like missing unique standard for product description, unique standard for the description of the product catalogs and unique standard for describing the exchangeable business documents.

E-commerce technologies by using standardized product descriptions predefined in catalogs accessible via web-search engines could help to avoid the problems with errors rising during the service or product description in particular offers and at the same time use of standardized codes make the interoperability easier and supports the global expansion of the product and service suppliers.

Fairchild and de Vuyst (2002) conducted early-stage research focused on the examination of the role of common product and service coding standards and the discussion about the correlation between a coding standard. In connection with the codes used, it is important to distinguish between classification codes and identification ones. While identification codes unambiguously identify the item and are mostly used for tracking and the record-keeping of the product, the classification code indicates the relation of an item to other items, similar and dissimilar, shows classes and subclasses within the catalog, and they are used for finding appropriate goods and services.

Nowadays there are used different product and service classification coding schemes:

UNSPSC (Universal Standards Products and Services Classification) is an open, global, multi-sector e-commerce standard managed by GS1 US® (UNSPSC, 2022). This classification system is used for company-wide visibility of spend analysis, cost-effective procurement optimization, and exploitation of e-commerce capabilities. This standard is cross-referenced with other classification systems like CPV, SIC, and HS. The UNSPSC classifies products and services on five levels: segment, family, class, commodity, and business function. The structure of code is designed by two-, four-, six-, and eight-digit levels, depending on the specific needs of the user. The latest release of the code set is 24.0301 (UNSPSC, 2022).

UCEC (Universal Content Extend Classification) is based on the UNSPSC. It uses its first four hierarchy levels and enriched them with attributes that are inherited at the commodity level (Omelayenko et al., 2013).

CPC (Central Product Classification) is used for describing products that are an output of economic activities, including transportable goods, non-transportable goods, and services. It classifies products based on the physical properties, nature of the product, and the principle of industrial origin. The classification consists of sections (identified by the first digit), divisions (identified by the first and second digits), groups (identified by the first three digits), classes (identified by the first four digits), and subclasses (identified by all five digits, taken together). The latest version is 2.1 (United Nations, 2015).

CPA (Classification of Products by Activity) product categories are designed to reflect the codes from NACE (Statistical classification of economic activities in the European Community). It is six-level structured: sections (identified by alphabetical code), divisions (identified by two-digit code), groups (identified by three-digit code), classes (identified by four-digit code), categories (identified by five-digit code) and subcategories (identified by six-digit code). The latest version is similar to CPC case 2.1 (Eurostat, 2022).

CPV (Common Procurement Vocabulary) is specially designed for public procurement aimed at standardizing the references used by contracting authorities and entities to describe the subject of procurement contracts (Alvarez-Rodríguez et al., 2014). CPV represents the main vocabulary for defining the subject of a contract and a supplementary vocabulary for adding further qualitative information. It is based on a tree structure comprising codes of up to nine digits (an eight-digit code plus a check digit) associated with a wording that describes the type of supplies, works, or services forming the subject of the contract. Its structure is created by division identification (first two digits), group identification (first three digits), class identification (first four digits), categories identification (first five digits), and optionally supported by the ninths digit, which serves as verification of previous digits. Nowadays is available version CPV 2008.

HS (Harmonized System) is a system intensively used by governments, and international organizations around the world. This system is used for the identification of traded products when assessing duties and taxes and for gathering statistics. The HS is organized into 21 sections and 99 chapters, prefaced by the Legal Notes, that clarify the proper classification of goods (based on

product's composition, form, and function). The HS code consists of six digits: the first two digits represent HS Chapter, the second two digits represent HS Heading and the third two digits represent the HS subheading. The current version is named HS Nomenclature 2022 edition (European Commission, 2022).

eCl@ss standard is an eight-digit coding system with additional machine-readable identifiers, that allow adding information about the supplier's name, type designation, or brand. It uses a four-level hierarchy, i.e. segments, main groups, groups, and commodity class (EClass, 2022). The latest release of eCl@ss code set is 12.0.

Besides the above-mentioned standards that are aimed at product and service classification, there are also other standards used in procurement, but they help identify for example sectors, companies, governments, payments, etc. (ETIM, eOTD, NAICS, SITC, EBOPS, WZ, GICS, etc.) and other proprietary product category systems like Google product taxonomy, BMEcat, etc.

3. Challenges connected with online standardized product catalog

Procurement (and e-procurement) includes a very wide range of different standards issues in different Groups. At one end of the chain are the principles of e-cataloging and product classification, then moving into issues related to the business transaction process – seeking bidding document/offer/selection of bidders/transaction/delivery/invoicing, etc. Of course, most of these issues are already being standardized, often in multiple groups. It is important to encourage the use of compatible systems for public procurement as well as for private procurement and to find as many as possible comfortable tools for e-procurement participants. There were published a few publications concerned with the e-procurement from which we identified the most interesting challenges that the society need face to.

3.1. Interoperability among the well-known classification standards

As follows from the review of existing product classification standards, they often contain thousands of product classes, and they are continuously updated based on the different products and services. The precondition of successful procurement is to use the same standard for coding the product or service. It may be a limitation in case of in the case of purchases respecting a different standard. Stolz et al. (2014) represent one of the possible solutions, how to solve the problem. They derived product ontologies from hierarchical product and services classification standards. The developed architecture is built on three layers (parser, transformation process, and serializer). The main objective of the model is to develop a fully automated system that transforms classes, properties, and individuals used in standards and usually saved in a format like .xls, .csv, .mdb, and .txt into entities of final ontology. This ontology is serialized as XML and the model generates a semantic sitemap for integration on the servers. Using this approach allows articulating more granular product descriptions across the Web of Documents and the Web of Data.

A different approach is based on the information retrieval methods and natural-language processing of the semi-structured texts, which doesn't require global adoption of the semantic interoperability standards (such as product classification ontologies) (Mehrbod and Grilo, 2018).

The linking of e-procurement platforms to other public administration databases that already store information that is necessary for the phases of procurement procedures is proposed as a useful approach to interoperability, due to following possible auto-fill of different sections of a tender document using data contained in these registers (European Commission, 2018). Interoperability, therefore, represents a means by which administrations can reduce the administrative burden on

economic operators and contracting authorities by saving time and effort, avoiding potential data-entry errors, and ultimately increasing the efficiency of e-tendering procedures.

3.2. Detection of possible collusions or procurement irregularities

Fazekas and Tóth (2016) stated that several variables of central importance for investigating collusion risks have usually a very high missing rate such as the name of the winning bidder or bid prices. The categorization used for identifying the products and services procured (for example CPV codes) is merely listed without any indication as to which product represents higher or lower importance in the whole contract, making market definitions problematic for bundled products. On a structural level, the procurement database records information on the tender level rather than per lot, which limits the use of the whole database as the actual transaction between the buyer and seller is not precisely identified. Competition authorities worldwide identify collusion by whistleblowers, anonymous tips, and ex officio case-by-case analysis. In addition to these methods, the DCCA (The Danish Competition and Consumer Authority) has developed a screening tool ("Bid Viewer") to identify potential collusion in public tenders. Bid Viewer utilizes computational screening methods, including machine learning and artificial neural networks, and is designed to uncover suspicious patterns in large public procurement datasets. The research on collusion detection was published by several authors (Kawai and Nakabayashi, 2022; García Rodríguez et al., 2022; Baránek et al., 2021; Sun and Sales, 2018; etc.).

3.3. The future: human/machine collaboration, use the data analysis approach

Even when category experts can improve classification to close to the 100% error-free level, there is still the question of prioritization. The classification process could be complemented by the trained computers, and they could actively propose support to the people involved in the procurement process (Ovsyannikova & Domashova, 2020). At the same time, data analytics could be used to examine detailed data and apply proper statistical methods to uncover new insights that support decision-making (Bag et al., 2020).

4. Conclusion

Procurement provides many already generally known benefits to business: reduce costs, make spending more transparent, increase productivity, eliminate paperwork, increase transactions' speed, standardize purchasing process and reduce errors within the ordering process. The process of procurement is not trivial, it refers to techniques, structured methods, and means used to streamline an organization's procurement process and achieve desired results while saving cost, reducing time, and building win-win supplier relationships. Implementing e-procurement into the business help to lower inefficiencies caused by long purchase cycles, missed discount, and transaction disputes.

Nowadays is it clear that there was a lot of work done in the field of standardization of product and service classification in the procurement process. As stated Gürdür and Asplund (2018), mandatory use of product and service classification standards in an international context would be ideal, but unfortunately, it is not the reality. In close connection with human society development also the standards need to be regularly updated by new categories and at the same time, the businesses face the problem with interoperability of the generally used standards. As is stated above, there are published researches aimed to develop a sort of connector among different standards. They are using different approaches implementing web ontologies (Stolz et al., 2014), linking the standards to public databases (European Commission, 2018), or information retrieval methods and natural-language processing of the semi-structured texts. But there is missing a complex solution. As was

presented in Ovsyannikova & Domashova (2020) data analysis methods could provide a way how to develop robust model that will be able to compare and update the product categories and support the missing interoperability among the existing product classification standards. With the information technology development, we cannot omit also the field already open for research - human/machine collaboration and use the data analysis approach applied to different steps of the e-procurement process. We expect their massive use also in the detection of possible collusions or procurement irregularities and automation of the whole procurement process.

5. Acknowledgement

This contribution was supported by the national project “The socio-economic potential of data sharing as a tool to support smart supply chain management.” (Contract No. VEGA 1/0873/21) funded by Grant Agency for Science; Ministry of Education, Science, Research and Sport of the Slovak Republic.

6. References

- Alvarez-Rodríguez, J. M., Labra-Gayo, J. E., Rodríguez-González, A., & De Pablos, P. O. (2014). Empowering the access to public procurement opportunities by means of linking controlled vocabularies. A case study of Product Scheme Classifications in the European e-Procurement sector. *Computers in Human Behavior*, 30, 674–688. <https://doi.org/10.1016/j.chb.2013.07.046>.
- Bag, S., Wood, L. C., Mangla, S. K., & Luthra, S. (2020). Procurement 4.0 and its implications on business process performance in a circular economy. *Resources, Conservation and Recycling*, 152, 104502. <https://doi.org/10.1016/j.resconrec.2019.104502>.
- Baránek, B., Musolff, L., & Titl, V. (2021). Detection of Collusive Networks in E-procurement. U.S.E. Research Institute. Working Paper Series, 21-11. https://www.uu.nl/sites/default/files/LEG_USE_WP_21-11.pdf
- EClass. (2022). An introduction to the standard. Retrieved April 26, 2022 from <https://eclass.eu/en/eclass-standard/introduction>.
- European Commission. (2022). Harmonised system. Retrieved April 27, 2022 from <https://trade.ec.europa.eu/access-to-markets/en/content/harmonised-system-0>
- European Commission. (2018). Interoperability between e-procurement systems and other government databases. Good Practices. Retrieved April 25, 2022 from https://ec.europa.eu/regional_policy/sources/good_practices/GP_fiche_18.pdf.
- Eurostat. (2022). CPA Ver. 2.1 Statistical classification of products by activity. <https://ec.europa.eu/eurostat/web/cpa>.
- Fairchild, A., & de Vuyst, B. (2002). Coding Standards Benefiting Product and Service Information in E-commerce. In 35th Annual Hawaii International Conference on System Sciences, Big Island, Hawaii, 2002 pp. 258b. <https://doi.org/10.1109/HICSS.2002.994396>.
- Fazekas, M., & Tóth, B. (2016). Assessing the potential for detecting collusion in Swedish public procurement. Retrieved April 25, 2022 from http://www.govtransparency.eu/wp-content/uploads/2021/08/Fazekas-Toth_SE_PPcartel_detection_20161115.pdf.
- García Rodríguez, M. J., Rodríguez-Montequín, V., Ballesteros-Pérez, P., Love, P. E. D., & Signor, R. (2022). Collusion detection in public procurement auctions with machine learning algorithms. *Automation in Construction*, 133, 104047. <https://doi.org/10.1016/j.autcon.2021.104047>.
- Gürdür, D., & Asplund, F. (2018). A systematic review to merge discourses: Interoperability, integration and cyber-physical systems. *Journal of Industrial Information Integration*, 9, 14–23. <https://doi.org/10.1016/j.jii.2017.12.001>.
- Kastanioti, C., Kontodimopoulos, N., Stasinopoulos, D., Kapetaneas, N., & Polyzos, N. (2013). Public procurement of health technologies in Greece in an era of economic crisis. *Health Policy*, 109(1), 7–13. <https://doi.org/10.1016/j.healthpol.2012.03.015>

- Kawai, K., & Nakabayashi, J. (2022). Detecting Large-Scale Collusion in Procurement Auctions. *Journal of Political Economy*. <https://doi.org/10.1086/718913>.
- Lawless, L. J. R., & Civile, G. V. (2013). Developing Lexicons: A Review. *Journal of Sensory Studies*, 28(4), 270–281. <https://doi.org/10.1111/joss.12050>
- Leukel, J., & Maniatopoulos, G. (2005). A Comparative Analysis of Product Classification in Public vs. Private e-Procurement. *The Electronic Journal of e-Government*, 3, pp. 201–212.
- McCue, C., & Roman, A. V. (2012). E-Procurement: Myth or Reality. *Journal of Public Procurement*, 12(2), 221–248. <https://doi.org/10.1108/jopp-12-02-2012-b003>.
- Mehrbod, A., & Grilo, A. (2018). Tender calls search using a procurement product named entity recogniser. *Advanced Engineering Informatics*, 36, 216–228. <https://doi.org/10.1016/j.aei.2018.04.005>
- Omelayenko, B., Ding, Y., Klein, M., Flett, A., Schulten, E., Brown, M., Botquin, Q., & Dabiri, G. (2013). Intelligent Information Integration in B2B Electronic Commerce. Springer Science & Business Media, pp.144.
- Ovsyannikova, A., & Domashova, J. (2020). Identification of public procurement contracts with a high risk of non-performance based on neural networks. *Procedia Computer Science*, 169, 795–799. <https://doi.org/10.1016/j.procs.2020.02.161>.
- Schooner, S. L., & Matsuda, E. (2021). Sustainable Procurement: Building Vocabulary to Accelerate the Federal Procurement Conversation. *Papers.ssrn.com*. <https://ssrn.com/abstract=3943341>.
- Stolz, A., Rodriguez-Castro, B., Radinger, A., & Hepp, M. (2014). PCS2OWL: A Generic Approach for Deriving Web Ontologies from Product Classification Systems. *Lecture Notes in Computer Science*, 644–658. https://doi.org/10.1007/978-3-319-07443-6_43.
- Sun, T., & Sales, L. J. (2018). Predicting Public Procurement Irregularity: An Application of Neural Networks. *Journal of Emerging Technologies in Accounting*, 15(1), 141–154. <https://doi.org/10.2308/jeta-52086>.
- UNSPSC. (2022, April 20). United Nations Standard Products and Services Code. <https://www.unspsc.org/>
- United Nations. (2015). Central Product Classification. Version 2.1. Retrieved April 28, 2022 from <https://unstats.un.org/unsd/classifications/unsdclassifications/cpcv21.pdf>
- Welz, T., & Stuermer, M. (2020). Sustainability of ICT hardware procurement in Switzerland: A status-quo analysis of the public procurement sector. *ICT4S2020: Proceedings of the 7th International Conference on ICT for Sustainability*, June 2020. pp. 158–169. <https://doi.org/10.1145/3401335.3401352>.
- Wu, X., & Liang, H. (2017). Government procurement issues and supporting role of standardization in China. *IEEE Xplore*. <https://doi.org/10.1109/INFOMAN.2017.7950388>.

ONLINE REPUTATION OF BUSINESS ENTITIES FROM THE FIELD OF SUPPLY CHAIN: AN EMPIRICAL STUDY ON THE CZECH MARKET

Michal Konečný

Faculty of Corporate Strategy, Department of Tourism and Marketing
Institute of Technology and Business in České Budějovice
27826@mail.vstecb.cz

Yaroslava Kostiuk

The Faculty of Operation and Economics of Transport and Communications
Department of Economics, University of Zilina
kostiuk@stud.uniza.sk

Faculty of Corporate Strategy, Department of Management
Institute of Technology and Business in České Budějovice
26567@mail.vstecb.cz

Michal Ruschak

Faculty of Corporate Strategy, Department of Tourism and Marketing
Institute of Technology and Business in České Budějovice
5977@ mail.vstecb.cz

DOI: 10-35011/IDIMT-2022-251

Keywords

Corporate reputation, development, reputation management, competitiveness, supply chain management, Czech Republic

Abstract

The paper deals with the issue of sustainable development of the corporate reputation of transport and logistics companies in the Czech Republic, specifically their online reputation, which is a current challenge for the development of their responsible and sustainable perceived image as their very fragile intangible assets. The research sample consisted of the 14 largest transport and logistics companies on the Czech market, which were selected based on the ranking of the online review magazine Recenzer.cz. Sentiment analysis was used in the analysis. The findings identified in this significant sample provide one perspective on the issue of sustainable corporate reputation development, primarily in supply chain management and secondarily in all relevant areas of business.

1. Introduction

In the era of globalization, the functioning of markets has a significant impact on the way companies create a competitive advantage. Customers currently expect the product to be feasible in terms of location and time, and that orders will also be completed on time (Shah, 2020). The development of long-term consumer relationships is also another important aspect (Li et al., 2020). The shorter the order processing time, the more satisfied the customer. As a result, the customer is more likely to consider further purchases (Nadeem et al., 2020). Because the cost of acquiring a new customer is much higher than the cost of retaining an existing customer, customer care is considered highly valued (Song et al., 2018). The COVID-19 pandemic had a significant impact on the creation of added value within national economies. The creation of added value in the transport sector is an important factor in the production of products and the provision of services in the environment of national economies. The creation of added value in the transport sector is an important factor in the production of products and the provision of services in the environment of national economies. With the globalization of production, the transport sector has become one of the main sectors that enables and accelerates the process of creating added value within all other sectors (Kostiuk et al., 2021). Courier companies should pay special attention to providing the highest standards of customer service. In the current economic reality, a satisfied customer is the main source of competition (Marcysiak, 2021). The basic criteria of customer service are the accuracy and quality of deliveries (Liang et al., 2019). The offer of courier companies' services is highly diversified in terms of quality and price. Customers can choose to deliver packages by courier within a certain time frame. Current challenges and threats from competitors have been the impetus for courier operators to facilitate the process of managing customer service quality by introducing a wider range of services and diversifying their operations (Liu et al., 2018). In addition, some courier operators have introduced a late afternoon or evening parcel delivery standard, or have begun to provide data on couriers as well as their telephone numbers (Alsaad & Taamneh, 2019). In an effort to constantly improve the quality of their provision, courier companies offering their services try to adapt the scope of their activities to the needs of individual customers (Lou et al., 2020). However, it is very important to realize that not all customers are able to give up the traditional way of shopping or the traditional perception of products and services (Štefko et al., 2011). The ongoing COVID-19 pandemic has affected global courier companies in a variety of ways. Many of these changes were still unknown, as customers constantly changed their behavior in response to the dynamic nature of the crisis, which was not a natural disaster with chronically static consequences (eg earthquakes, floods) but showed almost linear growth, as evidenced by increasing numbers of COVID-19 infected cases, since February 2020. In addition, customers were forced to look for alternative courier service providers because reputable brands faced a real challenge to keep up with demand, resulting in long delays and poor customer service (Sakas et al., 2021). Marcysiak (2021) focused on the quality of courier services during the COVID-19 pandemic. Based on a questionnaire survey he conducted online, he found that customers began to use those courier services that not only are fast on delivery and have a lower service price than others, but also focus more on sustainable development and ecology. The courier, express and parcel services (CEP) market has achieved impressive growth over the last ten years. E-commerce is one of the main drivers of the CEP market and generates significant revenues, especially during the coronavirus pandemic. Physical distancing, business blocking and other restrictive measures have accelerated growing trends in e-commerce. As consumers face global pandemic constraints, Internet users are more likely to shop online and order basic goods (Gulc, 2021). Despite adapting the latest technologies to ensure fast delivery of products at a reasonable price, most courier companies are poorly valued by customers, especially on social networking sites. In addition to focusing on innovative ways to increase responsiveness and efficiency, courier companies must understand the voice of both customers and employees (Rajendran, 2020). Gulc

(2020) assessed the strategic goals of courier companies and identified the key factors that determine how people perceive the quality of courier services in the online space. Reliability, visual identification and technical quality came out as key factor. A very valuable resource of today's business that can create its long-term competitive advantage and increase its market value is its reputation. A strong positive reputation must be built up over many years and can be damaged relatively quickly. In today's digital age, there are many threats to the company's reputation, which are further multiplied by the development of the Internet and social media (Szwajca, 2018). The disorganized nature of the Internet is an ideal environment for empirical research, which we focus on in the next part of the presented study.

2. Objectives and methods

Providing an analytical view of the online reputation of the largest transport and logistics companies in the Czech Republic is the main goal of the study and the initial research problem is based on it, and thus clarify how the transport and logistics companies are presented in the online environment. The research sample consists of 14 largest transport and logistics companies identified by the Recenzer portal (Největší dopravci v ČR, n.d.) as the largest carriers in the Czech Republic for 2022. A basic sentimental analysis is chosen as the basic methodological tool for empirical analysis (Pollák et al., 2019; Pollák et al., 2021), which can be quantified according to sentiment, respectively the polarity of the first ten results of a particular entity in Google search level of its online reputation. The subject's own name (name of the transport company) serves as a search phrase. The search results in each of the ten positions are then quantified according to the following key:

Table 1: Sentiment of results / position of results; Source: (Liu, 2012 In: Dorčák, et al., 2014).

Sentiment/Position of the result	1	2	3	4	5	6	7	8	9	10
+										
Positive sentiment	20	19	18	17	16	15	14	13	12	11
x										
Company owned website	10	9	8	7	6	5	4	3	2	1
±										
Neutral sentiment	2	2	2	2	2	2	2	2	2	2
-										
Negative sentiment	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11

To minimize the personalization of the results, an incognito search mode is chosen, with only the organic search results quantified. Results marked as ads are not considered. If there are more links to the test subject's own website within the search results, then the second to nth search results of this type are attributed to neutral sentiment. The polarity of the result is determined on the basis of data directly visible from the link, ie it is mainly the name and perex. The same procedure is followed in the analysis of each of the evaluated entities, where a partial reputation indicator is determined for each of the positions and in the next step the total value is created from their sum. The aggregate value for each test subject is then converted to percentages. Each of the examined subjects can in the final sum reach the max. 155 points, which in percentage terms is 100%, while one percent is 0.645 points. The ranking, which provides an overview of the mutual position of the tested subjects (SA score), is compiled on the basis of the total percentage of online reputation.

3. Results and discussion

From the sentiment analysis, it was found that in the first positions in the search engine, almost all the transport and logistics companies surveyed were a company website (except for Messenger,

which referred to the website of the software application and instant messaging platform developed by Meta Platforms). This fact can be caused by SEO optimization, which aims to optimize the company's website and thus achieve the first ranks in search. The second finding from the sentiment analysis is the neutrality of the contributions, which included a site such as Wikipedia, where no sentiment was recorded. The negativity of contributions can be justified by customers' dissatisfaction with the services provided by transport and logistics companies, whether it is, for example, communication and access of couriers when delivering shipments or misleading customers regarding the status and time of delivery of their shipments. Selected transport and logistics companies were subjected to a basic sentiment analysis. The following table shows the values of individual monitored indicators for each of the analyzed subjects as follows:

Table 2: Basic reputation scores

Brand/Position results	1	2	3	4	5	6	7	8	9	10	Score SA (%)
DPD	10	2	-18	2	2	2	14	13	2	-11	11,61
Zásilkovna	10	2	18	-17	2	2	2	13	12	11	35,48
Česká pošta	10	2	18	2	2	2	2	2	2	11	34,19
DHL	10	2	-18	2	2	2	2	13	2	11	18,06
PPL	10	-19	2	2	16	2	2	2	2	2	13,55
WeDo	10	19	-18	-17	2	2	-14	2	2	-11	-14,84
Pošta bez hranic	10	19	2	2	16	15	2	2	2	11	52,26
Toptrans	10	19	18	2	16	-15	2	2	2	11	43,26
GLS	10	2	18	2	2	2	2	2	2	-11	20
UPS	10	2	2	2	2	2	2	2	12	2	24,52
TNT	10	2	2	17	16	15	14	2	2	2	52,90
Geis	10	2	-18	2	16	2	2	13	2	2	21,29
Messenger	2	2	8	2	2	2	2	2	2	2	16,77
Fofr	10	19	-18	2	2	2	-14	2	-12	2	-3,23

After determining the sentiment of each of the ten search engine results for each of the transport and logistics companies, the evaluation points were determined on the basis of the sentiment rating point scale in Table 1. Table 3 shows the resulting score. According to the sum of points, it is possible to determine the order of transport companies: 1. TNT, 2. Pošta bez hranic, 3. Toptrans, 4. Zásilkovna, 5. Česká pošta, 6. UPS, 7. Geis, 8. GLS, 9. DHL, 10. Messenger, 11. PPL, 12. DPD, 13. Fofr a 14. WeDo. The results of the research show us the order of transport companies created on the basis of sentiment analysis. Based on the presented results, it is difficult to conclude that the sentiment analysis performed by us is a suitable measure of the online reputation of the given transport and logistics companies. In addition, it is also difficult to confirm that increasing Score SA (%) will also improve the company's perception of the company's reputation on the Czech market. To verify the sentiment analysis as a measure of the online reputation performance of the entities, it would be appropriate to consider creating a kind of questionnaire survey, in which respondents will evaluate the transport and logistics companies based on their perception and then compare the results with sentiment analysis.

4. Conclusion

If an Internet user looking for information about a particular business does not encounter positive indicators of its reputation, this may ultimately affect their overall perception of that business. This is especially true for potential customers who have not yet had personal experience with the company and their opinions are formed only based on information obtained from the online environment. Transport and logistics companies should make efforts to limit negative publicity and to make and improve their positive publicity. This can be achieved mainly through an active online communication policy, which includes the dissemination of positive information about the

company through major reputable online newspapers or social networks. The best way to remove negative or neutral publicity from the top ten search results is to replace negative publicity with a well-thought-out marketing communications policy that is implemented in an online environment. The most effective model of comprehensive online reputation management is to focus on the dominant determinants of reputation, specifically on Google search results and on the active management of profiles on social networks. According to Sasko (2014), actively used online reputation management tools can significantly facilitate companies' active communication with the public and help them in obtaining and evaluating feedback or speeding up the implementation of measures related to crisis marketing communication.

5. Acknowledgement

This article is one of the partial outputs of the currently solved research project 01SVV22. This research was funded by the Institute of Technology and Business in České Budějovice, grant number 05SVV2201.

6. References

- Alsaad, A., & Taamneh, A. (2019). The effect of international pressures on the cross-national diffusion of business-to-business e-commerce. *Technology in Society*, 59, 101158.
- Dorčák, P., Pollák, F. & Szabo, S. (2014). Analysis of the Possibilities of Improving an Online Reputation of Public Institutions. In: P. Doucek, G. Ch. and V. Oškrdal, IDIMT-2014: Networking Societies - Cooperation and Conflict: 22nd Interdisciplinary Information Management Talks. Poděbrady, CzechRepublic, 10-12 September 2014. Linz: Trauner Verlag, pp. 275–282.
- Gulc, A. (2020). Determinants of Courier Service Quality in e-Commerce from Customers' Perspective. *Quality Innovation Prosperity*, 24(2), 137–152.
- Gulc, A. (2021). Multi-stakeholder perspective of courier service quality in B2C e-commerce. *PLoS ONE*, 16(5), e0251728.
- Kostiuk, Y., Kohútová, V., Straková, J., & Koleda, N. (2021). Added value in the transport sector at the time before COVID-19 pandemic: a comparison of the EU countries. *Entrepreneurship and Sustainability Issues*, 9(2), 303–315.
- Li, X., Zhao, X., Xu, W. (Ato), & Pu, W. (2020). Measuring ease of use of mobile applications in e-commerce retailing from the perspective of consumer online shopping behaviour patterns. *Journal of Retailing and Consumer Services*, 55, 102093.
- Liang, C. C., Liang, W. Y., & Tseng, T. L. (2019). Evaluation of intelligent agents in consumer-to-business e-Commerce. *Computer Standards and Interfaces*, 65, 122–131.
- Liu, B. (2012). *Sentiment Analysis and Opinion Mining* Chicago, IL, USA: Morgan & Claypool Publishers.
- Liu, Y., Foscht, T., Eisingerich, A. B., & Tsai, H. T. (2018). Strategic management of product and brand extensions: Extending corporate brands in B2B vs. B2C markets. *Industrial Marketing Management*, 71, 147–159.
- Lou, Y., Feng, L., He, S., He, Z., & Zhao, X. (2020). Logistics service outsourcing choices in a retailer-led supply chain. *Transportation Research Part E: Logistics and Transportation Review*, 141, 101944.
- Marcysiak, A. (2021). Customer service quality management on the courier services market. *Entrepreneurship and Sustainability Issues*, 9(1), 190–203.
- Nadeem, W., Khani, A. H., Schultz, C. D., Adam, N. A., Attar, R. W., & Hajli, N. (2020). How social presence drives commitment and loyalty with online brand communities? the role of social commerce trust. *Journal of Retailing and Consumer Services*, 55, 102136.
- Největší dopravci v ČR. (n.d.). Recenzer. Retrieved April 29, 2022, from <https://www.recenzer.cz/dopravce/#nejvetsi>

- Pollák, F., Dorčák, P., & Markovič, P. (2019). Reputation Management. In U. Ayman, & A. K. Kaya (Eds.), *Promotion and Marketing Communications*. IntechOpen.
- Pollák, F., Dorčák, P., & Markovič, P. (2021). Corporate reputation of family-owned businesses: Parent companies vs. their brands. *Information (Switzerland)*, 12(2), 1–16.
- Rajendran, S. (2021). Improving the performance of global courier & delivery services industry by analyzing the voice of customers and employees using text analytics. *International Journal of Logistics Research and Applications*, 24(5), 473–493.
- Sakas, D. P., Kamperos, I. D. G., & Reklitis, P. (2021). Estimating risk perception effects on courier companies' online customer behavior during a crisis, using crowdsourced data. *Sustainability*, 13(22), 12725.
- Sasko, J. (2014, June 9). Dbáte na hodnotu svojej značky? Online reputačný manažment. Podnikajte. <https://www.podnikajte.sk/marketing/online-reputacny-manazment>
- Shah, P. (2020). Managing customer reactions to brand deletion in B2B and B2C contexts. *Journal of Retailing and Consumer Services*, 57(2), 102223.
- Song, P., Zheng, C., Zhang, C., & Yu, X. (2018). Data analytics and firm performance: An empirical study in an online B2C platform. *Information and Management*, 55(5), 633–642.
- Štefko, R., Dorčák, P., & Pollák, F. (2011). Shopping on the internet from the point of view of customers. *Polish Journal of Management Studies*, 4, 214–222.
- Szwajca, D. (2018). Dilemmas of Reputation Risk Management: Theoretical Study. *Corporate Reputation Review*, 21(4) 165–178.

CYBER SECURITY IN A DIGITAL WORLD

LEGAL PITFALLS OF SW REPLACEMENT AND THEIR SECURITY IMPLICATIONS

Michael Sonntag

Johannes Kepler University Linz, Austria

michael.sonntag@ins.jku.at

DOI: 10-35011/IDIMT-2022-259

Keywords

Copyright, API, database, security

Abstract

Software needs to be replaced. This is not always to the liking of those who wrote (and licensed) the software to be removed. Simultaneously the replacement should be as cheap, secure, and friction-free as possible. But is this really possible? Retaining even parts of the original software like its API or data structures can be almost inevitable to avoid complete re-development, but might be legally problematic. Based on an actual court case this article discusses such vendor lock-in problems and their impact on security.

1. Introduction

Software needs updates: sometimes not only via patches or newer version of libraries, but more extensive reworking. This paper is based on a real court case where a proprietary library in the software of a company C (Customer) was to be replaced by open-source libraries and custom programming. I.e. the dependence on another company L (Library developer) - and the associated licensing costs – should be removed. Obviously, the application itself already belongs to company C, but similarly the library is only licensed from L. In this case the company L also developed the application for C and transferred all rights of it to the customer – but only a runtime license for the library (and a development license for ongoing maintenance/extension of the application by the company). With the replacement process of the library – the application itself should remain to be further extended and improved in the future - a third company I (Implementor) was tasked: all their additional/new programming was to be again the property of the customer C (and the open-source libraries would be used under their respective terms). However, how does the implementor work to perform this replacement in a legal way, and so that C afterwards has full rights on the resulting program and L has no claims whatsoever on it? E.g. does I need a license for the original library during their – incremental! – replacement work? Is L required to grant such a license, and what can be done if not? The application also includes parts of the API of the library as it calls it in the original version: can this API – the interface definition – be “reused” and only a new implementation be provided by I? All these questions (and more) led to court proceedings in which the author was involved as a court-appointed expert. Also investigated here (although not part of the case except that the API in question was the security API) are the security implications: some well-investigated SW in use for years is replaced by a new version – what does this mean for security and especially which of the various options for replacement can be expected to produce the most security result?

2. License aspects

The library in the case had two kinds of licenses: a runtime and a development license. While the customer C had of course both licenses, the implementor had (very likely; not decided by the court in an official capacity) none. But here several questions are open: could the implementor “use” the license of the customer or would they need their own (or would they perhaps need no license at all)? Which kind of license would be needed, runtime or development? And could company L simply refuse to grant them any license at all (or only refuse a development license)?

If the implementor gradually changes the implementation from “with library” to “without library but including open source libraries and our own code” it seems unrealistic that no license would be needed at all: during development compiling the software, testing the partial replacements etc are all activities requiring the library on the technical level; it must be present on the development computers, it is executed, it is analyzed to provide auto-completion in a development environment etc. This will generally need at least some version of “runtime permission” for the library. This could only be avoided if neither compilations nor tests are performed – even indirectly – by the implementor. They would receive text files, rewrite them, and submit them to the customer. Note that feedback from tests would also be problematic: sending code to be executed and receiving back the output could legally be seen as “executing the library”, as the implementor decides when and what to execute and inspects the output – whether it is technically executed on servers of the customer or this initiated by their personnel might not be important as no decision is made by them at all; they are merely “technical tools”, performing predefined tasks assigned to them by the implementor. This can also be seen through a comparison: if a company runs software on a cloud service (or simply rented instead of owned computers), the cloud service might need a license, but the company starting and using the software is definitely primarily/also needing a license (on their own or derivative via the cloud provider), although they do not execute anything on their own computers. Compare to this also “client access licenses” for server OS or applications.

Regarding security such a non-use of the library might be advantageous, as it enforces development of tests, at least for functionality, but hopefully also for security. Also no errors of the previous implementation can be incorporated, as no code can be copied. On the other hand, because of the increased effort needed and the lengthy nature of tests, non-essential tests (like security in many eyes) might get neglected and new errors will be introduced. Note that existing tests will also mostly not be able to be executed for comparison because of the lack of the library. And as no direct access to the library exists, it is also unlikely that its documentation is accessible (in the actual case covered by the development license). This means that any documented assumptions, boundary conditions, required contexts etc are unknown and would have to be deduced solely from the use of the library in the application but without the library as such. Especially when checks are omitted as the library performs them, it is very likely that these will be forgotten and be missing in the new implementation altogether.

Would software development to move away from a library need a “development” license of the library? This is not easy to decide and probably depends significantly on the exact wording of the license. Note that a “development license” in this case does not refer to developing, i.e. changing, the library itself, but designing and implementing a program using the library (while a runtime license merely allows running programs developed by someone else and employing the library for this; typically when the company passes their own software – plus the library needed – on to third parties). In the actual case the development library was required for “developing applications” with “applications” defined as “software that uses the library in parts or completely [...]”. It could be argued that working on removing the library is exactly the opposite of developing applications that use the library – but equally possible is it to claim that during the process such an application is

worked on which is (at the moment, until full replacement) using the library. No definite solution can be given here, only that it is recommended for the library producer to distinguish clearly between two such licenses and define exactly what “development” means – as in both cases, runtime and development, the same and unchanging library is used. For customer and implementor detailed investigation what such varying licenses each allow in detail is necessary.

Whether implementor I could “participate” in the licenses of company C is another important question, which however is usually to be answered negatively: generally software licenses are “non-transferable” and “no sub-licensing”, i.e. neither can a part (e.g. a few “seats”) of the licenses of C be sold to the implementor nor can they be transferred in another way (rental/leasing/sub-license). While such would of course be legally possible in general, to the knowledge of the author such prohibitions are extremely common and ubiquitous. One potential chance to get around this would be to tightly integrate the actual persons working on the development project into the company C: they would then be counted as employees of the company and therefore be entitled to the license. This could be done e.g. via leasing personnel, but it needs careful checking whether this is sufficient. Also note, that this might not always be the desirable way to work, as the company C is then probably bound to specific persons and has to perform most of their management itself. Unfortunately, there seems to be no other way possible; even buying the whole company of implementor I would not be sufficient as long as it remains a separate legal entity. Of course, the company could itself remove the complete library and only then let the implementor work on it, but this is very inefficient (no testing possible at all before complete replacement; needs exact description of what is to be implemented as no comparison is possible etc) and probably not what is usually intended. See also the problems regarding the API and data structures, which would have to be (partially) removed as well.

Is the library provider required to grant a license (runtime/development or both) to the implementor? Generally, freedom of contracting prevents this: nobody is forced to conclude a contract with anyone. However, there are several exceptions, e.g. the post having to transport letters of everyone paying the postage. These can be set down in laws, stem from the principle of equality, or of non-discrimination. However, in my opinion nothing here is helpful to an implementor: while the library of course is a “monopoly” on itself, there are definitely lots of equivalent options – one of them being the aim of the replacement project! It is also technically possible (even if significantly more expensive) to obtain a different solution, i.e. substitution without a license (see before). Also, while problematic for the customer, there is no need to use (this) library at all. Moreover, there are factual and understandable business reasons why the library might not be licensed to the implementor: trying to retain one’s customers is a legal, normal, and accepted reason. There seems to exist no general requirement to render a move to competitors easier; it need just not be actively hindered. And while refusing a license might be problematic and expensive to the customer, it does not really prevent a company from “moving on”; they are not in an emergency as in the meantime they still do have a working solution (this means, simultaneously terminating the license for C might be a problem!). Note also that in the IT area some programs might be very long-lived, but that generally at least after some decades an (almost) completely new implementation is performed anyway. However, one possibility for a requirement to license is a preliminary contract (which itself is usually not required to be concluded!); as such the license to the customer C could perhaps be seen. But such licenses typically do not require the owner to grant a license to a third company too. This is also not in any way necessary to “fulfill” the contract or its intentions: the customer could always do every kind of development – including replacement – he needs itself. As a conclusion, absent explicit language in a previous contract the library owner is not required to grant any kind of license to a third-party implementor. Note that in this case also no economic reasons exist: the company C has already decided to not license in the future, so (absent other existing/expected contracts) no reason for helpful accommodation to them by L exists.

As a summary: the library provider is not required to provide a license to the implementor, but this company will almost always need it. It is therefore advisable to try to obtain the necessary license(s) before the transfer away from the library is disclosed. If no license can be obtained, performing the development in-house is probably the only option apart from the customer completely removing the library (see below for potential problems with this) before handing the incomplete package to the implementor for the development of the now missing parts. From the legal point of view it can be tried to include language into the license to allow limited sub-licensing (e.g. to contractors); this can be successful if for instance already the original development is not performed by the library provider or the customer itself. Seen from the security angle it is recommended to try very hard to license at least the documentation, as otherwise a lot of implicit knowledge is lost. For security this is very important because any “lack” of it is not immediately apparent and requirements are not easily deduced from mere usage of a program (here library).

3. API aspects

The library of producer L has an API, and while it may be related to or based on other sub-libraries employed, it will definitely be an extension – or there would not be a need for the library in most cases at all. This API is mirrored in the customer’s software: a function A with two parameters is defined in the library and an exactly matching call A’ of it is part of the software to execute it. The questions here are: is the API legally protected, and if yes, what does this mean for its replacement? According to the EU computer program directive Art 1 para 2, copyright protection applies to the expression of a computer program in any form, but not the ideas and principles which underlie its interfaces. From this we can conclude that interfaces itself must be able to be protected at least to some extent. The directive also states that only “expression” is protected like in any other copyrighted work. Therefore creative decisions by the implementors are protected, but technical requirements are not. For our library the consequence is that we cannot absolutely exclude it – usually at least some parts of the API will have at least a bit of protection (the exact amount is not of interest here). From this follows, that only those parts of the API may be reused (=simply replaced by a re-implementation), which are completely unprotected. Identifying these parts may be difficult and error-prone, with attached legal risks. All protected APIs need to be replaced with new ones, which may contain the same technical principles and underlying ideas, follow from identical requirements etc, but not the creative part. This has to take place in the software itself. Note that mere renaming and reshuffling argument lists will not be enough: the creative part of an API consists especially of the separation of a larger task into smaller sub-units, dynamic aspects (which functions to call when), the selection of paradigms (callbacks, synchronous, event-driven...) etc. So a significant restructuring of the application itself will be required too.

And while it is a legal matter, identification of the “problematic” parts of the API cannot be left to legal experts: they will not know which aspects are technically determined, stem from the requirements etc. Similarly it is unrealistic to expect programmers to be able to determine the requisite amount of creativity for and the extent of legal protection. It seems therefore better to work in interdisciplinary teams here – similar to the model “Chinese wall”: developing a new API specification and checking it is not an infringement of the existing implementation. This can then be passed to the third company for implementation. Note that while the US Supreme Court decided that Google could legally use the whole Java library API (US Supreme Court-API), this is based on US law (→ fair use) and that producing a directly competing product is hardly ever fair use. It is also interesting that it was deliberately left undecided whether APIs might at least in some cases be protected by copyright - or not at all.

A protected security API is especially problematic, as a complete restructuring usually means a complete redesign of the security architecture – which probably introduces bugs both in design and

implementation. Also, for most libraries/API the security architecture will not be explicitly documented. On the other hand such a redesign allows focusing on the actual and specific needs of the application and does not have to support various additional functionality or other use cases like a library has to do, potentially allowing simplification.

An issue discussed (but not decided by the court) in the actual case was, that the original software was developed by L too, i.e. they took their own library and “completed” it with the rest of the application. This meant, that the rights of the application passed to the company C. The question is: does that include the API? The “mirror” part is an element of the newly developed code for the application, for which there was no doubt it belongs to the customer – so were the rights in the API (exclusively?) transferred to them? This would mean that a simple re-implementation of the library would be sufficient and the separation of “protected API” from “other unprotected API” would not be necessary. The same can also occur with a third-party library: whenever the library is licensed, the API can of course be used. But can it also be used when the license expires or for interfacing with different code? For example, could Linux re-implement the complete Windows API (=windows application would only need to be recompiled to run under Linux)? The other way around: would re-implementing the Linux API in Windows force Microsoft to place it under the GPL? If usage is based solely on a license, then the answer is simple: as long as the license is in force, it can be used with the original library, afterwards it is definitely problematic. However, re-implementing the API with a different library/custom software and retaining (and keep paying!) the license is undesirable. Reusing the API with a different “library” than the original means, that a part of a protected work is duplicated. While the “original” duplication in the software (mirror of the API) is technically necessary for using the product, this is not true for an alternative library. This can also be compared to copying creative implementing code from the library into a replacement: this is (correctly) seen as copyright infringement. Why then should the API be handled differently? Consequently the license only applies for the “mirror” of the API and not an alternative implementation, the “original”. Therefore either a specific additional license is required (merely keeping the previous license might not be enough – the API is licensed for use together with the library but not for independent usage!) or the API must be replaced too. But what about the actual case, where the software (with the mirror API) was sold by the developer of the library (and consequently the API too)? As in most cases the library will only be licensed and not sold, this could mean that at most the mirror of the API was sold to the customer – re-implementing the library would however mean using not the mirror of the API but the API itself. That this was not meant to be “sold” follows also from the potential consequences: the developer of the library would not be able to license the library to other companies anymore, which was definitely not intended. From this follows, that the customer did obtain exclusive rights of the custom software, but likely only received non-exclusive rights on the (mirrored) API. Note, that an exclusive license of the API is not necessary for the intended purpose: the software can be used perfectly with the library without such rights, and only when the library is no longer to be used this becomes important.

As a consequence, this potential problem should be addressed in software contracts: which rights are obtained on the API of the library? The final result (probably “none” if used without the library) might not differ, but at least the customer knows in advance what moving away from the library might entail.

4. Data structure aspects

Most business applications do contain some sort of database for storing and retrieving structured data. As a consequence, this structuring must have been developed by someone – in this case it was again the company providing the library as it developed the application too. While there is no discussion that the parts of the data structure pertaining to the business of company C belong to that

company, what about those parts of the database which stem from the library? In the court case this was the permissions system for the web application, i.e. (a part of the very versatile) security subsystem of the library: a role-based access control system with a few extensions (e.g. including multi-tenancy – customer C is an international concern with legally separate companies in several European countries). While there was no question that the implementation of the data structures, i.e. the classes as well as the queries, were developed completely independent and anew by the implementor (using a different database abstraction layer), the database structure, including the columns, their names, their types etc were identical. I.e. the data structure was “copied” 1:1, but the realization of that structure in program code not at all. From this follows that the database needed no changes or conversion at all: simply exchanging the code accessing it was sufficient from the technical point of view. Note that the content of the database (which is structured according to L’s data structure!) indubitably belongs to the customer (Dokalik/Zemann 2018, RZ 6), and should – and often must – be retained. While in the concrete case the data structures used were commonplace and obvious combinations of a well-known permission system (see ECJ 1.3.2012, C-604/10 “Football league fixture lists“, marginal number 39: „By contrast, that criterion [→ creativity] is not satisfied when the setting up of the database is dictated by technical considerations, rules or constraints which leave no room for creative freedom [...]“; but note the low “no room” threshold!), this need not be the case: there might be creative extension (in the court case present in the library but not used by the application) or completely unique parts, e.g. for CRM/blogs/document storage/... modules. Such creative data models may be protected as part of a database (Metzger 2014, RZ 4). Security architectures are a prime example of being “outsourced” to a library – which from the security point of view is good, as they are hard to do correctly. The advantage is that security data, e.g. permissions, are usually orthogonal to other data, so technically a replacement is easy. This still means that the data is lost and has to be recreated if no transformation is possible. On the other hand, in most cases security will contain very little creativity if at all: technical and security requirements determine the structure to a large degree. For example, all role-based security system will need roles, permissions and connections between them (beside other elements). Also, the system should be as simple as possible to reduce errors in its usage. In the context of data structures security is therefore advantaged, as copying the structure will usually be no violation. It should be taken into account, that while e.g. the RBAC structure is “simple”, the individual permissions and their relations/groupings etc will vary widely according to the application. But these are database content and not database structure.

As these data structures were part of the application delivered to the customer, it was argued that they also belong to the customer C – they received an exclusive license for their application. However, while used within the application and delivered with it, from a logical point of view these data structures remain part of the library (which was also delivered with the application and where obviously no exclusive license existed – it should and was licensed to other customers as well). Note that the classes implementing these data structures are parts of the library and not the application. From the legal point of view this seems rather clear: there exists a license for the library and these structures may be used in that scope. Transferring the creative part to another software – the library replacement – is not possible, however, as far as these parts are protected by copyright. And this is where the problem lies: for source code it is trivial to decide whether it is protected by copyright, as almost none of it won’t be (Burgstaller 2017). So the code must be (and in this case was) re-implemented. However data structures are more complex, as technical requirements, the objects to be represented, efficiency, common approaches (e.g. ACID for databases) etc all reduce the possibilities significantly and cannot contribute to the necessary creativity (Koch 2003, p 796). It is therefore necessary to determine which parts of a data structure are really creative, and therefore protected, and which are not – and can be retained identically. A first guideline is, that if no reasonable alternative exists, it cannot be protected: creativity cannot exist absent a selection between possibilities. But this is not necessarily enough. From this can arise

a significant problem in a software transformation process, as additional code needs to be developed solely to transform any existing stored data to a new structure. And while replacing code might require (lots of) effort, replacing the database structure might be effectively impossible without losing the data contained. This is especially problematic as simple renaming or combining fields (which as opposed to splitting them is easy) will not be sufficient: names are rarely creative and separate from the structure of the data itself.

Beside copyright there is an additional problem related to this: if a data structure is not protected as a creative work, it might still have been a lot of work to develop (not implement: copyrighted code!). Taking over this effort without any own work can be unfair competition, as the original implementor is competed against with his own work, thereby sparing the second implementor own expenses (see Marko/Hofmarcher 2011). This has been subject of a supreme court decision in Austria (OGH 16.1.2007, 4 Ob 198/06f) and can be seen as (at least nationally, but probably similar in many countries) settled law. So even if the data structure is not creative, e.g. determined by the natural structure of the data to be stored, but a lot of work to discover or develop, reusing it (=not developing anew) may still be illegal. The consequence is, that any complex and unusual (and therefore probably creative), as well as any laboriously to create data structure must be redesigned. This might be necessary in any case, as a determination if and which alternatives exist is a prime determinant whether it is protected by copyright or not. And when trying to redesign it to determine its protection status, an alternative structure can be created simultaneously. Should the result be the same, then it is a) not under copyright protection, and b) no unfair competition has taken place. The only requirement here is to ensure documentation of this process. Fortunately, as already discussed above, security data structures are often relatively simple and most of the work is their implementation and the integration into the application, so it is unlikely that copying the structure alone (!) would be unfair competition.

It is therefore recommended to avoid using libraries which 1) define their own creative data structures, which are then 2) used in an application and 3) will need to be retained if the library is replaced. This means:

- Libraries solely consisting of “code to execute” are no problem in this regard. They need to be re-implemented; for their API see above.
- Libraries defining data structures for internal use only are harmless too: if the library is replaced by new code, new such internal data structures are necessarily and automatically developed too. As they need not be carried over, they can also be kept hidden from the persons performing the re-implementation to avoid any unconscious infringements.
- Libraries defining data structures integrated with the database of the application, e.g. where Joins (or other cross-references) are necessary: these should be avoided if possible, or kept to a minimum. Note that this can be a significant drawback, as e.g. security functionality, user accounts, CRM functionality etc is often provided by a library and its use will be a significant reason for using the library. And while e.g. security data structures are rarely creative or a lot of work, the same cannot be said about complex models for users or activities. Because of this, employing a library for these can be a significant risk and end in vendor lock-in surpassing mere work to avoid reuse of implementing code.

As a side-note it must be mentioned that this is not an issue specifically related to proprietary libraries: if the library is open source, e.g. (L)GPL, an incomplete replacement could be seen as still being a work based on the library – as it continues to include the creative data structures – and might then have to be provided under the same license upon distribution. Only very permissive licenses like BSD do not suffer from this problem.

5. Reusing code – or preventing it

When existing code is to be replaced by new code performing exactly the same functionality – often also in the exact same language – incentives for “creative reuse” are strong. However, taking implementing code from the library, inserting it into the new replacement and claiming it to be new and developed from scratch is practically guaranteed to be illegal: only very simple parts of program code are not protected by copyright, and regarding unfair competition even a few hours of work saved by such activity are illegal (see above). Note that for such activities already the decompilation stage is illegal (Art 6 para 2 lit c of the EU computer program directive, Computer program directive): the EU computer program directive clearly state that decompilation is not permitted if the information obtained through it is “to be used for the development, production or marketing of a computer program substantially similar in its expression, or for any other act which infringes copyright”. However, decompilation may be legal for the process of developing a replacement if the documentation of the library is insufficient, as then information is derived to achieve interoperability with the independently created computer program (the existing application). However, the interoperability target is not the library (which is to be removed!), but the custom program using it, i.e. only the API. And full access to the program using the API provides most of the information needed: what is the function expected to do and how is it called? Legal decompilation therefore seems to be rarely possible.

Regarding security this is a big problem, as testing security is difficult (e.g. verifying whether/for what explicit checks have been implemented) and rewriting code may introduce new problems. Additionally, even inspection of the source code may not immediately show, why something was implemented in a specific way to avoid a certain danger: there might simply be no comment and the reason might not be obvious. Additionally, security checks are today at least sometimes implemented as “aspects”, i.e. implemented in a different part of the code and inserted dynamically later (by a compiler or even at runtime). The first will usually be visible on decompilation only – or finding the location where this cross-concern is implemented and added, while dynamically inserted checks can only be found via debugging (note that the library might introduce such checks also into the program, not only itself!). So extensively tested (libraries are usually used by many application) and where perhaps numerous security issues have already been found must be replaced by a completely new implementation without knowledge about the details of the previous one: security issues must be expected.

While the legal position here is simple, how can an implementor ensure that its employees don’t do anything illegal, and library provider L verify that no copying of any elements occurred? The implementor has direct access to its own employees, so can forbid them any decompilation or copying. Note that verifying this via decompiling the library and comparing it to the new implementation is illegal (no interoperability!), so no actual direct verification is possible. Indirect verification is possible through checking the time needed for re-implementation if performed on a low level, e.g. for each class. Today this can also be approximated via versioning systems: the amount of new code can easily be extracted and compared to the time spent since the last addition. So if an employee is suspiciously productive, a closer investigation may be necessary – but this could have been a simple task or an excellent programmer too. The alternative, preventing them from accessing/using the library at all, renders any kind of comparative testing (does the new software behave the same as the old?) and gradual replacement impossible, so is usually not an option.

For the library producer the situation is even worse: usually they will have no access to the replacement implementation at all, so the second element for comparison is absent. If they do obtain access to a compiled version, decompilation for discovering/verifying copyright infractions

is again illegal (but note that this can be done “in secret” and only if suspicion of copying arises difficulties occur with how to claim to have discovered this).

A consequence of both is, that the customer cannot really be certain that no illegal activities were performed during the replacement project – they usually have no chance to verify the activities of the individual developers, and while they have access to both “versions”, decompilation for any kind of checking is forbidden for them too. Note that this problem is exacerbated for the replacement of open source libraries, as there not “one provider” exists and the (potentially proprietary!) replacement library would have to be made effectively public for them to be able to investigate it. Should on the other hand the replacement of a proprietary library be open source, such checks are easy to perform and legal, as no decompilation is necessary and the replacement can usually be obtained easily.

Recommendations for these problems are:

- Implementor: Provide clear guidelines which development activities are acceptable and which not, e.g. how “deep” testing is allowed (observing the behavior from the outside is ok, but deducing the inner workings is not). These should be agreed upon between the customer C and the implementor I.
- Customer: Try to avoid providing the original library to the implementor. This can be done e.g. via an in-house testing pipeline: source code is submitted by the implementors employees to the customer, who combines it with the library and other third-party elements (e.g. web pages, JavaScript etc which could only reasonably be provided “uncompiled”), performs tests, and returns the results to the implementor. Note that this is not very efficient as it means that the implementor will not have any access to the library for quick/intermediate/... tests. See above on other legal (non-)implications of such a model.
- Implementor/Customer: Performing random tests through decompilation solely for testing purposes to verify that no copyright infringement exists is, while illegal, probably very low on the scale of issues to prosecute. And while the library implementer has no right to access the replacement at all, some cooperation in this regard may be helpful. Note that providing to them the replacement implementation is usually not a problem: the only information they can deduce from this is which parts of the library are used by a specific customer – which usually does not disclose any secret knowledge. This is not very helpful for the developer in the sense of reducing their work either as they already possess code doing exactly the same thing, so in most cases they do not gain materially from this, only regarding certainty of non-infringement. One real danger of this approach is, however, that any replacement code might be leaked to the public.

6. Summary

Replacing existing code being part of a larger application from one supplier with that of another one (or developed in-house) can be very problematic from the legal point of view. It must be ensured that not only the process of replacement is performed legal, but also that no protected traces remain. It is therefore important to deliberately select which libraries/modules/frameworks to use, as you might be stuck with them for a long time. Note that the trend towards “microservices” helps here only to a limited degree: one third-party service is definitely easier to replace, but similar (and identical: inside each service – if counted recursively - often hundreds of libraries are used!) problems still exist: the more microservices exist, the more APIs need to be designed and the more they are removed from “reality” the more creative they probably are, as ever smaller slices need to be defined. All these APIs also need (at least for each pair of producer and consumer) matching

data structures. So replacing one microservice is much easier on the technical level, but still suffers the same problems as monolithic applications employing libraries. And while a library is typically licensed without a time-limit (=ensuring access to it as long as needed and payment is made), services can easily be discontinued or their licenses changed, necessitating modifications of the system. Similar as with libraries it is therefore recommended to try to design both APIs and their data structures as simple and based on reality as possible to avoid both copyright and unfair competition claims if changes are unavoidable.

If a security implementation that has been (hopefully) extensively tested and has stood the test of time has to be replaced with a new implementation, it is very likely that new problems are introduced. While a redesign can be an opportunity to implement a simpler/better model, this is unlikely in the case of replacing a library. Retaining the data and as much of the existing application are priorities. So the more restructuring is necessary, the more bugs will creep in both on the programming level as well as the conceptual: an existing system is made to fit a (slightly) different one. Therefore it is very important to ensure that either the system can be retained identically or is extensively tested and perhaps even redesigned: a new/better system at least gives additional advantages than a badly fitting replacement.

7. References

- Burgstaller, P. (2017). Urheberrechtsschutz für Computerprogramme, ÖBl 2017/19
- Computer program directive, Directive 2009/24/EC of the European Parliament and of the Council of 23 April 2009 on the legal protection of computer programs, LJ L 111/16 from 5.5.2009, <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32009L0024>
- Dokalik, D. & Zemann, A. (2018). Urheberrecht7 § 40f UrhG (Stand 1.10.2018, rdb.at)
- Koch, F. (2003). Handbuch Software- und Datenbank-Recht, Berlin, Springer 2003
- Marko, R., & Hofmarcher, D. (2011). Anregung, Nachahmung oder Leistungsübernahme? MR 2011, 36
- Metzger, A. (2014) Urheberrechtsschutz von Datenmodellen, Dateiformaten und Schnittstellen. In: Conrad, I., & Grützmacher, M., Recht der Daten und Datenbanken im Unternehmen, Köln, Verlag Dr. Otto Schmidt, 2014, 247
- US Supreme Court-API, Google LLC v. Oracle America, Inc., No. 18-956, slip op. (Sup. Ct. 2021)

EMPIRICAL EVALUATION OF PASSWORDS: INFLUENCE OF THE MODIFIED VERSION OF ZXCVCBN

Jiří Sedláček

Faculty of Informatics and Statistics
Prague University of Economics and Business
sedlacek@vse.cz

DOI: 10-35011/IDIMT-2022-269

Keywords

User authentication, password strength estimation, password guessing, password cracking

Abstract

Passwords are still a widely used method of user authentication. Password strength estimation (PSE) programs can be useful (for the end users and administrators) only if they provide “a reasonably good” estimation of password strength. The passwords themselves as well as the tools for their evaluation were tested mainly for English, or other commonly used languages. First, the aim and process of modification of the well-known zxcvbn program suitable for production deployment in the Czech, Slovak or mixed language environment such as at the Prague University of Economics and Business (VŠE) is described. Later, the results of password testing without or with zxcvbn are presented. The main findings are: (1) We used a large dataset of more than 3 million previously leaked passwords of about 4.5 million Czech users. The passwords were divided into categories according to the descending frequency. The password strength estimate has improved for all categories. (2) We prepared two equally large randomly selected samples of real hashes of passwords of the users from VŠE – before and after the deployment of the modified zxcvbn. The ratio of broken passwords (using the program John the Ripper) has decreased several times.

1. Literature Review and Related Work

In this part of the paper, we summarize the main findings from the extensive literature dealing with the password policy development, the way users choose and use passwords, and the ways of user-chosen passwords strength estimation. We briefly characterize the *zxcvbn* program and the reasons of its modification for use in non-English language environments.

1.1. How Users Choose and Use Passwords

The (common) situation of not using password management programs or other methods of random password generation (such as *diceware*) leads to several fundamental and serious consequences.

- User-created passwords are *not randomly generated*. They use only some of the possible combinations. Such passwords have *lesser real entropy* than randomly generated passwords of the same length using the same set of possible characters.

- The user must *remember* the password (of course, if he or she does not write it down somewhere and this poses another security risk; its extent depends on how and where the password is stored).
- The need to remember (or to write down) a password in practice means that users often *reuse* the same or a very similar password for many different accounts.
- The entropy of user-created passwords *cannot be calculated exactly*. Password strength estimation programs (PSE) use various algorithms for this estimation. However, they often fail in practice, as we will illustrate later with real examples.

Proven by many research articles as well as real password leakages (Morris & Thompson, 1979; Veras et al., 2014; Ur et al., 2017), users often choose passwords that are simply too short (prone to *brute-force attack*) or are based on widely used words (“password” is a notorious example), names or surnames, animals, names of famous actors or singers, popular movies, songs etc.

Passwords based on common words are easier to guess because a *dictionary attack* (more precisely, a dictionary attack combined with rules) is much faster and more effective than a brute-force attack. Using Wikipedia, the attacker can now easily create large dictionaries not only for English (German, Spanish, etc.) but also for less common languages such as Czech. Wikipedia currently contains 138 language versions of more than 10,000 articles (Wikipedia contributors, 2022). An extensive list of first and last names or movie or song titles can be easily added, too.

There are several reasons why users choose such weak passwords, and they can be valid at the same time. First, it is the need to remember the password. The users usually have dozens of accounts to log in. This can result in reusing very weak passwords based on common words. Besides, the users often do not know what makes the passwords weak and what is the impact of improper reuse. A simple example: the users may be aware that the word “password” is weak but may be convinced that “password123” or “P@ssw0rd” are strong ones (Das et al., 2014; Ur et al., 2016; Stobert & Biddle, 2018).

Many users simply do not realize how serious problems the unauthorized use of their account can cause (not only to them, but also to their family members, coworkers, or the whole company they work for). However, weak passwords and security breaks are not just the faults of users. Adams and Sasse (1999) were one of the first to discuss the need to change the attitude of users.

1.2. Password Strength Estimator (PSE)

As previously mentioned, real entropy cannot be accurately and unambiguously estimated for user-selected passwords (not randomly generated). That leads to a practical problem: what rules, procedures, tools, or measures can be used (and should be used) to ensure that users are likely to choose “good passwords”. And conversely, which well-intentioned measures or rules are not effective and are in fact only an unnecessarily burden or annoy users.

Short passwords are always weak – they can be broken by a brute force attack (or by a more effective method like the dictionary attack). Therefore, any *password policy* should require a certain *minimum password length* (increasing because of the performance of computers and thus the ability of attackers, too). Rules as “at least one capital letter, one number, or another character” do have a certain rational basis. But both practice and academic studies have shown the ineffectiveness of such rules (see e. g. Weir, 2010). Therefore, the current NIST guidelines state that such rules *should not* be applied (Grassi et al., 2018). Unfortunately, these rules are still used by many websites.

Is there a better way to prevent users from choosing a very weak password? The idea was probably first published by Klein (1990). Such programs can be called *Password Strength Estimators* (PSEs) or *Password Strength Meters* (PSMs).

It took many years for such programs to be used in practice. However, a large study by de Carné de Carnavalet and Mannan (2014) shows that the programs used in real life are often not well designed and the results are poor. The only exception was *zxcvbn*, the program described below. Later, Stockley (2016) performed a much simpler but also more illustrative study. He selected just a few “bad passwords” and tested six widely used PSE programs written in JavaScript. Again, only the *zxcvbn* program marked all passwords correctly as “very weak”.

The bad results of most programs are not so surprising. There is not a single and guaranteed algorithm for detecting a weak password. But bad PSE is (in our opinion) worse than no such program because the user may get false information that his password is good while it is very weak. The already mentioned current NIST guidelines recommend checking the weakness of the password during its creation (Grassi et al., 2018). However, the careful selection of the PSE program is not enough. It is also necessary to deal with modifications of the program for other cultural environments than English because passwords are greatly influenced by that factor.

1.3. Original *zxcvbn* program

The *zxcvbn* program was originally created as an in-house development for the website Dropbox.com because the author was not satisfied with the results of several commonly used PSE programs at that time (Wheeler, 2016). The author had two main goals: (1) It should provide good and consistent estimates of password strength. (2) Because the program was intended to be used within a web browser, the program had to be resource-efficient. For the same reason it was programmed in JavaScript. Currently there are implementations in many other languages (C, C++, Python, PHP, Rust, Go, Java, C#/ .NET and others) and therefore the program is suitable for any type of application.

The program uses a pragmatic combination of relatively simple but carefully designed algorithms and several dictionaries (to be both light on resources and effective). Dictionaries include (for English) the most common general words (30,000), the most frequent names (about 5500) and, surnames (30,000), words from movie titles (30,000) and some others.

Besides word-based passwords, it can also detect other weak passwords like a combination of words (or parts of words) and numbers (e. g. “password111”, “pass123456”), letter, number, and keyboard sequences (“abcdefgh”, “12345678”, “asdfgh”), including bidirectional (“123454321”, “asdftrw”) and also year sequences or dates in several formats or common letter substitutions (like “p@assw0rd”). Many other PSEs often fail miserably on that. By the way, the name of the program (*zxcvbn*) is derived from the keyboard sequence in the bottom row of the US keyboard.

However, if we study various lists of worst passwords or even extensive databases of leaked passwords, we can easily conclude that many passwords are influenced by the language or rather by the cultural environment of the users (see e. g. AlSabah et al., 2018). The process and the results of creating a modified version of *zxcvbn* suitable for deployment in the Czech (Slovak) environment are described in the following chapters.

2. Methodology and data

We describe the process of modification of the original *zxcvbn* and the data and procedures used for testing the modified *zxcvbn*. The author of *zxcvbn* was aware of the bias of the original version to English (or more precisely to US English) and mentioned that in his paper (Wheeler, 2016).

2.1. Modified *zxcvbn*

If we look more thoroughly into databases of leaked passwords, we can divide them into several categories (whether and how they are affected by cultural environment or other factors):

Passwords (or their fragments) that are almost *independent* of the user's language (or cultural) environment. Typical examples are numbers. Password “12345678” or “123456789” (influenced by required minimal length) is among the “top five” in virtually all password lists.

Word-based passwords are very frequent and *very influenced* by language and culture. Therefore, it is necessary to prepare several different dictionaries (common words, names, surnames etc.) for Czech, Slovak (or any other language we are interested in).

Domain specific passwords are related to the user or the institution or the service. In the famous LinkedIn leak, the password “LinkedIn” was the second most frequent one. That is easy for *zxcvbn* by design. A so-called “user dictionary” can be (and should be) used. It is a small (up to a dozen of items) dictionary but it is dynamic. In the example above, the word “LinkedIn” would be used for every user while other items will be different (e. g. name, surname, username etc.).

Other passwords are *partially dependent* on language or culture. For Czech (if we ignore Czech letters with diacritics signs – not recommended or even possible to use in passwords), the alphabet layout is basically the same as the US keyboard, but with one exception. The US keyboard is “qwerty” while the Czech one is “qwertz”. *Zxcvbn* uses a little bit different algorithm for keyboard layouts, but we can say that keyboard layouts are stored in the “special dictionary” and “qwerty”, “Dvorak” and some other less common layouts are already in. Other layouts can be added easily.

The modified version of *zxcvbn* with all Czech and Slovak dictionaries was prepared independently by Pavlíček (2019) as a fork of the original *zxcvbn* and it is available on GitHub. The process of creation, size consideration and some other tests like speed tests are described more in detail in Doucek et al. (2020). Here is a short summary.

There is a minor modification in the program code, CZ and SK keyboard layouts were added but the main work is the creation of several Czech and Slovak dictionaries. Commons words were prepared from the Czech (Slovak) Wikipedia (8,000 most frequent ones). “Names” are the most frequent names, surnames and nicknames (23,000). “Titles” are the most frequent words in local movie titles (4,000) and there is also a separate dictionary for the most frequent leaked passwords of Czech (Slovak) users (25,000). When the total size is the primary concern, smaller Czech/Slovak dictionaries are also already prepared (about half size). But all tests were done with “standard size” dictionaries described above – the total size (program + all dictionaries) is slightly below one megabyte.

Please note that the modified version of *zxcvbn* also contains original US English dictionaries albeit at a reduced size. It is necessary for two reasons: (a) Our analyses show that many native Czech users create passwords based on English words. (b) In an environment like our university, many students are not Czech.

Initial testing was done during the program development. Later, the finished program was tested by the author of this paper using two different data sets and methods. We can name those methods as

(a) a “back test” with previously leaked passwords and (b) a ratio of cracking hashes of passwords of real users from VŠE with/without *zxcvbn*.

2.2. Data for back testing: previously leaked passwords

First, we used a large dataset of previously leaked passwords of Czech users. It is a “merged collection” from several leaks. Of course, using such a dataset has certain disadvantages and has to be taken into account when evaluating results. However: (a) There is no other way to collect such a large dataset. (b) Similar “merged collections” are regularly used for evaluating “English-only” passwords. For comparison see the dataset of 10 million passwords published by Burnett (2015). Besides, we also tested modified *zxcvbn* on real hashes of users from our university (see below).

We strongly believe that all leaked passwords (more than 3 million for 4.5 million accounts) should be detected as “weak” in the “ideal world”. We have the data, the hackers too, and they can be used (at least for an *offline attack*). In the “real world”, we cannot expect a 100% success rate if we use *zxcvbn* or any other program (limitation of algorithms + used built-in dictionaries because of size/speed concerns). Also, the most frequent passwords are the most dangerous.

Therefore, passwords were divided into categories by decreasing frequency (see Table 1 below). “Group 1” is the most important. It has only 31 passwords, but each is reused at least a thousand times (up to 21,237). No security measures can prevent hackers from trying all those passwords in an *online attack* and the chance of finding a user with such a password is quite high. If the hacker invests enough time and effort, there is a danger of breaking dozens of accounts – unless we prevent the use of such extremely weak passwords.

2.3. Data and method for cracking hashes of passwords

We used two randomly selected samples (1000 each) of real hashes of passwords of users from the VŠE: (a) Several years old saved hashes of closed accounts – before the usage of *zxcvbn*. (b) Live accounts (in April 2022): each password was already checked by modified *zxcvbn* before the user was allowed to use such a password. We use the freely available program *John the Ripper* (2022).

For reproducibility, we use only (quite large) freely downloadable *dictionaries* (hk_hlm_founds.txt + hashes.org; both can be downloaded from WeekPas.com, 2022) and predefined *rules* from John the Ripper (135 rules). The rules create thousands of common “simple” modifications and substitutions for each item in the dictionary (e. g. for the item “slunicko” the modifications like Slunicko, slunicko1... slunicko999, Slunicko1...Slunicko999, substitutions S1unick0 and combinations like S1unicko01... S1unicko01... S1unicko0999 and many others).

3. Results and discussion

3.1. Back testing of previously leaked passwords

In real usage, it is not so important if the program marks the password as “extremely weak” or only “weak”. The problem is if it marks a weak password as “strong” and thus does not prevent the user from choosing such a password and (besides) gives a false sense of security. It is particularly important if the leaked password is known to be reused often (see the description of “Group 1” above). Therefore, the results are divided into several categories. The scale for the results is: 0 = extremely weak, 1 = very weak, 2 = weak, 3 = quite strong, 4 = strong.

Because the most frequently used passwords are also the most important (also for space reasons), the results are presented only for Group 1 – Group 5 (+ Unique passwords for comparison). The

first five groups represent a small portion of all passwords, but many more user accounts. There is a high probability that attackers try those passwords first, especially in case of an online attack. In this scenario, the number of attempts is always limited, even with a distributed attack.

Table 1: Selected results for back testing

Group	Frequency of passwords		No. of passwords	Number of passwords (US)		Number of passwords (CZ)	
	From	To		quite strong	strong	quite strong	strong
Group 1	1,000	21,237	31	0	0	0	0
Group 2	500	999	99	3	1	0	0
Group 3	200	499	394	0	1	0	0
Group 4	100	199	854	10	4	1	3
Group 5	50	99	1957	19	2	2	0
...
Unique	1	1	2,769,485	409,425	144,463	296,915	120,037

Discussion: for Group 1 even the original *zxcvbn* did not mark any password with a better score than “2”, but did not score so well for other groups. If we look at the number of occurrences for the most important scale (3 and 4: quite strong and strong), the modified *zxcvbn* was 100% successful for Group 1, 2 and 3 (zero passwords for both 3 a 4 scale) and mostly successful for Group 5 (two cases in scale 3, zero in scale 4). Unfortunately, for Group 4 (still quite frequent passwords: from 100 to 199), a few passwords “slipped through” the test: one was marked as “quite strong” and 3 as “strong”. But it was already mentioned that in the real world you cannot expect 100% success under all conditions.

In our opinion, looking for the average score makes sense, too (not presented in the table for space reasons). For example, the password “Slunicko” (one of the most frequent ones) has a score 2 in the original *zxcvbn* and a score 0 for the modified *zxcvbn*. Trivial variation like “Slunicko1” has already a score 3 in the original version, but a score 1 in the modified version. The modified *zxcvbn* gives us an additional “*safety margin*” for the most variations of such passwords. The average score is better in *all cases* (Group 1 to Group 12). For the most reused passwords, the average is near zero (from 0.04 to 0.08 for the first three groups). And the average is about four times (Group 4) up to 7.5 times (Group 2) lower than for the original program.

3.2. Results for cracking hashes of passwords

The methodology is described in chapter 2.3. The sample was always 1000 hashes (results can be easily converted to percent). The size of “hk_hlm_founds.txt” dictionary is almost 390 MB (38,647,798 items), but “hashes.org” is much larger (almost 14 GB, 1,397,237,946 items).

Table 2: Result for cracking hashes of passwords of users from VŠE

	Old hashes (before <i>zxcvbn</i> deployment)		New hashes (April 2022, modified <i>zxcvbn</i>)	
Dictionary	hk_hlm_founds	hashes.org	hk_hlm_founds	hashes.org
No. of cracked passwords	197	442	64	199
Total time	00:07:16	05:01:45	00:07:14	05:01:26

Discussion: The percentage of cracked hashes with modified *zxcvbn* is slightly higher than we expected, but still, it is a large improvement (3.1 times for a smaller dictionary, 2,2 times for a much larger dictionary).

4. Conclusions

Both types of tests show (a) the general importance of using of *zxcvbn* (or similar program) as a proactive measure. (b) The differences in password usage and testing in the non-English environment. (c) Significant improvement for both types of tests. Therefore, we recommend the deployment of modified *zxcvbn* in any environment with a significant number of Czech (Slovak) users.

However, no single measure can solve such a complex problem as *password management*. Any admin should be aware of several related topics including: (a) Education of the users remains important, see chapter “How Users Choose and Use Passwords”. (b) Besides, some types of popular and effective attacks (like phishing) *do not depend* on the strength of the passwords. To prevent such attacks, regular training of users is again important. (c) Using two-factor authentication is recommended, depending on the conditions. E.g., at our university, it is currently mandatory for users with special privileges (such as system administrators or study assistants).

5. Acknowledgments:

This paper was written with a contribution from the Prague University of Economics and Business, IG Agency, grant number VŠE IGS F4/13/2021.

6. References

- Adams, A. &, Sasse, A. (1999). Users are not the enemy: Why users compromise security mechanisms and how to take remedial measures. *Communications of the ACM*, 1999, 42(12), 40–46. DOI: 10.1145/322796.322806
- AlSabah, M., Oligeri, G., Riley, R. (2018). Your culture is in your password: An analysis of a demographically-diverse password dataset. *Computers & Security*, 77, 427–441. DOI: 10.1016/j.cose.2018.03.014
- Burnett, M. (2015). Today I am releasing ten million passwords. Retrieved April 20, 2022, from <https://xato.net/today-i-am-releasing-ten-million-passwords-b6278bbe7495>
- Das, A., Bonneau, J., Caesar, M., Borisov, N., Wang, X. (2014). The Tangled Web of Password Reuse. In: *Proceedings of the NDSS Symposium 2014*. DOI: 10.14722/ndss.2014.23357
- Doucek, P., Pavlíček, L., Sedláček, J., Nedomová L. (2020). Adaptation of password strength estimators to a non-English environment — the Czech experience. *Computers & Security*, 2020, 95, DOI: 10.1016/j.cose.2020.101757
- de Carné de Carnavalet, X. & Mannan, M. (2014). From very weak to very strong: analysing password-strength meters. In: *Proceedings of the NDSS Symposium 2014*. DOI:10.14722/ndss.2014.23268
- Grassi, P. A., Garcia, M. E., Fenton, J. L. (2018). Digital identity guidelines: Authentication and lifecycle management. NIST Special Publication 800-63-3. DOI: 10.6028/NIST.SP.800-63-3
- John the Ripper password cracker (2022). Retrieved March 20, 2022, from <https://www.openwall.com/john/>
- Klein, D. V. (1990). Foiling the cracker: a survey of, and improvements to, password security. In: *Proceedings of the 2nd USENIX Security Workshop*, 5–14
- Morris, R. & Thompson, K. (1979). Password security – a case history. *Communications of the ACM*, 22(11), 594–597. DOI: 10.1145/359168.359172
- Pavlíček, L. (2019). *Zxcvbn-Czech*. Retrieved April 15, 2022, from <https://github.com/lpavlicek/zxcvbn-czech>
- Stobert, E. & Biddle, R. (2018). The Password Life Cycle. *ACM Transactions on Privacy and Security (TOPS)*, 21(3), DOI: 10.1145/3183341
- Stockley, M. (2016). Why you still can't trust password strength meters. Retrieved April 15, 2022, from <https://nakedsecurity.sophos.com/2016/08/17/why-you-still-cant-trust-password-strength-meters/>

- Ur, B., Bees, J., Segreti, S. M., Bauer, L., Christin, N., Cranor, L. F. (2016). Do Users' Perceptions of Password Security Match Reality? In: Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, 3748–3760. DOI: 10.1145/2858036.2858546
- Veras, R., Collins, Ch., Thorpe, J. (2014). On the Semantic Patterns of Passwords and their Security Impact. In: Proceedings of the NDSS Symposium 2014. DOI: 10.14722/ndss.2014.23103
- WeekPas.com (2022). Retrieved March 20, 2022 from <https://weakpass.com/wordlist/1256>, <https://weakpass.com/wordlist/1931>
- Weir, M. et al. (2010). Testing metrics for password creation policies by attacking large sets of revealed passwords. In: Proceedings of the 17th ACM conference on Computer and communications security, 162–175. DOI: 10.1145/1866307.1866327
- Wheeler, D. L. (2016). zxcvbn: Low-Budget Password Strength Estimation. In: Proceedings of the 25th USENIX Security Symposium, 157–173
- Wikipedia contributors. (2022). Wikipedia. In Wikipedia, The Free Encyclopedia. Retrieved April 15, 2022, from <https://en.wikipedia.org/w/index.php?title=Wikipedia&oldid=1082688466>

MULTI-LEVEL CYBERSECURITY GOVERNANCE FRAMEWORKS FOR PUBLIC ADMINISTRATION

Františka Romanovská, Tomáš Pitner

Masaryk University, Czech Republic
xromanov@fi.muni.cz, tomp@fi.muni.cz

DOI: 10-35011/IDIMT-2022-277

Keywords

Cybersecurity, public administration, multi-level governance, Global Cybersecurity Index

Abstract

The public administration faces an increasing number of cyberattacks nowadays, which is expected to grow. Many countries create a cybersecurity strategy to improve their resilience. In this article two national cybersecurity strategies are compared with a focus on establishing multi-level cybersecurity governance, i.e., specifying *cybersecurity responsibilities for regions or municipalities*. Subsequently, *selected territorial units in the countries* and their cybersecurity stance are examined. It is concluded that the selected national strategies do not employ multi-level cybersecurity governance; therefore, their territorial units act nonuniformly. As a possible initiative, the idea of a regional cybersecurity centre is outlined.

1. Introduction

As society is increasingly more dependent on technologies and the Internet, there is also a growing number of various cyberattacks. The attacks may aim at individuals or whole organisations. Quite often, the organisations are those in the public sector, such as health care, research institutions, governments, public administration, and providers of critical infrastructure (Geneva Centre for Security Sector Governance & Achten, 2021) (INTERPOL, 2020) (Chigada & Madzinga, 2021). According to (Microsoft, 2021) (CISA, 2022), cyberattacks increasingly focus on governments and public administrations. The Microsoft Digital Defence Report (2021) sees a positive shift in the number of reported incidents which helps to extend cybersecurity knowledge.

The number of cyberattacks on public administration is expected to grow further. Countries and governments must establish suitable measures such as sufficient capacity, policies, organisations, technologies, and cooperation between organisations. However, according to Global Cybersecurity Index 2020 (GCI) (International Telecommunication Union, 2021) the biggest obstacles for countries from the European region seem to be the organisational measures. These organisational measures pursue the governance and coordination of cybersecurity within the individual countries and their cybersecurity organisations.

The paper focuses on two areas of cybersecurity – multi-level governance of cybersecurity and cybersecurity in the public administration. Multi-level governance of cybersecurity is currently rarely supported by the governments of the examined countries. While the public administration is, in most cases, divided into levels, the cybersecurity of the country is not, even though there are clear advantages of this approach. The highest level creates a framework, defines obligations, and

provides services to the level(s) below. The first level below employs the framework and once again provides services to the level(s) below. Thanks to this cascade, the higher levels provide more complex services; therefore, they have more capacities to, e.g., resolve more complicated problems, monitor level(s) below and, according to the outputs, modify their services or (in case of the highest level) the framework. The lower the level, the closer it is to its clients. Moreover, the higher representation of institutions can indirectly lead to higher public awareness. (The Committee of the Regions, 2009)

2. Multi-level governance of cybersecurity

Multi-level governance is a state where the central government hands over some of its responsibilities to agencies that are upwards and downwards on the governmental stream (Hooghe & Marks, 2002). The concept of multi-level governance can also be applied to the area of cybersecurity: each level of the government emphasises different responsibilities, from creating policies and regulations to ensuring the cybersecurity of municipality-owned corporations.

According to (Kaklauskaitė, 2020), the focus in multi-level governance of cybersecurity in the EU is on the EU's agencies and the national governments, while regions and municipalities are in the background. Kaklauskaitė (2020) suggests that there is a need to broaden the scope of multi-level governance of cybersecurity in the EU also on a regional level because there is a closer connection to the local and regional cybersecurity actors. Extending the responsibilities beyond the national level by, e.g., creating regional cybersecurity institutions, could improve the organisational and other measures depending on the responsibilities of such institutions; therefore, improving the GCI of many (European) countries.

Considering that the cybersecurity of a member state is a sensitive matter, the rules should be more of a framework rather than strict regulation. While every region will probably face similar cybersecurity problems, the difference is in the level above that determines the law and regulations in a specific country. For example, in the Czech Republic, the national legislation defines critical infrastructure and systems of national significance; however, the regions administrate only a subset of these. Regions in the same country have the same legislation, while in different countries, the legislation can vary. Therefore, it is not possible to enforce detailed cybersecurity policies and regulations of regions from the level of the European Union. However, it is possible to create guidelines to help with establishing cybersecurity on all the necessary governmental levels. The implementation itself will be then in the hands of each country.

To explore if any multi-level cybersecurity governance is already employed, the approach to the cybersecurity of two countries is described in the next chapter.

3. Cybersecurity on the national level

The GCI was employed to choose the countries for closer examination of their approach to multi-level cybersecurity governance. It was important to select those countries that are fairly developed in the realm of cybersecurity but not to the point that every aspect of GCI has the perfect score. This condition ensured the examined cybersecurity strategies have room to grow and to see if they recognize the lacking areas. Furthermore, at least some multi-level cybersecurity governance was expected to be either introduced in the strategies or already used. Australia was chosen as an example of a bigger country with states and territories; Belgium was chosen as an example of a member state of the EU.

3.1. The Commonwealth of Australia

Australia has nearly 26 million inhabitants (Australian Bureau of Statistics, 2022) and an ICT market worth over A\$122 billion (Digital Industry Group Inc. and AlphaBeta, 2019). According to GCI, Australia has the perfect score in Legal Measures and Capacity Development but lacks a little in Organisational Measures (18.98/20), Technical Measures (19.08/20), and Cooperative Measures (19.41/20).

Following a cybersecurity strategy from 2016, the Australian Government released a Cyber Security Strategy (2020), where a vision of improving cybersecurity through actions of different stakeholders was shared. The necessary actions were divided between Australian governments, businesses, and the community. Throughout the whole strategy, the public-private partnership is very prominent. One goal even is that the government and large businesses will help small and medium enterprises (SMEs) with their cybersecurity awareness and capability. The strategy also contains an Action Plan – a list of initiatives with responsibilities divided between the three actors, a description of the initiative and an explanation of who benefits from it. The metrics are based on the initiatives; however, only the measurement of success is described. Detail funding commitments are laid out *ibidem*.

The strategy itself does not explicitly mention governing cybersecurity on regional levels. However, three actions by the government touch upon the subject of state/territorial or local governments:

- The initiative to improve incident response procedures within the state and territory governments in cooperation with private sector organisations and the Australian Federal Government.
- Providing technical assistance and supporting law enforcement capabilities to Commonwealth, state, and territory law enforcement agencies.
- Investing in the expansion of Joint Cyber Security Centres (JCSCs). JCSCs are seven centres (2 virtual) located across Australia with the goal of supporting business partners, NPOs, individuals, and academia within agencies of various governing levels. The main activity of JCSCs is to provide a sharing platform and workspaces for collaboration.

3.2. The Kingdom of Belgium

Belgium is a western European country with more than 11 million inhabitants (Federal Public Service for Foreign Affairs, Foreign Trade and Development Cooperation, 2022). The country is divided into three regions – Flemish Region, Brussels-Capital Region, and Walloon Region. The regions have their own governments with authority over agriculture, employment, planning, or the environment. The ICT economic sector is worth over 4% of Belgium's gross domestic product (Belgian Federal Government). According to GCI, Belgium has the perfect score (20/20) in all the measures but lacks Organisational ones (16.25). However, in Belgium's cybersecurity strategy from May 2021 (Centre for Cyber Security Belgium, 2021), insufficient capacity is considered the most prominent problem, especially in the public sector.

The goal of the 2021 strategy is to present a vision of free and secure cyberspace that is resilient against threats. Similarly to the Australian strategy, it considers cybersecurity a shared responsibility of four different groups of stakeholders: citizens, companies (including educational institutions), government services, and organisations of vital interest (operators of critical infrastructure). The strategy presents six objectives divided into actions; however, the description of actions is superficial. The responsibilities of the government and governmental organisations are described in detail in the strategy. Because the federal government has a complex structure

(horizontal, vertical, and programmatic services), and regions and communities have their own ministries and directorates, cybersecurity is a federal matter and is managed on the national level. Consequently, regional responsibilities are not mentioned in the strategy. (Centre for Cyber Security Belgium, 2021)

4. Cybersecurity on the regional level

Both strategies described above bear some resemblance in the approach of shared responsibility for cybersecurity and, to an extent, overlooking local public administrations' involvement. To examine how the states of Australia and regions of Belgium manage the lack of cybersecurity guidance from the strategies, two Australian states – Victoria and Queensland – and two Belgian regions – Brussels-Capital and Flemish – were selected.

4.1. Victoria and Queensland States (Australia)

Between 1 July 2019 and 30 June 2020, state/territory governments faced more than 300 cybersecurity incidents, which is the second-highest number right after the Australian Government (more than 400 incidents) (Australian Cyber Security Centre, 2020). Victoria and Queensland are those states that reported the most cybersecurity incidents in 2020 – 2021 (Australian Cyber Security Centre, 2021). As can be seen below, their approach differs; while one has its own cybersecurity strategy, the other one has more of an operational stance.

4.1.1. Victoria

Victoria was the first Australian state that created its own cyber strategy (Victorian Government Melbourne, 2021). The strategy aimed to understand cyber risks and ensure sufficient abilities for responding to cyber incidents. The following cybersecurity strategy was created in 2021 with a five-year duration, and it has three main missions: (1) Safe and reliable delivery of government services, (2) a vibrant cyber economy, and (3) a cyber-safe place to work, live, and learn. One of the strategy's goals is to support local cyber-businesses and grow local cybersecurity experts to develop the cybersecurity capabilities and knowledge to help ensure the cyber-resilience of the state.

The first mission intends to secure governmental systems and services to ensure the confidentiality and integrity of private information and ensure reliable delivery of IT-dependent services to Victoria's stakeholders. The second mission aims to use the development of the cybersecurity sector to grow local companies and the state's economy. Furthermore, a new educational and training programme will help raise the number of local experts. The third mission supports the safety of Victoria's stakeholders in the online environment. The goal is to create a culture of cyber-resilience among individuals, households, and companies. The strategy itself is further elaborated into a delivery plan that is updated every year.

4.1.2. Queensland

While the Queensland government has its own cybersecurity department, it does not seem to have created a cybersecurity strategy. The department provides information about cybersecurity incidents, security standards and policies and operates Information Security Virtual Response Team that assists in solving incidents. Furthermore, the department offers training related to cybersecurity and other cybersecurity services (Queensland Government Customer and Digital Group, 2021). The cybersecurity unit (CSU) provides services for the state's public administration, including local municipalities and government-owned corporations (GOCs). The services provided to local

authorities and GOCs include help with cybersecurity and information security risks to improve protection against cyber threats. The total number of services provided is 24; however, these four are recommended: Protective DNS (DNS Resolutions), Vulnerability Scanning, Monitoring of e-mails, and Sharing of cyber threat intelligence (Queensland Government Customer and Digital Group, 2022). The complete list of services includes e.g. cybersecurity exercises and training, protection of networks, or management of cybersecurity risks and incidents. Furthermore, the CSU organises conferences for the cybersecurity community of public administration.

4.2. Brussels-Capital Region and Flemish Region (Belgium)

Since Belgium has three regions, the two of them – Brussels-Capital and Flemish – were chosen to demonstrate the nonuniform methods. While neither region has its own cybersecurity strategy, one has created a whitepaper on the topic of cybersecurity plan, and the other has a foundation for its cybersecurity action plan, albeit focused predominantly on the private sector. This section does not cover the Walloon region because while it seems a new plan that includes cybersecurity is being developed in 2022, not much information can be found (Grandclaudon, 2022).

4.2.1. Brussels-Capital Region

The Brussels-Capital is a region with over 2 million inhabitants and has its own parliament that oversees the Government of the region (Région de Bruxelles-Capitale, 2020). Brussels Regional Informatics Centre (BRIC) and Brussels Prevention & Security (BPS) created a whitepaper in 2018 called “Towards a regional Cybersecurity plan” (Brussels Regional Informatics Centre, 2018). It follows the General Security and Prevention Plan (2019) for the region and proposes a methodological framework to respond to cyber threats. Upon recommendation of the Centre for Cyber Security Belgium, there is a need to establish cybersecurity on the regional level because the public sector is categorised as an operator of essential services according to the NIS directive. The key cybersecurity stakeholders on the regional level were identified as BRIC and BPS. Their focus is on raising awareness, managing IT policies, and centralising the management of overall security – including creating a regional security policy. Raising awareness of regional stakeholders was also evaluated as one point of prevention against cybercrime by BPS (Plan Global de Sécurité et de Prévention, 2019). Another point was to create a single point of contact in each region and municipality to strengthen cybersecurity. Furthermore, a knowledge and training centre should be established to help with education and training while also creating a place for cooperation with universities in the region.

The whitepaper resulted in a cybersecurity plan for the Brussels-Capital Region. The plan intends to protect information systems and the infrastructure by monitoring cyber threats and organising the regional capacities. The four key areas of the plan are cyber resilience of critical infrastructure, developing different kinds of resources (industrial, technological, and human), raising awareness, and prevention of cyber incidents while strengthening cooperation. One of the preventive actions includes establishing a Regional Cybersecurity Centre as a space for cooperation.

4.2.2. Flemish Region

Most sources and documents about cybersecurity in the Flemish Region focus on the private sector. A document serving as a foundation for the Cybersecurity action plan of the Flemish region was published in May 2020 (Vlaamse minister van Werk, Economie, Wetenschap, Innovatie, en Sport, 2019). This document is focused only on the private sector and peripherally also affects the educational sector (specifically research in education). A short section of the document is dedicated to government and local authorities. It is stated that no development of governmental organisations is required with the intention to make use of the triple helix approach to promote cooperation

between the local authorities, educational institutions, and the private sector. Considering the GCI evaluated the Organisational measures of Belgium as the least developed, it might be better to incorporate some new cybersecurity organisations on the regional level.

The basis for the cybersecurity action plan finds the most significant opportunity for the Flemish region in its world-renowned research in cryptography. The idea is to transform this research into concrete applications. The action plan should focus, according to the document, on the economic sector and building and retaining the capacity of human resources. Three main parts are mentioned: (1) Investing in research, (2) Implementation of cybersecurity applications in the business community to improve cybersecurity in the private sector and support of collaborative research, and (3) Creation of overarching policy for raising awareness, training, legal, and ethical aspects of cybersecurity with a focus on the private sector.

5. Conclusion

It could be seen from the examples that even countries with high GCI scores do not project multi-level cybersecurity governance into their cybersecurity strategies. Not only the strategies are very abstract in general, but the Australian national cybersecurity strategy does not mention the responsibilities of local governments such as cities, while state and territorial governments are mentioned marginally. The Belgian cybersecurity strategy does not mention regions and their responsibilities at all, and an illustration of Belgian cybersecurity governance in the strategy is missing any vertical division to include regions and municipalities.

Therefore, the lower governmental levels, such as regions or states, react accordingly, and their approach is justifiably nonuniform. Since a clear guideline is missing, some have their own cybersecurity strategy, while others have none. Comparison of the different approaches was not performed. Some have specialised institutions to provide services to the public administrations, while others focus solely on the private sector. Even though cooperation with the private sector is necessary, local governments and (local) government-owned companies must also ensure cybersecurity. For this reason, creating a multi-level cybersecurity governance framework could be helpful, especially because regions are often overlooked when cybersecurity is discussed, even though they are closest to the relevant local stakeholders (Digital Wallonia Agency, 2021).

The whitepaper of the Brussels-Capital Regions briefly mentions the idea of a regional cybersecurity centre. Nevertheless, the idea is not further explored. However, such a regional cybersecurity centre can have a great potential to ensure cybersecurity for the public sector in the region. Not only the strategy of Belgium but also other sources find capacity, especially in the public sector, problematic (Centre for Cyber Security Belgium, 2021) (Národní úřad pro kybernetickou a informační bezpečnost, 2021). The Report on the state of cybersecurity in the Czech Republic in 2020 (Národní úřad pro kybernetickou a informační bezpečnost, 2021) even mentions that 68% of respondents stated remuneration as the reason why candidates declined a job offer. This problem was especially prominent in the public and healthcare sectors. Therefore, an appropriately employed regional cybersecurity centre could help solve these problems. Depending on the responsibilities and services provided, the centre could support capacity development, awareness-raising, and resilience against cyber threats.

Public administration is a specific area with limited financing and resources, a higher risk of vendor lock, and many specialised laws and regulations. Albeit regional cybersecurity centres seem to be suitable solutions for problems of the public sector, further research is needed.

6. References

- Australian Bureau of Statistics. (2022). Australian Bureau of Statistics. Australian Bureau of Statistics. <https://www.abs.gov.au/>
- Australian Cyber Security Centre. (September 2020). ACSC Annual Cyber Threat Report (July 2019 to June 2020). Tech. rep. <https://www.cyber.gov.au/sites/default/files/2020-09/ACSC-Annual-Cyber-Threat-Report-2019-20.pdf>
- Australian Cyber Security Centre. (September 2021). ACSC Annual Cyber Threat Report 2020-21 (1 July 2020 - 31 June 2021). Tech. rep. <https://www.cyber.gov.au/sites/default/files/2021-09/ACSC%20Annual%20Cyber%20Threat%20Report%20-%202020-2021.pdf>
- Australian Government. (August 2020). Australia's Cyber Security Strategy 2020. Tech. rep. <https://www.homeaffairs.gov.au/cyber-security-subsite/files/cyber-security-strategy-2020.pdf>
- Belgian Federal Government. (n.d.). ICT sector. ICT sector. https://business.belgium.be/en/investing_in_belgium/key_sectors/ict
- Brussels Regional Informatics Centre. (2018). Towards a regional cybersecurity plan. Tech. rep. https://bric.brussels/en/news_publications/publications/papers/towards-a-regional-cybersecurity-plan-september-2018
- Bruxelles Prévention & Sécurité . (August 2019). Plan Global de Sécurité et de Prévention. Plan Global de Sécurité et de Prévention. https://bps-bpv.brussels/sites/default/files/2019-05/C2259_Plan_GVPP_FR.pdf
- Centre for Cyber Security Belgium. (May 2021). Cybersecurity Strategy Belgium 2.0 2021-2025. Tech. rep. https://ccb.belgium.be/sites/default/files/CCB_Strategie%202.0_UK_WEB.pdf
- CISA. (February 2022). 2021 Trends Show Increased Globalized Threat of Ransomware. 2021 Trends Show Increased Globalized Threat of Ransomware. <https://www.cisa.gov/uscert/ncas/alerts/aa22-040a>
- Digital Industry Group Inc. and AlphaBeta. (September 2019). Australia's Digital Opportunity. Tech. rep. <https://digi.org.au/wp-content/uploads/2019/09/Australias-Digital-Opportunity.pdf>
- Digital Wallonia Agency. (December 2021). Action plan . Tech. rep. https://projects2014-2020.interregeurope.eu/fileadmin/user_upload/tx_tevprojects/library/file_1640103236.pdf
- Federal Public Service for Foreign Affairs, Foreign Trade and Development Cooperation. (2022). Belgium at a glance. Belgium at a glance. https://www.belgium.be/sites/default/files/belgium_at_a_glance_en_lowres.pdf
- Geneva Centre for Security Sector Governance, & Achten, N. (May 2021). Cyber Threats during the COVID-19 outbreak and activities of National CERTs in the Western Balkans. Tech. rep. https://www.dcaf.ch/sites/default/files/publications/documents/CyberThreatsDuringCOVID19_ActivitiesCERTs_in_WB_0.pdf
- Grandclaudon, J. (January 2022). Digital Wallonia 4 Cyber. Un programme pour répondre aux défis de la cybersécurité en Wallonie. Digital Wallonia 4 Cyber. Un programme pour répondre aux défis de la cybersécurité en Wallonie. <https://www.digitalwallonia.be/fr/publications/digitalwallonia4cyber>
- Hooghe, L., & Marks, G. (2002). Types of Multi-Level Governance. Les Cahiers européens de Sciences Po, 03. doi:10.4337/9781849809047.00007
- Chigada, J., & Madzinga, R. (2021, February). Cyberattacks and threats during COVID-19: A systematic literature review. SA Journal of Information Management, 23. doi:10.4102/sajim.v23i1.1277
- International Telecommunication Union. (2021). Global Cybersecurity Index 2020. 172.
- INTERPOL. (August 2020). Cybercrime: COVID-19 impact. Tech. rep. <https://www.interpol.int/content/download/15526/file/COVID-19%20Cybercrime%20Analysis%20Report-%20August%202020.pdf>
- Kaklauskaitė, M. (2020). Multi-level Governance in Cybersecurity: What Role for the European Regions? European Cybersecurity Journal, 6, 44–51. <https://cybersecforum.eu/wp-content/uploads/2020/08/ECJ-VOLUME-6-2020-ISSUE-1.pdf>
- Microsoft. (October 2021). Microsoft Digital Defense Report. Tech. rep. <https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RWMFli>

- Národní úřad pro kybernetickou a informační bezpečnost. (July 2021). Zpráva o stavu kybernetické bezpečnosti České republiky za rok 2020. Tech. rep. https://www.nukib.cz/download/publikace/zpravy_o_stavu/Zprava_o_stavu_KB_2020.pdf
- Queensland Government Customer and Digital Group. (December 2021). Cyber Security. Cyber Security. <https://www.qgcio.qld.gov.au/information-on/cyber-security>
- Queensland Government Customer and Digital Group. (April 2022). Local Government Authorities. Local Government Authorities. <https://www.qgcio.qld.gov.au/information-on/cyber-security/cyber-security-services/queensland-councils>
- Région de Bruxelles-Capitale. (November 2020). The Parliament of the Brussels-Capital Region. The Parliament of the Brussels-Capital Region. <https://be.brussels/about-the-region/the-parliament-of-the-region>
- The Committee of the Regions. (Sep 2009). The Committee of the Regions' White Paper on multilevel governance. The Committee of the Regions' White Paper on multilevel governance(211), 1-27. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52009IR0089>
- Victorian Government Melbourne. (April 2021). Victoria's Cyber Strategy 2021. Victorian Government Melbourne. https://www.vic.gov.au/sites/default/files/2021-06/DPC_Cyber%20Security%20Strategy_Accessible%20PDF.pdf
- Vlaamse minister van Werk, Economie, Wetenschap, Innovatie, en Sport. (2019). Quaternota aan de Vlaamse regering. Tech. rep. https://www.ewi-vlaanderen.be/sites/default/files/quaternota_aan_de_vlaamse_regering_-_vlaams_beleidsplan_cybersecurity.pdf

LITERATURE REVIEW OF AUDIT OF DATABASE SECURITY

Felix Espinoza, Miloš Maryška

Faculty of Informatics and Statistics
Prague University of Economics and Business
felix.espinoza@vse.cz, milos.maryska@vse.cz

DOI: 10-35011/IDIMT-2022-285

Keywords

Audit, Database Security, Computer Assisted Audit Tools

Abstract

A security audit is an assessment of an organization's security. This paper deals with an Audit of Database Security which is an extremely important topic. The goal of this paper is to analyse the current situation in the field of Audit of Database Security and identify the most important data sources which can influence a definition of the research gap in the definition of the framework for the Database Audit. The analysis is done in 4 different databases (Scopus, Web of Science etc) based on selected key words. The results provide interesting finding. There are a lot of papers which are identified as related based on the key words, but we found out that a majority of these papers/articles is not related to the requested topic. After detailed analysis only 16 papers from 689 taken into detailed abstract assessment were marked as topic related.

1. Introduction

A security audit is an assessment of an organization's security posture and IT infrastructure. Conducting an IT security audit helps organizations find and assess vulnerabilities existing within their IT networks, applications, databases etc (Martin, 2022). ISACA defines six key reasons and goals to perform a security audit. These are to identify security problems, gaps and systems, establish a security baseline to which future audit can be compared, comply with internal organization security policies, comply with external regulatory requirements, determine if security training is adequate, and identify unnecessary resources (Martin, 2022).

The Audit of Database Security is an extremely important topic which's importance will increase each day thank to the Ukraine crisis and number of hacker attacks. Security audits help protect critical data, identify security issues, define new security policies, and assess the effectiveness of security strategies in general and in Database security.

When we search for the Database Audit, we find that the first paper named "Audit system for database" was published by B. Thompson in the Journal of Data Processing already in 1975 (Thomson, 1975). The second paper was published in 1981 and then approx. 1 paper was published per year until 1990. During the nineties, the importance of this topic grew significantly until now. A similar situation is when we use as a keyword "Database Security". The first paper about database security was published in 1975 already and approx. 2 papers about this topic were published every

year until 1989. From 1990 the number of papers started to increase. The same trend is visible in both most known international databases Web of Science and Scopus.

Table 1: Number of papers devoted to the Database Audit and Database Security published in Web of Science and Scopus

	Database Audit		Database Security	
	Web of Science	Scopus	Web of Science	Scopus
1975	1	-	-	5
1978	-	1	2	16
1981	1	4	2	25
1985	1	7	2	43
1990	3	5	9	72
1995	16	11	41	174
2000	53	15	146	223
2005	123	42	406	769
2010	179	53	742	991
2015	270	43	1.313	1.269
2020	392	89	1.771	2.002

Table 1 confirms the statement, that database audit and database security are seen in research as a topic of increasing importance so we can state based on the personal experience, that database audit and database security are important topics.

Database Security can be defined as a set of tools, controls, and measures, which should define and assure database integrity, availability and confidentiality from malicious cyberattacks and illegitimate use. Database security is not only related to the data stored in the database, but also to the data management system itself (IBM Cloud Education, 2019; Imperva, 2021; Technopedia, 2022).

Database Audit can be defined as an observation of a database to know about all actions done in the database. Database auditing is about monitoring and recording of defined user actions which can influence trust into data. Database audit is a mandatory part of each and every financial audit which is considering not only financial data but also IT systems which are used for any actions with the financial data (Jayaram, 2021; Oracle, 2005; Technopedia, 2012; Yehuda, 2021).

The goal of this paper is to analyse the current situation in the field of Audit of Database Security and identify the most important data sources which can influence a definition of the research gap in defining the framework for Database Audits.

2. Theoretical Background

Database Security defines protection especially for the Data in the database, the Database management system itself, and any applications used together with the database management systems, as well as Physical security of the Database Management Systems (DBMS) and related infrastructure etc.

Each of the elements mentioned above is closely related to the following risks: unauthorized access or activities with the data, malware infections, physical damage of the hardware and infrastructure, or corruption of the data stored in database.

There are lots of components attached to the data, and any one of them can become a reason for data breach or theft. Database Audit solves various tasks which are closely related to the Database Security but not only (Yehuda, 2021). The main tasks solved in the area of Database Audit are:

- Audit of access of users and systems to the database and data stored in the database.
- Monitoring of defined actions which are done by users or other systems on the database server.
- Database vulnerability audit and threat detection.
- Analysis of any change, which was done on the database, and which can be related to security of the data etc.

3. Methodology

This review is performed to provide an overview and summary of up-to-date studies related to Database Audit and Database Security

During Q1/2022, two investigators analyzed the four literature databases Web of Science, Scopus, Science Direct, and Google Scholar.

Authors were searching for papers published since 2015, and authors did not limit the research area because database security (including data security) is important in all areas including medicine (especially), engineering, physis, public administration etc.

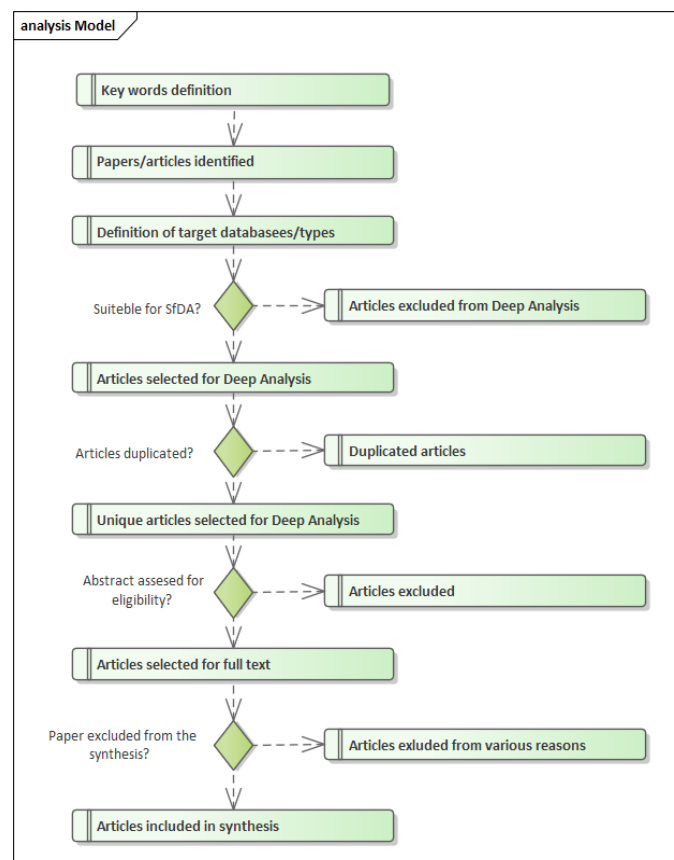


Figure 1: Analysis process - general

Authors used the following combinations of keywords for searching in the four selected databases:

- Database audit, **Database security**, **Database Audit Security**, Database security monitoring, Automated security monitoring, **Automated database security monitoring**

- **Computer Assisted Audit, Computer Assisted Audit Tools, Computer Assisted database Audit, Computer Assisted database Audit Tools, Computer Assisted database security Audit, Computer Assisted database security Audit Tools**

The process of articles/papers selection can be described by the process shown in Figure 2.

4. Results

Combination of key words in each of the selected databases returned significantly different numbers of results as shown in table 2. Google Scholar and Science direct returned significantly higher number of results in comparison to the pure scientific databases Web of Science and Scopus. Based on this finding and basic screening of returned results (150 articles analysed in both databases) it was decided to exclude these two databases from detailed analysis.

We counted two types of results:

- Articles published in Journals (column “Article” in table 2) with Impact Factor or SJR
- Others which contains papers from conferences, reviews etc (column “Others” in table 2)

Table 2: Number of papers in selected databases according to the selected combination of key words (authors)

Key Words	SfDA	Web os Science		Scopus		Science Direct		Google Scholar	
		Others	Article	Others	Article	Others	Article	Others	Article
Database audit	No	281	2.197	607	1.630	4.702	19.685	91.800	18.200
Database security	No	5.393	5.923	8.808	6.611	19.379	60.944	630.100	31.900
Database Audit Security	Yes	111	73	107	70	2.863	6.062	31.800	5.000
Database security monitoring	No	907	478	795	500	11.450	28.298	151.500	20.500
Automated security monitoring	No	32	23	53	32	4.164	6.433	1.300	16.500
Automated database security monitoring	Yes	32	23	53	32	4.164	6.433	1.300	16.500
Computer Assisted Audit	Yes	64	149	121	436	2.428	3.657	17.750	2.650
Computer Assisted Audit Tools	Yes	30	36	30	49	1.747	2.367	13.630	3.370
Computer Assisted database Audit	Yes	4	7	4	35	1.517	1.750	13.380	3.620
Computer Assisted database Audit Tools	No	3	1	2	5	2.743	1.405	7.720	9.080
Computer Assisted database security Audit	Yes	1	1	-	-	964	957	12.270	4.530
Computer Assisted database security Audit Tools		1	-	-	-	865	795	13.060	4.140
Total Returned results		6.859	8.911	10.580	9.400	56.986	138.786	985.610	135.990
Total Results in "Selected for Deep Analysis (SfDA)"		242	289	315	622	13.683	21.226	90.130	35.670
Unique Results in "Selected for Deep Analysis"			244		537				

We decided to analyse:

- Articles only based on our experience with the quality of papers of the conferences etc.
- Articles indexed in Web of Science or Scopus - to reach a minimum level of quality which is assured by blind review requested by Web of Science and Scopus.

The process of the article selection is described by Figure 3.

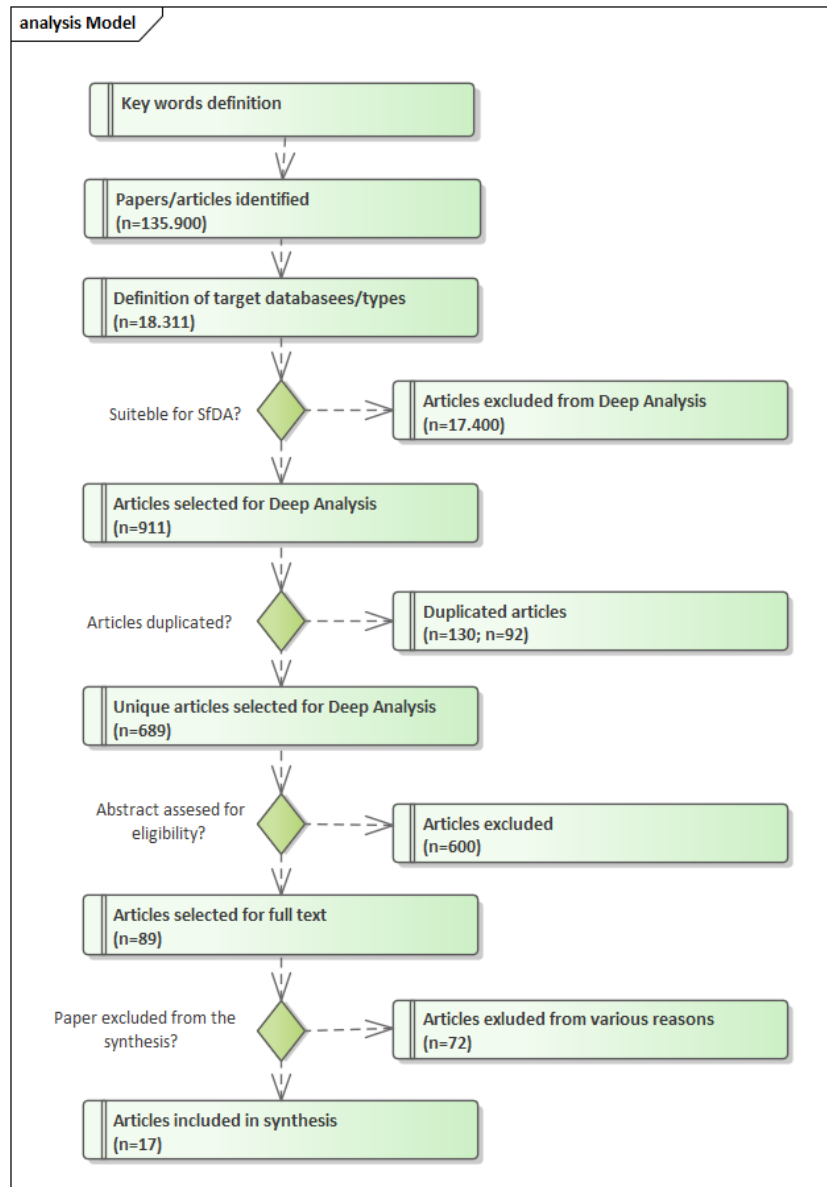


Figure 3: Analysis process – including counts

Table 2 shows that there are duplicates in results returned based on the selected key words. Duplicates are quite low, only three in Web of Science and 5 in Scopus. We have identified higher number of duplicates when we compare the results provided by Web of Science and Scopus. The total number of results from both databases is 911. The number of duplicates is 130 when we compare papers from each of the databases. In this case we have 781 articles. After comparison of uniqueness of the papers between both databases, we identified another 92 duplicates. The rest of papers (689) was chosen for **detailed second phase of the analysis – basic screening**. The basic screening was based on reading and assessing the abstract of each of the 689 paper and determining whether the paper fits the topic fully, fits the topic partially does not fit the topic at all and key words were somehow identified in the text by Web of Science and Scopus.

Based on the content of the abstract and keywords, 600 articles were excluded from full text reading because they did not meet the target of the process defined above. The 116 articles were selected for the phase of reading of full text papers. The 89 articles included into reading of the full text were excluded from the final detailed discussion. The main reason for this decision was, that the full text did not cover selected area, although the abstract was showing a possibility of such.

The result from the full text reading was 17 articles which are included into the discussion bellow.

Table 3: Analysis of selected papers; Legend: WoS = Web of Science, Scop = Scopus, P = Paper, A = Article, CAA = Computer Assisted Audit, DAS = Database Audit Security

Authors	Title	WoS	Scop	P	A	CAA	DAS
(Ahmad et al., 2019)	Secure and transparent audit logs with BlockAudit	X			X		X
(Ra et al., 2021)	A Federated Framework for Fine-Grained Cloud Access Control for Intelligent Big Data Analytic by Service Providers	X			X	X	
(Shen, Liu, et al., 2017)	An Enhanced Cloud Data Storage Auditing Protocol Providing Strong Security and Efficiency for Smart City	X			X	X	
(Ding et al., 2021)	Construction of searchable encrypted audit certificate systems for relational database		X		X		X
(Esiefarienrhe & Ekka, 2018)	Modified role based access control model for data security		X		X		X
(Evgrafov et al., 2017)	Considerations for database privileged access		X		X		X
(Gabriel et al., 2018)	Data Breach Locations, Types, and Associated Characteristics Among US Hospitals	X			X		X
(Hauger & Olivier, 2018)	NOSQL DATABASES: FORENSIC ATTRIBUTION IMPLICATIONS	X			X		X
(Islam et al., 2018)	Factors associated with security/cybersecurity audit by internal audit function	X			X		X
(Khanuja & Adane, 2020)	Monitor and detect suspicious transactions with database forensics and Dempster-Shafer theory of evidence	X			X		X
(Mouleeswaran et al., 2016)	Facilitating public audits and data dynamicity with security for data stored in cloud computing		X		X		X
(Sallam et al., 2016)	Data and syntax centric anomaly detection for relational databases	X			X		X
(Calderon Noboa, 2017)	Computer-assisted audit for tax collection and management	X			X	X	
(Shen, Shen, et al., 2017)	An Efficient Public Auditing Protocol With Novel Dynamic Structure for Cloud Data	X			X		X
(Wagner et al., 2017)	Carving database storage to detect and trace security breaches	X			X		X
(Yan et al., 2019)	Database Audit Workload Prioritization via Game Theory	X			X		X
(Zaman et al., 2017)	Self-Protection against Insider Threats in DBMS through Policies Implementation	X			X		X

Based on the detailed analysis of the papers mentioned in Table 3 we can say that articles in bold are directly related to the investigated topic and the others provide at least some value for the analysed topic.

(Esiefarienrhe, 2018) describes a modified Role Based Access Control model. This model extends traditional role-based access control which is used as standard in relational data storage. The model presented in this paper evaluates and executes security policies which contain versatile access conditions against the dynamic nature of data. Authors integrate roles and authenticated access rules and audit trail.

(Evgrafov, 2017) describes key areas related to the management of access of users to database data resources. He describes data classification, definition of controls, segregation of duties and access control and their review as a key parameter for successful management database privileged access.

As a last area related to all of the already mentioned is database auditing, which is critical for databases containing sensitive data. The authors conclude that privileged access is a key component of overall database security, which should include controls on both physical and remote access, access audit reviewing, and controls on user application access.

(Mouleeswaran, 2016) deal with data management and trustworthiness of services. The authors mention challenges in security with a focus on ensuring security in storing data in cloud systems. Important parts of this paper are problems in identifying the complexity and security with updates in dynamic data design a verification scheme for aggregating the above features.

(Calderon, 2017) discusses Oracle's routine operation based on the computer-aided audit platform of tax collection and management, points out some problems resides in the process, and then presents suggestions for perfecting computer-aided audit of collection of taxes and management. Authors say that auditors should pay close attention to clues discovered in computer-assisted audits. Compliance testing in computer-aided audit is evidence of the soundness and effectiveness of internal control by the tax authorities in the context of the current computerized conditions.

5. Discussion & Conclusion

This paper deals with the analysis of the literature in Audit of Database Security. The analysis confirms that database audit and database security are seen in research as a topic of increasing importance. This is an extremely important topic whose importance increase every day thank to the Ukraine crisis and the number of hacker attacks.

This paper brings several interesting findings. The first one is that only 92 articles were marked as duplicates in both databases. Authors expected a higher number of duplicates. The second one is that a limited number of authors and papers deal with the area of database audit.

If we consider all the mentioned results, we can state that there is significant space for additional research. One of the key areas which can be analysed is for example the area of frameworks supporting companies/users during database audits.

6. References

- Ahmad, A., Saad, M., & Mohaisen, A. (2019). Secure and transparent audit logs with BlockAudit. *Journal of Network and Computer Applications*, 145, 102406. <https://doi.org/10.1016/j.jnca.2019.102406>
- Calderon Noboa, J. E. (2017). Computer-assisted audit for tax collection and management. *Revista Publicando*, 4(12), 151–159
- Ding, Y., Li, S.-J., Wang, Y.-J., Chen, J.-W., Yuan, F., & Zhang, K. (2021). Construction of searchable encrypted audit certificate systems for relational database. *Journal of Cryptologic Research*, 8(3), 432–443. Scopus. <https://doi.org/10.13868/j.cnki.jcr.000449>
- Esiefarienrhe, B. M., & Ekka, A. H. (2018). Modified role based access control model for data security. *International Journal of Scientific and Technology Research*, 7(11), 182–186
- Evgrafov, G., Andrews, S., Ding, S., Stevens, N., Valeri, S., & Vuolo, M. (2017). Considerations for database privileged access. *Pharmaceutical Engineering*, 37(6), 42–45
- Gabriel, M. H., Noblin, A., Rutherford, A., Walden, A., & Cortelyou-Ward, K. (2018). Data Breach Locations, Types, and Associated Characteristics Among US Hospitals. *American Journal of Managed Care*, 24(2), 78–84
- Hauger, W. K., & Olivier, M. S. (2018). Nosql Databases: Forensic Attribution Implications. *Saiee Africa Research Journal*, 109(2), 119–132. <https://doi.org/10.23919/SAIEE.2018.8531952>
- IBM Cloud Education. (2019, August 27). Database Security: An Essential Guide. <https://www.ibm.com/cloud/learn/database-security>

- Imperva. (2021, July 13). What is Database Security | Threats & Best Practices | Imperva. Learning Center. <https://www.imperva.com/learn/data-security/database-security/>
- Islam, M. S., Farah, N., & Stafford, T. F. (2018). Factors associated with security/cybersecurity audit by internal audit function: An international study. *Managerial Auditing Journal*, 33(4), 377–409. Scopus. <https://doi.org/10.1108/MAJ-07-2017-1595>
- Jayaram, P. (2021, January 28). A quick overview of database audit in SQL. SQL Shack - Articles about Database Auditing, Server Performance, Data Recovery, and More. <https://www.sqlshack.com/a-quick-overview-of-database-audit-in-sql/>
- Khanuja, H. K., & Adane, D. (2020). Monitor and detect suspicious transactions with database forensics and Dempster-Shafer theory of evidence. *International Journal of Electronic Security and Digital Forensics*, 12(2), 154–173.
- Martin, C. (2022, March 23). An Integrated Approach to Security Audits. ISACA. <https://www.isaca.org/resources/news-and-trends/industry-news/2022/an-integrated-approach-to-security-audits>
- Mouleeswaran, S. K., Grace Selvarani, A., & Kanya Devi, J. (2016). Facilitating public audits and data dynamicity with security for data stored in cloud computing. *Asian Journal of Information Technology*, 15(8), 1275–1280. Scopus. <https://doi.org/10.3923/ajit.2016.1275.1280>
- Oracle. (2005, July 1). Database Security Guide. https://docs.oracle.com/cd/B19306_01/network.102/b14266/auditing.htm#CHDJBDHJ
- Ra, G., Kim, D., Seo, D., & Lee, I. (2021). A Federated Framework for Fine-Grained Cloud Access Control for Intelligent Big Data Analytic by Service Providers. *IEEE Access*, 9, 47084–47095. <https://doi.org/10.1109/ACCESS.2021.3067958>
- Sallam, A., Fadolkarim, D., Bertino, E., & Xiao, Q. (2016). Data and syntax centric anomaly detection for relational databases. *Wiley Interdisciplinary Reviews-Data Mining and Knowledge Discovery*, 6(6), 231–239. <https://doi.org/10.1002/widm.1195>
- Shen, J., Liu, D., Liu, Q., He, D., & Sun, X. (2017). An Enhanced Cloud Data Storage Auditing Protocol Providing Strong Security and Efficiency for Smart City. *Journal of Information Science and Engineering*, 33(4), 923–938. <https://doi.org/10.6688/JISE.2017.33.4.4>
- Shen, J., Shen, J., Chen, X., Huang, X., & Susilo, W. (2017). An Efficient Public Auditing Protocol With Novel Dynamic Structure for Cloud Data. *Ieee Transactions on Information Forensics and Security*, 12(10), 2402–2415. <https://doi.org/10.1109/TIFS.2017.2705620>
- Technopedia. (2012, September 28). What is a Data Audit? - Definition from Techopedia. Techopedia.Com. <http://www.techopedia.com/definition/28032/data-audit>
- Technopedia. (2022, March 31). What is Database Security? - Definition from Techopedia. Techopedia.Com. <http://www.techopedia.com/definition/29841/database-security>
- Thomson, B. (1975). Audit System for Database. *Data Processing*, 17(1), 26–27
- Wagner, J., Rasin, A., Glavic, B., Heart, K., Furst, J., Bressan, L., & Grier, J. (2017). Carving database storage to detect and trace security breaches. *Digital Investigation*, 22, S127–S136. <https://doi.org/10.1016/j.diin.2017.06.006>
- Yan, C., Li, B., Vorobeychik, Y., Laszka, A., Fabbri, D., & Malin, B. (2019). Database Audit Workload Prioritization via Game Theory. *Acm Transactions on Privacy and Security*, 22(3), 17. <https://doi.org/10.1145/3323924>
- Yehuda, Y. (2021, February 24). Database Audits: Why You Need Them and What Tools to Use. <https://www3.dbmaestro.com/blog/database-audits-why-you-need-them-what-tools-to-use>
- Zaman, F., Raza, B., Malik, A. K., & Anjum, A. (2017). Self-Protection against Insider Threats in DBMS through Policies Implementation. *International Journal of Advanced Computer Science and Applications*, 8(3), 239–249

SUSTAINABILITY AND PERFORMANCE MANAGEMENT AND BUSINESS REPORTING

A BIBLIOMETRIC ANALYSIS OF SUSTAINABILITY REPORTING IN HIGHER EDUCATION

Petr Petera

Department of Management Accounting
Prague University of Economics and Business
petr.petera@vse.cz

DOI: 10-35011/IDIMT-2022-295

Keywords

Sustainability, Sustainability Reporting, Higher Education, Universities, Green Reporting, Sustainable Development Goals, Standardisation

Abstract

Sustainability reporting by corporations has been substantially growing in recent years. Interestingly, while higher education institutions should be natural leaders in promoting sustainability ideas, this is not the case in sustainability reporting. For a long time, higher education institutions lagged far behind corporations. This can be considered alarming because involvement of universities and other institutions of higher education is crucial for sustainable development.

But recently the situation has begun to change, and higher education institutions have started to pay more attention to both sustainability management and sustainability reporting. These developments give hope that the ability of universities to produce interdisciplinary professionals capable of meeting the challenges of sustainability will grow.

Also, the amount of literature dealing with the issue of sustainability reporting by higher education institutions has started to grow and there is currently no up-to-date bibliometric analysis of this area. This is the gap that this paper seeks to fill. The paper provides a bibliometric analysis of articles indexed in the Web of Science focused on sustainability reporting in higher education. The analysis uses modern tools (Bibliometrix for R) to identify leading journals, influential authors, important articles, and keywords.

1. Introduction

Institutions of higher education and especially universities have the responsibility for being role models in the area of sustainability practice as they educate the leaders of future. Sustainability reporting has an important place in the process of sustainability-oriented practice because it is one of the key drivers of the whole process of sustainability management from data collection to evaluation of sustainable development (Adams, 2013). And yet, even in the relatively recent past, universities have lagged significantly behind the business sector in terms of integrated reporting (Adams, 2018).

We believe that the academic research in this area has a potential not only to reflect the current situation but can serve also as a catalyst in the area of acceptance of sustainability mindset in university settings.

This paper therefore strives to investigate the status quo and dynamics of high-quality literature on sustainability reporting in higher education. We pursue this goal through bibliometric analysis of articles indexed in the Web of Science Core Collection. This paper may be useful for researchers from the area of sustainability by providing them an up-to-date information on the studied topic and by depicting possible ways of further research.

2. Methodology

This chapter provides a description of the process of obtaining of relevant articles as well as the characteristics of bibliometric analysis.

2.1. Sample selection

In order to find the articles on sustainability reporting in higher education, a search in the Web of Science Core Collection (hereinafter abbreviated “WoS”) has been performed utilizing the relevant keywords.

Because preliminary attempts to search in the fields “Title”, “Abstract”, “Keywords”, and “Keywords Plus” led to an enormous number of false hits, it was necessary to limit the search to the field “Title”. At the same time, it was crucial to prepare a very broad query minimizing the risk of omitting important articles. Very important was also capturing only articles fulfilling all criteria, i.e. addressing sustainability reporting specifically in higher education settings, which requested utilization of relatively complex query including numerous possible synonyms and their combinations.

Specifically, we searched for the selected keywords in the field “Title” using the following query: (sustainab* report* univer*) OR (sustainab* disclos* univer*) OR (sustainab* communica* univer*) OR (sustainab* report* higher educat*) OR (sustainab* disclos* higher educat*) OR (sustainab* communica* higher educat*) OR (sustainab* communica* HEI*) OR (green* report* univer*) OR (green* disclos* univer*) OR (green* communica* univer*) OR (green* report* higher educat*) OR (green* disclos* higher educat*) OR (green* communica* higher educat*) OR (green* communica* HEI*) OR (social* report* univer*) OR (social* disclos* univer*) OR (social* communica* univer*) OR (social* report* higher educat*) OR (social* disclos* higher educat*) OR (social* communica* higher educat*) OR (social* communica* HEI*) OR (environment* report* univer*) OR (environment* disclos* univer*) OR (environment* communica* univer*) OR (environment* report* higher educat*) OR (environment* disclos* higher educat*) OR (environment* communica* higher educat*) OR (environment* communica* HEI*) OR (responsib* report* univer*) OR (responsib* disclos* univer*) OR (responsib* communica* univer*) OR (responsib* report* higher educat*) OR (responsib* disclos* higher educat*) OR (responsib* communica* higher educat*) OR (responsib* communica* HEI*) OR (GRI report* univer*) OR (GRI disclos* univer*) OR (GRI communica* univer*) OR (GRI report* higher educat*) OR (GRI disclos* higher educat*) OR (GRI communica* higher educat*) OR (GRI communica* HEI*) OR (CSR report* univer*) OR (CSR disclos* univer*) OR (CSR communica* univer*) OR (CSR report* higher educat*) OR (CSR disclos* higher educat*) OR (CSR communica* higher educat*) OR (CSR communica* HEI*). This search was realized on 5 May 2022 and returned 475 results. In the second step, all non-English texts were removed leading to 350 results. Third, documents of type “proceedings papers”, “book reviews”, “meeting abstracts”

were removed, which left us with 248 results. Fourth, titles and abstracts of the remaining documents were evaluated, and another 161 documents were removed as they had the specified keywords in their title, but in fact were not on sustainability reporting in higher education (e.g., an article with title “The disclosure of social networking sites in university student’s communication with their peers”). This step left us with 87 documents.

Finally, the full texts of the remaining 87 articles were downloaded (except for three unavailable articles from journal “Transformations in Business & Economics” and one unavailable article from journal “Journal of Environmental Protection and Ecology”) and read in order to exclude the remaining irrelevant articles. On the basis of reading of these full texts, another 7 articles were removed. It is possible to sum up that the process generated 80 articles for bibliometric analysis.

2.2. Bibliometric analysis

Bibliometric analysis is a rigorous method that investigates patterns and statistical characteristics regarding journals, authors, keywords, individual documents (papers) as well as other properties of a scientific field (Donthu, Kumar, Mukherjee, Pandey, & Lim, 2021; Merigo & Yang, 2017). The growing popularity of bibliometric analysis goes hand in hand with the increasing number of software tools supporting this method (for example, VOSviewer, Bibliometrix, Biblioshiny, Leximancer). Bibliometric analysis is primarily used for an analysis of large volumes of literature (Donthu, Kumar, Mukherjee, Pandey, & Lim, 2021) but can be used also for smaller data sets (Agostini, Nosella, Sarala, Spender, & Wegner, 2020; Di Vaio, Hasan, Palladino, Profita, & Mejri, 2021).

This paper uses bibliometric analysis as its primary method, but provides also basic results of textual analysis. For bibliometric analysis this paper uses software Biblioshiny, which is a web-interface for bibliometrix (Aria & Cuccurullo, 2017).

3. Results and discussion

In this chapter are presented and discussed the key results of a bibliometric analysis of the set of 80 articles on sustainability reporting in higher education (see chapter 2.1 Sample selection).

3.1. Main characteristics of selected documents

Main bibliometric characteristics of the analyzed documents can be found in Tab. 1.

Table 1: Main bibliometric characteristics (number of analyzed documents = 80)

Description	Results	Description	Results
Basic information		Document Contents	
Timespan	2011:2022	Keywords Plus (ID)	171.00
Sources (Journals, Books, etc.)	29.00	Author's Keywords (DE)	248.00
Documents	80.00	AUTHORS	
Average years from publication	3.78	Authors	212.00
Average citations per documents	22.09	Author Appearances	249.00
Average citations per year per doc	3.47	Authors of single-authored doc	5.00
References	3,642.00	Authors of multi-authored doc	207.00
Document types		Authors Collaboration	
Article	72.00	Single-authored doc	6.00
Article, early access	2.00	Documents per Author	0.38
Editorial material	3.00	Authors per Doc	2.65
Review	3.00	Co-Authors per Doc	3.11
		Collaboration Index	2.80

The results of analysis depicted in Tab. 1 indicate several important facts. The topic of sustainability reporting in higher education is relatively new. Moreover, the topic is still relatively under-researched, especially in comparison to sustainability reporting in corporate settings. According to our knowledge, the number of documents obtained through the similar query for corporations would be several times higher.

Regarding the document types, it is important to highlight two observations. First, there are two documents classified as an “early access”, i.e. without publication year. For the sake of this literature review, the year of acceptance was taken as the year of publication so that these papers can be reasonably classified (see also subchapter 3.2). Second, only three papers are classified as reviews by WoS. Paper by Ceulemans, Molderez, and Van Liedekerke (2015) is a systematic literature review based on several databases and next to sustainability reporting deals with sustainability assessment, performance and indicators. Adhikariparajuli, Hassan, and Siboni (2021) prepared a newer systematic literature review on CSR reporting in the context of higher education. This review is relevant, but it seems that the used search query was narrow (Adhikariparajuli, Hassan, & Siboni, 2021, p. 3–4) as it contained only term “CSR”. Finally, paper by Huber and Bassen (2018) is not a literature review, but a conceptual paper evaluating whether a modification of the sustainability code for the use in the higher education contributes to fulfilling of selected reporting principles. It is possible to conclude that comprehensive and up-to-date literature review is still needed.

The vast majority of documents was prepared by multiple authors, there are only five single-authored documents. The collaboration index is calculated as the number of authors of multi-authored documents (207) divided by the number of multi-authored documents (74) and equals to 2.80, which informs us that the number of co-authors falls between 2 and 3 in the researched area.

3.2. Analysis according to journals and years

Information regarding the numbers of documents (N) published in individual journals together with the latest impact factor (IF 2020) and article influence score (AIS 2020) can be found in Tab. 2. Inclusion of information regarding the impact factor and article influence score may be helpful for decision regarding choice of journals for publication of research on the discussed topic.

Table 2: Number of articles in journals (number of analyzed documents = 80)

Source title	IF 2020	AIS 2020	N
International Journal of Sustainability in Higher Education	2.854	0.383	22
Sustainability	3.251	0.462	15
Journal of Cleaner Production	9.297	1.289	6
Administrative Sciences	n/a	0.357	4
Meditari Accountancy Research	n/a	0.450	3
Sustainability Accounting Management and Policy Journal	3.354	0.589	3
Transformations in Business & Economics	1.725	0.171	3
Accounting Auditing & Accountability Journal	4.117	0.918	2
Australian Journal of Public Administration	1.800	0.470	2
Other			20
Total			80

On the basis of Tab. 2 it is possible to say that the highest number of documents on sustainability in higher education was published in International Journal of Sustainability in Higher Education, followed by Sustainability journal and Journal of Cleaner Production. It is also obvious that 20 journals published only one document on the studied topic. Overall, there is a significant fragmentation of documents across different journals.

For the authors intending to prepare an article on topic of sustainability reporting in higher education the results are not very encouraging because the article influence scores of journals with

two or more documents on sustainability reporting in higher education are relatively low (except for Journal of Cleaner Production and Accounting Auditing & Accountability Journal). This may be one of the reasons why the documents are scattered across so many journals.

Regarding the journals characteristics, we also explored, which journals are the most often cited within the investigated set of 80 documents and results are depicted in Tab. 3.

Table 3: Top five most local cited sources (number of analyzed documents = 80)

Source title	Number of local citations
Journal of Cleaner Production	561
International Journal of Sustainability in Higher Education	369
Sustainability	148
Journal of Business Ethics	145
Accounting Auditing & Accountability Journal	107

The results in Tab. 3 provide “local” information because the column “Number of local citations” informs about the number of citation of a given journal coming from within the analyzed 80 documents. The results are not surprising, journals “Journal of Cleaner Production” and “Accounting Auditing & Accountability Journal” are in general highly cited.

Last but not least, the annual production of papers is shown in Figure 1. It is important to remind that two documents classified as “early access” were put in the year of their acceptance.

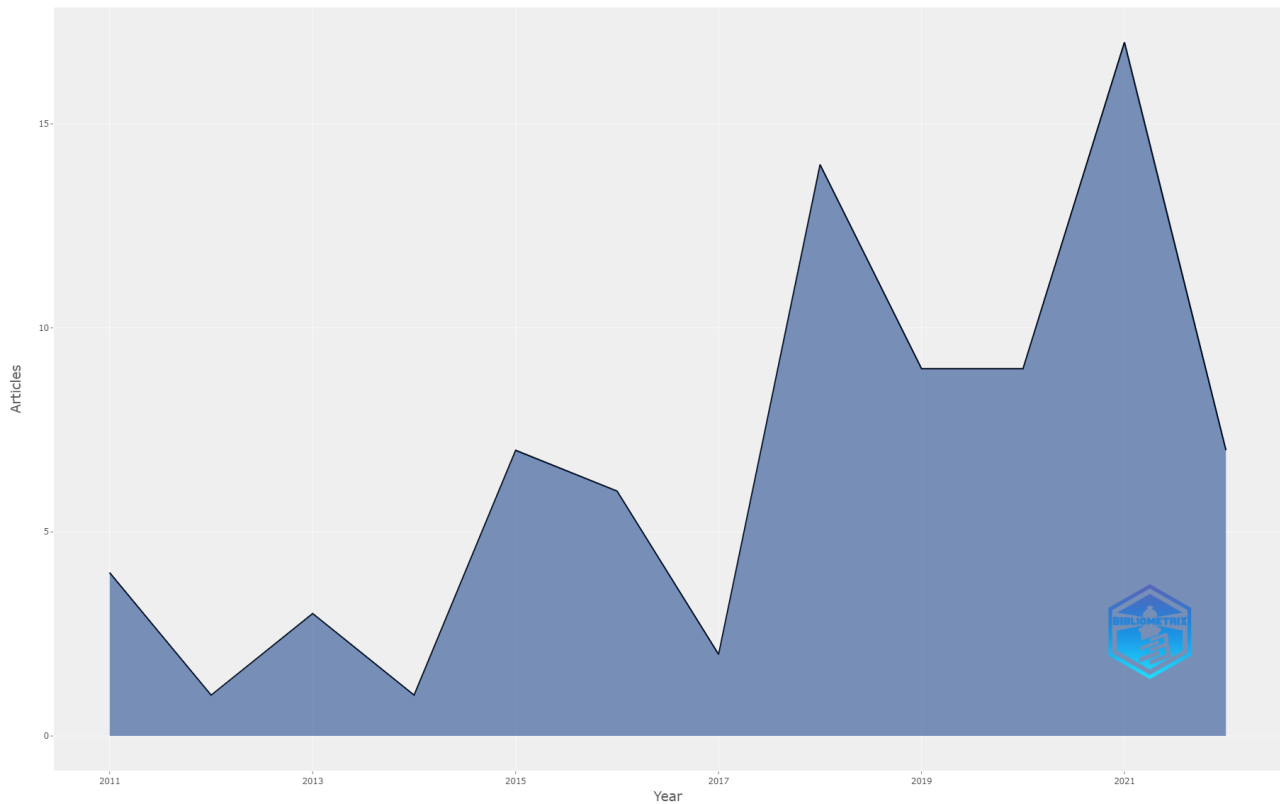


Figure 1. Annual scientific production (number of analyzed documents = 80)

On the basis of Figure 1, it is possible to say that the number of published documents fluctuates, but recently has increased significantly, data for year 2022 are incomplete and the number of published documents will rise.

3.3. Top cited authors and articles

In Tab. 4 can be found top five authors according to the number of articles (N) and articles fractionalized (AF). For each author is also provided the total number of citations of their articles (TC), and total citations per year (TCpY).

Table 4: Top five cited authors (number of analyzed documents = 80)

Author	N	AF	TC	TCpY
Sánchez, Raquel Garde	6	1.83	109	16.067
López-Hernandez, A. M.	6	1.83	109	16.067
An, Yi	5	1.20	32	6.933
Rodríguez Bolívar, M. P.	4	1.33	95	11.400
Sassen, R.	4	1.50	46	9.600
Zheng, X. S.	3	0.70	6	1.433
Lozano, R.	2	1.33	271	25.792
Adams, C. A.	2	2.00	100	11.900

In order to be included in Tab. 4, the author had to have more than 2 articles or fractionalized number of articles higher than 1.00. The first two authors co-authored six articles and so their characteristics are the same.

In Tab. 5 can be found top cited documents (with over 50 citations) and their characteristics total citations (TC), total citations per year (TCY), and normalized total citations (NTC).

Table 5: Top cited documents (number of analyzed documents = 80)

Paper	TC	TCY	NTC
Lozano (2011)	194	16.167	1.9303
Ceulemans, Molderez, & Van Liedekerke (2015)	151	18.875	2.3028
Alonso-Almeida, Marimon, Casani, and Rodriguez-Pomeda (2015)	129	16.125	1.9673
Fonseca, Macdonald, Dandy, and Valenti (2011)	122	10.167	1.2139
Adams (2013)	81	8,100	1.5187
Ceulemans, Lozano, & Alonso-Almeida (2015)	77	9.625	1.1743
Hipp, Gulwadi, Alves, and Sequeira (2016)	67	9.571	2.4217
Sanchez, Bolivar, & Lopez-Hernandez (2013)	60	6.000	1.1250
Djordjevic and Cotton (2011)	54	4.500	0.5373
Brusca, Labrador, & Larran (2018)	54	10.800	3.5829
Townsend and Barrett (2015)	50	6.250	0.7625

From Tab. 5 it is obvious that the majority of top cited documents was published in year 2015 or earlier, which indicates that there are not exceptionally highly cited new documents.

3.4. Analysis by countries

Analysis per corresponding author's country is shown in Tab. 6

Table 6: Top corresponding author's country (number of analyzed documents = 80)

Country	Articles	Freq	SCP	MCP	MCP ratio
Spain	18	0.2278	17	1	0.0556
Italy	10	0.1266	9	1	0.1000
Australia	8	0.1013	5	3	0.3750
Germany	5	0.0633	5	0	0.0000
China	5	0.0633	2	3	0.6000
United Kingdom	5	0.0633	4	1	0.2000
USA	5	0.0633	3	2	0.4000

In the column SCP are single country publications and multiple country publications are in the column MCP. MCP ratio is calculated by dividing the total number of papers and MCP and represents the degree of cooperation between countries; the highest MCP ratio has China (0.6000).

3.5. Analysis of keywords

There is a large amount of possibilities regarding the analysis of keywords. In this paper are presented the results of analysis of trigrams (growth in time, i.e., analysis of word dynamics) in abstracts because the results of this analysis are quite interesting.

Table 7: Word growth (number of analyzed documents = 80)

Year	GRI	SDGs	Standalone Sustainability Reports	Italian Public Universities	Latin American Universities
2011	2	0	0	0	0
2012	2	0	0	0	0
2013	2	0	0	0	0
2014	2	0	0	0	0
2015	8	0	1	0	0
2016	10	0	1	0	0
2017	10	0	3	0	0
2018	10	0	3	0	0
2019	12	0	4	0	0
2020	12	2	4	1	0
2021	12	10	5	3	4
2022	14	12	5	4	4

The results in Tab. 7 document that the most often trigram in abstract is “GRI” (global reporting initiative), which is a universal standard for sustainability reporting. Interestingly, this standard is used only rarely by organizations of higher education. The reason for the frequent occurrence of this trigram in the abstracts is probably the fact that GRIs are used as a framework for analysis of the status quo of reporting and also the fact that suitability of the GRI standards for higher education institutions is often debated (see e.g. Bice & Coates, 2016; Bonatxea, Gutierrez-Goiria, Vazquez-De Francisco, & Sianes, 2022; Huber & Bassen, 2018; Son-Turan & Lambrechts, 2019).

Another important trigram is “SDGs” (sustainable development goals), and it is not surprising that this phrase is used so frequently because integration of SDGs into sustainability management and reporting is the current trend in all kinds of organizations, including higher education organizations.

The remaining trigrams are less frequent and there is no specific explanation for their relatively frequent occurrence except the fact that the analyzed set of documents is relatively small and therefore even relatively low frequency is enough to get among the five most frequent trigrams.

4. Conclusions, limitations and ideas for further research

This paper provides an up-to-date bibliometric analysis of documents on sustainability reporting in higher education and is based on the documents indexed in Web of Science Core Collection. The comprehensive query returned 80 relevant documents, which indicates that the field of sustainability reporting in higher education is relatively under-researched. We provide key statistical characteristics of the data set, an overview of the key journals, authors and documents (mostly journal articles). Last but not least, the analysis according to the countries and keywords (word dynamics) is presented.

The paper has common limitations resulting from the properties of bibliometric analysis and from the fact that the field is under-developed resulting in a small number of papers, which prevents the meaningful use of more sophisticated methods of bibliometric analysis. Yet, we believe that our paper may be useful for any researcher intending to publish in the field of sustainability reporting in university settings.

Regarding the future research, we found that despite the fact that the number of articles on sustainability reporting in higher education is growing, there are no high-quality up-to-date systematic literature reviews. It is important to highlight that our search was limited to the WoS database and the number of articles in other databases is even higher. Promising future research could focus on the problem of transferring sustainability reporting principles from the corporate environment to universities, as well as on finding specific indicators applicable to universities.

5. Acknowledgement

This paper is one of the research outputs of the project “Interaction and integration of strategic management accounting and sustainability accounting” supported by the Grant No. F1/46/2021 – Internal Grant Agency of the Prague University of Economics and Business.

6. References

- Adams, C. A. (2013). Sustainability reporting and performance management in universities Challenges and benefits. *Sustainability Accounting Management and Policy Journal*, 4(3), 384–392. doi:10.1108/sampj-12-2012-0044
- Adams, C. A. (2018). Debate: Integrated reporting and accounting for sustainable development across generations by universities. *Public Money & Management*, 38(5), 332–334. doi:10.1080/09540962.2018.1477580
- Adhikariparajuli, M., Hassan, A., & Siboni, B. (2021). CSR Implication and Disclosure in Higher Education: Uncovered Points. Results from a Systematic Literature Review and Agenda for Future Research. *Sustainability*, 13(2), 1–23. doi:10.3390/su13020525
- Agostini, L., Nosella, A., Sarala, R., Spender, J. C., & Wegner, D. (2020). Tracing the evolution of the literature on knowledge management in inter-organizational contexts: a bibliometric analysis. *Journal of Knowledge Management*, 24(2), 463–490. doi:10.1108/jkm-07-2019-0382
- Alonso-Almeida, M. D., Marimon, F., Casani, F., & Rodriguez-Pomeda, J. (2015). Diffusion Of sustainability reporting in universities: current situation and future perspectives. *Journal of Cleaner Production*, 106, 144–154. doi:10.1016/j.jclepro.2014.02.008
- Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, 11(4), 959–975. doi:10.1016/j.joi.2017.08.007
- Bice, S., & Coates, H. (2016). University sustainability reporting: taking stock of transparency. *Tertiary Education and Management*, 22(1), 1–18. doi:10.1080/13583883.2015.1115545
- Bonatxea, I. A., Gutierrez-Goiria, J., Vazquez-De Francisco, M. J., & Sianes, A. (2022). Is the global reporting initiative suitable to account for university social responsibility? Evidence from European institutions. *International Journal of Sustainability in Higher Education*, 23(4), 831–847. doi:10.1108/ijshe-04-2021-0129
- Brusca, I., Labrador, M., & Larran, M. (2018). The challenge of sustainability and integrated reporting at universities: A case study. *Journal of Cleaner Production*, 188, 347–354. doi:10.1016/j.jclepro.2018.03.292
- Ceulemans, K., Lozano, R., & Alonso-Almeida, M. M. (2015). Sustainability Reporting in Higher Education: Interconnecting the Reporting Process and Organisational Change Management for Sustainability. *Sustainability*, 7(7), 8881–8903. doi:10.3390/su7078881
- Ceulemans, K., Molderez, I., & Van Liedekerke, L. (2015). Sustainability reporting in higher education: a comprehensive review of the recent literature and paths for further research. *Journal of Cleaner Production*, 106, 127–143. doi:10.1016/j.jclepro.2014.09.052

- Di Vaio, A., Hasan, S., Palladino, R., Profita, F., & Mejri, I. (2021). Understanding knowledge hiding in business organizations: A bibliometric analysis of research trends, 1988-2020. *Journal of Business Research*, 134, 560-573. doi:10.1016/j.jbusres.2021.05.040
- Djordjevic, A., & Cotton, D. R. E. (2011). Communicating the sustainability message in higher education institutions. *International Journal of Sustainability in Higher Education*, 12(4), 381–394. doi:10.1108/14676371111168296
- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, 285-296. doi:10.1016/j.jbusres.2021.04.070
- Fonseca, A., Macdonald, A., Dandy, E., & Valenti, P. (2011). The state of sustainability reporting at Canadian universities. *International Journal of Sustainability in Higher Education*, 12(1), 22–40. doi:10.1108/14676371111098285
- Hipp, J. A., Gulwadi, G. B., Alves, S., & Sequeira, S. (2016). The Relationship Between Perceived Greenness and Perceived Restorativeness of University Campuses and Student-Reported Quality of Life. *Environment and Behavior*, 48(10), 1292–1308. doi:10.1177/0013916515598200
- Huber, S., & Bassen, A. (2018). Towards a sustainability reporting guideline in higher education. *International Journal of Sustainability in Higher Education*, 19(2), 218-232. doi:10.1108/ijsh-06-2016-0108
- Lozano, R. (2011). The state of sustainability reporting in universities. *International Journal of Sustainability in Higher Education*, 12(1), 67–78. doi:10.1108/14676371111098311
- Merigo, J. M., & Yang, J. B. (2017). A bibliometric analysis of operations research and management science. *Omega-International Journal of Management Science*, 73, 37–48. doi:10.1016/j.omega.2016.12.004
- Sanchez, R. G., Bolivar, M. P. R., & Lopez-Hernandez, A. M. (2013). Online disclosure of university social responsibility: a comparative study of public and private US universities. *Environmental Education Research*, 19(6), 709–746. doi:10.1080/13504622.2012.749976
- Son-Turan, S., & Lambrechts, W. (2019). Sustainability disclosure in higher education A comparative analysis of reports and websites of public and private universities in Turkey. *International Journal of Sustainability in Higher Education*, 20(7), 1143–1170. doi:10.1108/ijsh-02-2019-0070
- Townsend, J., & Barrett, J. (2015). Exploring the applications of carbon footprinting towards sustainability at a UK university: reporting and decision making. *Journal of Cleaner Production*, 107, 164–176. doi:10.1016/j.jclepro.2013.11.004

THE MATURITY LEVEL ASSESSMENT OF INTERNAL CONTROL ASSURANCE

Vlasta Svata

Department of System Analysis
University of Economics, Prague
svata@vse.cz

DOI: 10-35011/IDIMT-2022-305

Keywords

Capability Maturity Models, CMMI, COBIT 2019, Cobit Performance Management, Internal Control Assurance Focus Area, internal control assessment work sheet

Abstract

The article explains how Capability Maturity Models from CMMI can be integrated with COBIT 2019 in order to design the worksheet for maturity self assessment of the internal control assurance focus area. First the scope of focus is described and then by the help of maturity assessment rules that are embedded in COBIT 2019 the design of work sheet is presented along with an example of completed answers and results. The proposed procedure allows the organization's management to get a quick answer to whether their organization reaches the fourth level of the internal control system maturity, which is currently an appropriate level that reduces the risks of COVID and digitalization.

1. Introduction

Capability Maturity Models (CMMs) are a simplified representation of the world and contain elements based on concepts developed by Philip B. Crosby, W. Edwards Deming, Humphey, and Radice. It consists of a sequence of levels of maturity of certain classes of objects and represents the expected, desired or typical path of evolution of these objects. Objects are most often individual processes. The idea of CMM application for software development goes back to the 80s when several US military projects involving software vendors resulted in significant budget overruns and long delays. In response to these failures, the United States Air Force decided to financially support a study that aimed to create an abstract model for objective evaluation of software vendors. This research was commissioned from the Carnegie Mellon University Software Engineering Institute (SEI-CMU) in Pittsburgh. The result was a model CMMI for an objective assessment of the capabilities of software subcontractors. The premise of the CMMI is that the quality of the system or product is highly influenced by the quality of the processes used for its development and maintenance. As this premise is accepted by many other organizations the concept of maturity level appeared in many different regulations, for example, in COBIT, ISO / IEC 33 000 (framework for the assessment of process quality characteristics (e.g. process capability and organizational maturity) and P3M3 (Portfolio, Programme, and Project Management Maturity Model).

CMMI uses two ways to improve processes. This occurs at two levels, which are capability levels and maturity levels. Each type of level is used for a different representation of process improvement.

Continuous representation uses capability levels to characterize the state of the organization's processes in relation to each area of the process. This is a continuous improvement of one specific process. The assessment is based on the combination process performance indicators, which are specific for each process (Base practices, Work products) and Process capability attribute indicators which are common for all the processes (generic practices and generic work products).

Staged representation uses levels of maturity to characterize the overall state of an organization's processes in relation to the model as a whole. It thus makes it possible to improve a set of related processes across different process areas. The maturity levels are measured by the achievement of the specific and generic goals associated with each predefined set of process areas.

One of the main benefits of introducing the CMMI evaluation model in organizations is that it makes it possible to reduce the costs of the improvement process across companies, for which the achievement of their goals depends on several functions and groups. (Chrissis et al. 2011; Kulpa and Johnson, 2003).

In addition to the general models for assessing the maturity of the processes mentioned above, there are other models / tools that seek to evaluate processes related to specific aspect (e.g. information security or cybersecurity) or type of assessment (e.g. attestation SOC -Reporting of controls at service organizations). According to a survey by Rob Van Os (Rob Van Os, 2016), these include:

- Open Group information security management maturity model (O-ISM3)
- ISO/IEC 21827:2008 Information technology — Security techniques — Systems Security Engineering — Capability Maturity Model (SSE-CMM)
- Cybersecurity Capability Maturity Model (C2M2)
- NIST Cybersecurity Framework
- Cybersecurity Maturity Model Certification
- Security Operations Center Capability Maturity Model (SOC-CMM)
- and many others.

These models are complex and using them is time consuming. Furthermore, they usually need specialized professionals having needed knowledge and skills.

On the base of the secondary research focused on capability and maturity assessment and available IT management process frameworks next gaps in research were identified:

- Great majority of guidelines and regulations deals with the capability assessment of individual processes that are described in frameworks like COBIT or ITIL and there are no guidelines dealing with maturity assessment using staged representation model.
- Published maturity models are mainly focused on the area of information and/or cybersecurity or on internal audit. There are no guidelines for maturity assessment of the enterprise internal controls as a whole, covering not only activities of internal audit, but related processes like internal control system, monitoring and compliance management.

Therefore, the research question of this article is: How to provide maturity level assessment of internal control assurance?

The main output is to introduce simple self assessment maturity model for the assessment of the internal control assurance with impact on information security.

2. CMMI and COBIT 2019

COBIT 2019 represents one of the most popular frameworks for enterprise IT governance and management system development. Its essential part is Cobit Performance Management (CPM) which is the general term for all activities and methods enabling to assess the quality of the governance and management system and to identify the steps towards higher level of quality achievement. CPM is aligned with CMMI® Development V2 and in the same time it is built on next CPM principles (ISACA, 2018, p. 37):

1. The CPM should be simple to understand and use.
2. The CPM should be consistent with, and support, the COBIT conceptual model.
3. The CPM should provide reliable, repeatable and relevant results.
4. The CPM must be flexible, so it can support the requirements of different organizations with different priorities and needs.
5. The CPM should support different types of assessment, from self-assessments to formal appraisals or audits.

These general starting points were further elaborated in the set of COBIT documents into more detailed instructions, enabling to link the principles of CMMI with the principles of CPM. Next are presented the most important instructions and/or components that are necessary to understand in order to be able to describe the application of CPM over the chosen area, which is in our case the internal controls system assurance.

2.1. CPM Core Instructions/Components

In CMMI the process area is a set of related processes in an area that, while being implemented, meet a number of objectives that are considered important for improvement in the area and it is associated with maturity levels.

In COBIT 2019 the process area is interpreted as focus area. A focus area describes a certain governance topic, domain or issue that can be addressed by a collection of governance and management objectives and their components (COBIT 2019, 2018, p.14). Performance measure of the focus areas are maturity and will be achieved if all required capability levels are achieved. (ISACA, 2018, p.40) describes next maturity levels:

0. Incomplete—Work may or may not be completed toward achieving the purpose of governance and management objectives in the focus area.
1. Initial—Work is completed, but the full goal and intent of the focus area are not yet achieved.
2. Managed - Planning and performance measurement take place, although not yet in a standardized way.
3. Defined—Enterprise wide standards provide guidance across the enterprise.
4. Quantitative—The enterprise is data driven, with quantitative performance improvement.
5. Optimizing—The enterprise is focused on continuous improvement.

In CMMI individual processes can be measured by the help of capability levels. The capability level assessment is based on combination of process performance indicators and process capability indicators.

In COBIT 2019 the individual governance and management processes are described in (ISACAa, 2018) as process components of objectives. Processes are divided into practices and practices into activities. Each process activity is associated to capability level and this relationship is an inherent part of *COBIT® 2019 Framework: Governance and Management Objectives* guide enabling clear definition of processes at different capability levels. (ISACAc, 2018, p. 39) describes next capability levels:

0. Lack of any basic capability, incomplete approach to address governance and management purpose, may or may not be meeting the intent of any process practices
1. The process more or less achieves its purpose through the application of an incomplete set of activities that can be characterized as initial or intuitive—not very organized.
2. The process achieves its purpose through the application of a basic, yet complete, set of activities that can be characterized as performed.
3. The process achieves its purpose in a much more organized way using organizational assets. Processes typically are well defined.
4. The process achieves its purpose, is well defined, and its performance is (quantitatively) measured.
5. The process achieves its purpose, is well defined, its performance is measured to improve performance and continuous improvement is pursued.

In CMMI (ISO/IEC 33000) the needed information for process capability assessment are process outcomes, base practices and work products.

In COBIT 2019 these terms were aligned and replaced by the next terms (ISACAc, COBIT 2019, p. 38):

- Process outcomes are process practices; process outcomes are understood as the successful completion of the process practices
- Base practices are equal to the COBIT 2019 process practices for each governance and management objective.
- Work products are equal to the Information Flows and Items under component C in each governance/management objective.

2.2. Rating of Process Indicators

The process capability level assessment consists of the evaluation of a number of different indicators, such as the process activities recommended for a given capability level, and / or the fulfilment of the required inputs and outputs recommended for each process practice. There are basically next ways of indicators rating that depend on the context in which the assessment is made and the type of indicator:

1. Formal method of rating using independent binary rating pass/fail; suitable for hard indicators, mainly inputs and outputs (e.g. Reports of violations are created?)
2. Less formal methods (often used in performance-improvement contexts); suitable for soft indicators (e.g. "Do you engage with stakeholders and communicate the enterprise

requirements and objectives for monitoring?”). The range of ratings is larger, such as the following set:

- Fully—The capability level is achieved for more than 85 percent.
 - Largely—The capability level is achieved between 50 percent and 85 percent.
 - Partially—The capability level is achieved between 15 percent and 50 percent.
 - Not—The capability level is achieved less than 15 percent.
3. Combination of formal and less formal methods is suitable for maturity assessment, as it is done at two levels- first you have to assess the level of capability of all the focus area processes and second you have to assess the maturity level of the focus area itself.

3. Maturity Assessment of Internal Control Assurance Focus Area

3.1. Assumptions of the solution

1. First of all there is need to identify the processes of the focus area internal control assurance. (COBIT 5 for Assurance, 2018, p. 53) states that “The processes comprised in the Monitor, Evaluate and Assess (MEA) domain of COBIT 5 can be regarded as the core assurance processes required within every enterprise.” Using this statement, the domain MEA in COBIT 2019 covers four objectives and each objective relate to one process, so the objectives can be viewed as processes and are the next
- MEA01 Performance and conformance monitoring
 - MEA02 Internal control management
 - MEA03 Compliance with external requirements management
 - MEA04 Assurance management.

The description of the above objective process component and needed inputs and outputs has been extended by a description of components important for information security management. The reason is, that the growing importance of information security is an inherent part of digital transformation.

2. In (ISACA, 2018, p.43) it is presented, that the target capability level logically depends on the level of their criticality for an organization. The higher capability level (3-4) is recommended for the most critical objectives/processes while the lower capability levels 1-2 are enough for less critical objectives/processes. In the same time the document states that in many cases it is not recommended to aim for the highest rating (level 5) because it is not cost-effective to operate processes at this level within a reasonable time frame and other resources. Therefore, many objectives/processes do not identify activities needed for this capability level. Similar situation occurs in case of the lowest capability level 1. Capability level 1 means that process consists of incomplete set of activities, it is intuitive and not very organized and therefore it is meaningless to formally describe any activity that relate to this capability level. Based on this assumption it was decided to focus on the capability level 4 as in times of COVID and accelerated digital transformation internal control assessment is one of the most critical area in an organization.
3. In COBIT 2019 the process capability level assessment is based on activities. Each capability level is assessed on the basis of the level of performance of activities that go across the practices of the process and are assigned to that level. The formulation of these

activities is often general and it is difficult to determine the extent of their implementation. Based on the process general definition (ISACA, Glossary) “process is a collection of activities influenced by the enterprise’s policies and procedures that takes inputs from a number of sources, (including other processes), manipulates the inputs and produces outputs”. The process assessment in this research is based on process outputs because they allow a more formal method of independent binary rating (output is available or not).

3.2. Design of the Assessment Work Sheet for Internal Control Assurance

With respect to the above assumptions it was designed the internal control assessment worksheet where the core outputs of the area identified processes are listed and rated using combination of formal and less formal methods of assessment. Table 1 shows an example of the internal control assessment sheet.

Table 1: Example of completed sheet (source author)

Process area-Internal audit	Number of processes: 4 Number of processes with achieved capability 4 (L or F): 3 Process area maturity level: 3	
Process: MEA01 Managed Performance and Conformance Monitoring	No of outputs: 12 No of existed outputs: 7 Capability level 4: 58% - L	
Approved monitoring goals and metrics		no
Monitoring requirements		yes
Information security monitoring process and procedure		yes
Monitoring targets		no
Agreed-on infosec metrics and targets		no
Processed monitoring data		yes
Processed monitoring infosec data		yes
Performance reports		yes
Infosec reports and corrective action plans updated		yes
Remedial actions and assignments		yes
Status and results of actions		no
Tracking process for corrective actions on infosec issues		no
Process: MEA02 Internal control management	No of outputs: 12 No of existed outputs: 5 Capability level 4: 42% - P	
Results of benchmarking and other evaluations		no
Results of internal control monitoring and reviews		yes
Defined information security assurance scope and approach to assess internal controls		yes
Evidence of control effectiveness		no
Evidence of effectiveness of information security controls		no
Self-assessment plans and criteria internal controls		no
Results of reviews of self-assessments		no
Results of self-assessments		no
Information security assurance assessment		no
Remedial actions		yes
Control deficiencies		yes
Assessment results and remedial actions		yes
Process: MEA03 Compliance with external requirements management	No of outputs: 11 No of existed outputs: 6 Capability level 4: 55% - L	
Log of required compliance actions		no
Compliance requirements register		yes
External information security compliance requirements		yes
Communications of changed compliance requirements		yes

Updated policies, principles, procedures and standards	yes
Updated external requirements	yes
Compliance confirmations	no
Identified compliance gaps	no
InfoSec compliance report	no
Compliance assurance reports	no
Reports of noncompliance issues and root causes	yes
Process: MEA04 Assurance management	No of outputs: 19 No of existed outputs: 14 Capability level 4: 74% - L
Results of assurance provider evaluations	yes
Competence in skills and knowledge	yes
Assurance plans	yes
Assessment criteria	yes
High-level assessments	no
Engagement plan	yes
Assurance review practices	yes
Assurance review scope	yes
Updated engagement plan	yes
Assurance objectives and expected benefits	yes
Updated engagement plan	yes
Refined scope	yes
Detailed assurance work program	yes
Documented design of internal controls	no
Control effectiveness testing	no
Assurance review report	no
Assurance review results	no
Audit infosec report and recommendations	yes
Remedial actions	yes

In this example the maturity level of the process area Internal Control Assurance is the third as one process MEA02 Internal Control Management did not achieve rating L or F within the 4th capability level assessment. In the same time it is apparent, that the main shortage of this process is missing evidence of internal control effectiveness and self-assessment practices.

In this example, the focus is only on evaluating the required outputs needed to achieve the 4th level of process capability. The analysis of data flows described in the COBIT 19 Core Framework shows that key inputs to achieve the required outputs of the Internal Control assurance area are provided by processes EDM05 (EDM05 Ensured Stakeholder Engagement), DSS (DSS06 Managed Business Process Controls, DSS01 Managed Operations, DSS02 Managed Service Requests and Incidents, DSS05 Managed Security Services), APO (APO01 Managed Management Framework, APO11 Managed Quality and APO12 Managed Risk). The most important process within the area from needed inputs point of view is MEA04 Managed Assurance Process. The result of this fact is that the improvement of maturity process area Internal Control Assurance is highly influenced by the capability levels of the above-mentioned processes.

4. Future Research and Conclusion

The future research in this topic can take in account not only the process outputs, but the process inputs as well. This improvement together with the development of Excel table supporting this model can open the possibility of incorporating automatic controls of links between process inputs and outputs. For example

- if the evaluation criteria are not available at the input, compliance reports cannot be performed,

- if scope analysis is not performed, scope assurance cannot be determined, etc.

COVID19 together with the continuous digitalization of the enterprises have big impact on the IT processes changes. These changes must be managed with respect to the involved changes of internal control systems, their monitoring and assessment. Both the governance and management authorities need a simple and flexible tool for internal control assessment which can offer feedback for them in form of maturity level assessment. The main output of the research is the design of the work sheet enabling self-assessment whether the organization achieves fourth maturity level of the Internal Control Assurance area consisting of four identified processes. The proposed method is especially suitable for organizations that are subject to Act No. 320/2001 Coll. on financial control in public administration, but also for all organizations that are interested in improving the quality of their internal systems using best practices in this area.

5. Acknowledgement

The paper is supported by IGA project of VŠE No. IG409031.

6. References

- Chrissis, Mary Beth, Mike Konrad, Sandy Shrum, 2011. CMMI for development: guidelines for process integration and product improvement. 3rd ed. Upper Saddle River, NJ: Addison-Wesley. SEI series in software engineering. ISBN 978-0-321-71150-2.
- CMMI Cybermaturity Platform, 2018
- ISACAa (2018), COBIT® 2019 Framework: Governance and Management Objectives, ISBN 978-1-60420-764-4
- ISACAb (2018), COBIT® 5 for Assurance, ISBN 978-1-60420-340-0
- ISACAc (2018), COBIT® 2019 Framework: Introduction and Methodology, ISBN 978-1-60420-763-7
- ISACAd (2018), COBIT 2019 Design Guide: Designing an Information and Technology Governance Solution, ISBN 978-1-60420-765-1
- ISAC Ae, Glossary, <https://www.isaca.org/resources/glossary>
- Kulpa (2003), Kulpa, Margaret K, Kent A Johnson, 2, Interpreting the CMMI: a process improvement approach [online]. Boca Raton, Fla.: Auerbach/CRC Press, ISBN 978-0-203-50461-1, <http://www.books24x7.com/marc.asp?isbn=0849316545>
- ROB VAN OS (2016), SOC-CMM: Designing and Evaluating a Tool for Measurement of Capability Maturity in Security Operations Centers [online]. B.m. Master Thesis. Luleå University of Technology Department of Computer Science, Electrical and Space Engineering, <http://www.soc-cmm.com/>

COMPETENCY MANAGER AS A VERY USEFUL COMPETENCY MANAGEMENT TOOL

Jana Holá

University of Pardubice, Faculty of Health Studies
jana.hola@upce.cz

Markéta Moravcová

University of Pardubice, Faculty of Health Studies
marketa.moravcova@upce.cz

Lukáš Čegan

University of Pardubice, Faculty of Electrical Engineering and Informatics
lukas.cegan@upce.cz

Eva Hlaváčková

University of Pardubice, Faculty of Health Studies
eva.hlavackova@upce.cz

DOI: 10-35011/IDIMT-2022-313

Keywords

Software application, competency, management, nursing

Abstract

The Competency Manager provides competency management in relation to the holder in accordance with the standards of safe and quality health care providing. The application is created based on the competency model of a general nurse. The model meets the required standards of the quality and safe health care within the hospital quality certification. The competency model is based on the range of competencies of each general nurse providing health care in connection with the profession, the development and long-life education within the hospital mission. The application is intended for all professional groups of hospital staff and has been implemented in the hospital intranet environment. The Competency Manager software application was implemented for the Hospitals of the Pardubice Region (Nemocnice Pardubického kraje, a.s.) under the license agreement in 2021. The Competency Manager application was created as a result of the Technology Agency of the Czech Republic project: The Competent Nurse of 21st Century conducted in 2019-2021. The Hospitals of the Pardubice Region were involved in the project as an application supervisor.

1. Introduction

For proper nursing care provision, the importance of competency definitions is undeniable. Equally definition of competency is important for setting up a nursing education curriculum. It is also important to identify the development process of nursing competency for professional growth. Nevertheless, the concept of nursing competencies has not been fully developed. The challenges remain in determining the definition and structure of the nursing competency, the levels of competencies necessary for nursing professionals, training, and management methods. Therefore, further research is needed to develop a comprehensive concept of nursing competency (Fukada, 2018). Glajchová et al. (2021) state that setting of competencies and performance of the profession within the defined and fixed range is an area that also affects the perception and performance of the nurse's profession as such. In the qualitative survey that preceded the presented questionnaire survey, most informants commented on exceeding competencies as a fact that is part of the daily work routine.

The article follows the article titled Information System Architecture for Competency Model (Holá, Čegan, 2019) that explained and clarified the chosen software system architecture for building a competency management system and described the technical solution. The article focuses on the support methodology for creating the content of a specific application of the system called the Competency Manager. The Competency Manager is a tool for competency management and was implemented in the Hospitals of the Pardubice Region ICT system to manage the nurses' competencies primarily. At present, the authors concentrate on creating of competency models for other professionals group employees in the hospital.

2. Methodological Framework

One of the basic prerequisites for the model successful creation and implementation is the involvement of stakeholders and users who will work with the model and help to promote it based on their willingness to participate in the development already during the project preparation. Therefore, a stakeholder-based strategy (Gallagher-Ford et al., 2011) based on the evidence-based practice was chosen as the implementation strategy.

According to Ivlev, Kneppo, Barták (2015), the most relevant criteria for the selection of the expert group are the experts' experience in dealing, the experts' theoretical background (awareness) and the experts' knowledge, the experts' current position and the level of his or her education and scientific record. The selected expert group (panel) was therefore made up of experts who would work with the model and for whom the development and subsequent implementation presented a wide range of issues and concerns from the beginning as they were involved in the competency allocation and evaluation. The group was based on two basic sources of competencies from the Czech legislation regulating professional competency based on the EU curriculum and the needs of an organization. The expert panel of 11 senior nurse managers of the Hospital of the Pardubice Region and two external experts as representatives of other 2 application guarantors for evaluation were set up to determine the key competencies.

All experts of the expert group have had more than 20 years of experience as general nurses and have held management positions for the last 5 years as minimum. The expert panel worked in the form of guided discussion based on brainstorming. The researchers of the project gradually brought topics according to the chosen procedure for discussion. The reviewers commented on the conclusions of the expert panel and thus provided feedback, approving the accepted consensus. The expert group defined the requirement for a competent nurse as a nurse who is authorized, independent, professionally qualified, able, but also willing to deliver performance or carry out an

activity in the required quality, within the required time in compliance with the nursing care processes defined by the quality standard (learns quickly, cooperates, delegates, is educationally equipped, his/her behaviour and actions are in line with the ethical standards). The definition of a competent nurse and the basis for the creation of competencies is based on the concept of Raven (2011) which proves that expert competency (given by law in case of nurses) may not be sufficient to define the competency. Professional competency must be linked to motivation, desirable attitudes. He sees the way of competency development, the way to professionalism in connection with professional development, which must be regularly verified and enhanced. The same conclusions are reached by Beauvais (2019) and Becher (2001).

The idea of the model system design is based on the system definition according to Hall and Fagen (1968). A system is a set of elements and their properties, connected by mutual relations. Here the competence management system can be understood as a set of elements that are individual components of the whole, are in constant mutual interaction and the common synergy forms the properties of the whole. The main elements of the competency model system are a defined competency (the described performance), a holder (an employee), a competency allocator and verifier (a manager) and their interaction in the processes of the recruitment, adaptation, evaluation, and education within the competency development (Armstrong, 2008).

During the competency model development, all the techniques recommended by Kubeš (2004) were applied: taking over, combining, and creating a new model in order to capture and develop the intellectual capital, the bearers of which currently work as hospital nurses. The takeover was performed by using researchers' existing experience and the COPA model (Lenburg, 1999). The combination was reached by incorporating the specifics of the organization for which the model is created into the adopted model. The existing experience and currently set processes were added to the model, and thus a new model was developed; it contains hitherto undescribed areas of competency and comprehends the situation in the hospital, preferences, goals, and possibilities in terms of operation. Kubeš (2004) also shows the way to the requirements for competency models so that the model is sufficiently general, specific, and generic. The authors supplemented the requirements in terms of the main goal, namely, to ensure the management of competencies in relation to the bearer (the competency life cycle), and the evaluation and development in the context of personnel management (Armstrong, 2011).

The Evidence-Based Competency Model according to Winter (2018) was used for the initial classification of competencies in 5 categories: resource use, cooperation, quality, and safety, evidence-based practice (EBP) and information and communication technology (ICT). The COPA model (Lenburg, 1999) is based on the need to adapt and meet goals in clinical and academic settings and is specifically focused on nursing. The model follows the current and future needs of the professional practice, and the creation is based on the expert panel working in compliance with issues listed below.

- What are the basic competencies and outputs needed for practice?
- What are the criteria available to define these required competencies?
- What will be the most effective ways to learn or expand new competencies?

According to Lenburg (2009), the competency model for a nurse should include the competencies in the following areas.

- Competency to determine the severity of the situation: assessment and intervention skills in the context of safe care, patient monitoring, and treatment procedures.
- Communication competencies - verbal, nonverbal communication, written, presentation, PC skills.

- Critical thinking competencies: evaluation, decision-making, linking information to determine nursing progress, prioritization, research, implementation of best practice in the context of the Evidence Based Practice
- Competencies focused on maintenance and building relationships - morality, ethics, respect for cultural and religious differences, cooperation, and advocacy of the patient.
- Management competencies: planning, organizing, delegating, capacity utilization, performance and safety assessment and improving the quality of care.
- Leadership skills: cooperation, assertiveness, creativity etc.
- Pedagogical and educational competencies: within the development of the field, patient education and mentoring.
- Integration of knowledge: linking nursing to other related disciplines.

3. Competency Model Development

The expert group defined the competency management system as the life cycle (acquisition, consolidation, development, transfer). Thus, it proposed the main functionalities, methods of acquiring competencies, their maintenance and development, and ways to objectively and correctly evaluate the results of fulfilling the required competencies.

The new model and subsequently the application on the competency management resulted from the main requirements set by the expert group. There were 2 basic questions: What key competencies should a nurse have in a particular workplace? And how do we want to verify and develop these competencies? The main requirements were then described as processes leading to achievement of the defined goals: setting competencies for a specific position, assigning competencies to a specific employee, reassessing competencies in the adaptation period and in the stabilization period and in managing changes in the employee's career.

The model setup requirements were as follows:

- the model should include specific but also general competencies that are common to all employees such as management, soft skills, education and training, and quality and safety competencies,
- the model should enable the creation of sufficiently specific competencies directly related to the defined work and should also serve for the development of the employee and his evaluation,
- the developed model is generic (generally applicable to other professions),
- the model must contain templates for individual workplaces,
- the spectrum of competencies of each employee is up-to-date and corresponds to reality, a digital footprint and archiving is provided, expiration settings and expiration annotations force to keep the relevant participants updated,
- the model connects each specific competency with the educational activity at the time of adaptation or training and the further development (the education plan) and links it to the internal documentation, i.e. the model should enable the management of the competency within the life cycle in relation to the main phases of the personnel management: adaptation and training, performance management and employee self-evaluation, consolidation and development of competencies related to the career development.

The EB model by Winter (2018) was used as a suitable springboard but it appeared insufficient for division and categorization of the competencies. The COPA model has proved more appropriate (Lenburg, 1999). Using the above-mentioned COPA model, the expert group identified key competencies in the following 8 areas, see tab. 1.

There were 81 competencies defined for the group of employees in the profession of a general nurse which is shown in table 1. Some competencies that have not yet been managed were systematized, such as leading the adaptation process, competencies of trainers, mentors, peers, crisis intervention coordinators, etc. The selection and definition of competencies was accompanied by the unification of concepts and internal processes of the 5 health care facilities concerned.

Table 1 The Overview of the Created Competence Categories

Category	Number	Example
Key nursing competencies	20	Cardiopulmonary resuscitation
Specific nursing competencies - performed under professional supervision or independently based on the acquired certificate (a certified or accredited course, specialization education)	25	Chronic wound management
Quality and safety	8	Prevention of hospital acquired infections
Educational and pedagogical competencies	5	Mentor, educator, trainer
Administration	4	Auditing, documentation man., IS
Evidence-Based Practice	4	Best practice implementation
Management	9	Leadership, communication
Soft skills for professionalism	6	Development of cooperation

The key competencies selection considered the type of a workplace and type of care provided. The birth certificate (see tab. 2, a basic unit for each competency) was created, also the rights for granting and reassessing of competency were set, each specific competency was connected to the educational activity at the time of adaptation or training and to the further development (a training plan) and linked to the internal documentation. There is a guide of the created application to clarify the key competencies as well as by whom, when and based on what they are re-evaluated and how they will be developed.

Table 2 The Birth Certification of Competency

Competency Name	Care of a Patient with a Stoma
Description	Assesses and treats the condition of the stoma and skin, recognizes complications, prevents risks, etc.
Group of competencies	Key nursing competency
Approval authority	Head nurse
Competency requirements	Nursing performance under the supervision of a trainer in the adaptation process
Reassessment of competence	Annual performance review
Intended for	Nurse and paramedics at surgery
Compulsory/recommended education	Internal training per 2 years
Internal standards concerned	Internal standard XX and documents XX

4. Discussion

The competency model centralizes all necessary competencies and reviews the required and completed education which will enable the systematic creation of a training plan and effectively maintain or increase the level of achieved competencies and expand their spectrum if necessary.

Within personnel management, the competency model will enable linking of an employee evaluation to his or her professional and career development. Armstrong (2008) described that clarifying the job descriptions and developing key competencies as well as objective evaluation of employee performance are the core elements of leadership and help to enhance engagement. The specific competency model provides a tool for leadership (Bedrnová et al.; 2012). Dalkrani and Dimistriadis (2018) proved that understanding sense of work and the development clearly influences job satisfaction. The support and development of competencies strengthen one's own identity and professionalism and are sources of satisfaction / dissatisfaction and well-being of practice nurses in the UK (Wood, 2021).

The competency management and even the creation and implementation bring the significant benefits to an organization. During the competency management system producing, the deep links between the personnel processes from recruitment to onboarding and training to performance evaluation and staff development were revealed. The competency management created and defined not only the primary framework for setting the key competencies for each professional group, but also the main competencies in accordance with the organization's mission as well as the framework for annual performance review and self-appraisal of employees to boost their development. The Numminen study (2016) revealed the significant connections between commitment and competency settings, fluctuation intentions, and job satisfaction.

The additional benefits will come from the application as part of a continuous improvement in the quality of health care. The competency model connects all key competencies and lifelong learning which will enable the systematic creation of a training plan and effective maintenance or increasing the level of achieved competencies or increasing the level of safety and quality of care provided. According to Marx (2019) from the Joint Commission on Accreditation (i.e. the accreditation authority for granting a quality certificate), the most common causes of adverse events are as follows and the competency model responses to minimize the risks, see tab. 3.

The main benefits of the Competency Manager implementation consist in the process systematization, setting up the standard processes within the personnel management at all levels and at the lowest level of direct management, the effective education using organizational potential and better conditions for spreading the good name of the hospital by the employees by improving the quality of personnel management.

The formed groups of competencies often find an intersection in competencies published and recommended abroad, e. g. the Nursing Practice and Skill (Schub E., Balderama B., 2017) and the Leadership Competencies for Healthcare Services Managers (International Hospital Federation, 2015). The inability to adopt the entire models is due to the differences in the assigned professional competencies of the nurses as well as the different internal management system. The proposed system simply shows the way to get to the required level of competency management. It is a tool intended for the management staff and expands their knowledge of the system management. The system does not retain the ambition of a single possible solution but provides an insight into a possible solution, a scenario of possible settings. In any case, the proposed system is broad enough to serve as a basis for setting up of the competency management anywhere. The bonus is that the proposed system is also based on the principles of open communication to increase employee engagement. These principles often appear in the literature as the principles of leadership (Armstrong, 2008) and management (Bedrnová et al., 2012). These are, above all, the principles of partnership, mutual benefit, justice, openness, and moral authority.

Table 3 Possibilities of Elimination of the Adverse Events Main Causes by the Software Competency Model Functionalities

Causes of Adverse Events	Competency Manager Functionality
Defective or insufficient communication	The key competency in connection with education, the system for monitoring of competency settings and relevant communication
Insufficient onboarding during the adaptation process	Defining the key competency helps to set the prioritized activities, the system provides clearer administration for verification and reassessment of competencies, and stores the history of the adaptation process as part of educating
Insufficient supervision of subordinate staff (vaguely or incorrectly assigned competencies)	The system standardizes the setting of competencies, the creation of templates, sets the requirements, and offers streamlining of work within the management of competencies, education, evaluation, and personal development
Insufficient staffing	The overview of currently set competencies provides greater flexibility for the work potential exploitation, the professional competency management, training, and evaluation for enhancing engagement and stability.

5. Conclusion

The created competency model is ready for implementation and integration into a common intranet environment, including a tutorial for administration and specification the IT equipment parameters. It has been designed with intuitiveness and user friendliness in mind. To increase user availability and comfort, it is also optimized for mobile devices. The work with the application itself was the subject of courses supporting the competencies in the field of employees' digital literacy and competencies for creating new competencies. On the part of the operating organization, in addition to meeting the IT requirements to connect to the source or production databases of other systems, e. g. VEMA (2022), it is necessary to ensure personnel capacity for administration (regular content updating, setting user sign-in data and access rights, training, etc.) and further development. The additional staff capacity needs to be set aside in the field of education to ensure all areas of lifelong learning are linked to the individual competencies. Ensuring of efficient operation fully depends on the top management support. The implementation of the application requires a change in the processes, or work at all levels of management, but also in the attitude of the employees themselves in the sense of their own self-development which should be conceptual for fulfilling their own long-term work objectives. Thanks to the chosen strategy of the main stakeholders' involvement, the authors assume the easier acceptance of the mentioned changes.

The proposed system follows the idea of the different approaches unification within the organization. The system is sufficiently understandable, accessible, general, verifiable, and timeless. These principles clearly help to explain and implement the system. The comprehensibility of the system results from the simple description and use of the terminology of professional practice and common management sciences. Availability is based on the absence of relevant access barriers in the implementation of the system. In general, the system is available because it can be deployed in any organizational environment regardless of the specifics of the organization scope, regardless of a size or region. The validity of the system is conclusive especially in determining the state of competency management (during the audits) and in increasing its level. The system is also timeless as, despite the rapid technology development, the basic ideas and principles remain the same, the form is stable, the content of the principles is permanent, and the competence description can be changed according to the current state.

The principles accurately reflect the basic organizational culture in which all employees like to work. The proposed competency management model using the Competency Manager application

can therefore also contribute to increasing the quality of care and organizational culture. The work on the project was complicated by the pandemic situation, was often relegated to the background, and the completion itself was delayed by 3 months (June 2021). However, the implementation of the model and the completion for other professions have been permanently blocked by other hospital priorities. Nevertheless, despite the situation, the competency model for nurses is functional.

6. Acknowledgements

The paper was created within the project titled The Competent Nurse for the 21st Century: The Analysis and Design of the Optimization of Nursing Education and Professional Practice funded by the Technology Agency of the Czech Republic, project no. TL01000094.

7. References

- Armstrong M. (2008) Human Capital Management: Achieving Added Value Through People. 1. ed. London: Kogan Page. ISBN: 978-0749453848
- Armstrong M. (2011) Řízení pracovního výkonu: Cesta k efektivitě a výkonosti. 1. ed. Praha: Fragment. ISBN: 978-80-253-1198-1
- Beauvais, A.M. (2019) Leadership and Management Competence in Nursing Practice. New York: Springer Publishing Company. 2019. ISBN: 978-0-8261-2524-8
- Bedrnová et al. (2012) Manažerská psychologie a sociologie. 1. ed. Praha: Management Press. ISBN: 978-80-7261-239-0
- Becher, T. (2001). The incapable professional. In J. Raven & J. Stephenson (Eds.), Competence in the Learning Society. New York: Peter Lang
- Dalkrani M., Dimistriadi E. (2018) The Effects of Job Satisfaction on Employee Commitment. International Journal of Business and Economic Sciences Applied Research. Vol 11, No.3, 16-23 DOI: 10.25108/ijbesar.113.02
- Fukada M. Nursing Competency: Definition, Structure and Development. Yonago Acta Med. (2018) Mar; 61(1): 1–7. Published online 2018 Mar 28. DOI: 10.33160/yam.2018.03.001
- Lenburg, C. (1999) The Framework, Concepts and Methods of the Competency Outcomes and Performance Assessment (COPA) Model. Online Journal of Issues in Nursing. Vol 4, No. 2, Manuscript 2. Available: <https://ojin.nursingworld.org/MainMenuCategories/ANAMarketplace/ANAPeriodicals/OJIN/TableofContents/Volume41999/No2Sep1999/COPAModel.html>
- Gallagher-Ford L, Fineout-Overholt E, Melnyk BM, Stillwell SB (2011). Implementing an evidence-based practice change. Am J Nurs 111(3): 54–60. DOI: 10.1097/10.1097/01
- Glažchová, A et al. (2021) Job satisfaction of general nurses in standard and intensive care units: "The nurse is a jack-of-all-trades!". Kontakt, 2021, roč. 23, č. 4, s. 289-296
- Hall A. D., Fagen M. (1968) Definition of System. Walter F. Buckley: Modern Systems Research, s. 82.
- Holá, J., Čegan, L. (2019) Information System Architecture for Competency Model. IDIMT-2019 Innovation and Transformation in a Digital World. Linz : Trauner Verlag, 2019, s. 369-376. ISBN 978-3-99062-590-3
- International Hospital Federation (2015) Leadership Competencies for Healthcare Services managers. Available from: Leadership_competencies_healthcare_services_managers.pdf (ache.org)
- Ivlev, Ilya & Kneppo, Peter & Barták, Miroslav. (2015). Method for Selecting Expert Groups and Determining the Importance of Experts' Judgments for the Purpose of Managerial Decision-Making Tasks in Health System. E a M: Ekonomie a Management. 18. 57-72. DOI:10.15240/tul/001/2015-2-005
- Kubeš, M. et al. (2004) Manažerské kompetence. Způsobilost výjimečných manažerů. 1. ed. Praha: Grada Publishing, 2004. 184 s. ISBN 80247-0698-9

- Numminen O. et al. (2016) Newly graduated nurses' occupational commitment and its associations with professional competence and work-related factors. *Journal of Clinical Nursing*. 25 (1-2) (pp 117-126). DOI: 10.1111/jocn.13005117
- Raven J. (2011) Competence, Education, professional development, psychology, and Socio-Cybernetics. In G.J. Neimeyer (Ed.). *Continuing Education: Types, Roles, and Societal Impact*. Nova Science Publisher, Inc., Hauppauge, New York. ISSN 11788-3619
- Schub E., Balderama B. (2017) Nursing Practice and Skills Cinahl Information Systems. Available from: NRCP_NPS_CaringPatient-w-ChemicalExposure.pdf (ebshost.com)
- VEMA (2022) Mzdový a personální informační systém. Available from: <https://www.vema.cz/cs/ekonomicky-system%20>
- Winter, P.B. (2018) The design of an Evidence-based Competency Model. *Journal for Nurses in Professional Development*. Vol 34/4, 206-211. ISSN 3169-9798
- Wood, E. et al. (2021) Sources of satisfaction, dissatisfaction and well-being for UK advanced practice nurses: A qualitative study. *Journal of Nursing Management*. ISSN 0966-0429. DOI:org/10.1111/jonm.13245

CARBON REPORTING: EVIDENCE FROM THE CZECH FINANCIAL SECTOR

Ladislava Volková

Department of Management Accounting
Prague University of Economics and Business
ladislava.volkova@vse.cz

DOI: 10-35011/IDIMT-2022-323

Keywords

IDIMT, ESG, nonfinancial reporting, CO₂ footprint, carbon reporting, climate risk disclosure

Abstract

This paper is a content analysis that aims to give evidence on carbon emissions disclosures of Czech banks and insurance companies in the period 2019-2021. First, it narrows literature review on Carbon accounting with focus on the Czech Republic. Further it analyses carbon footprint reports of the financial companies. The paper adds to the current knowledge how environmental reporting progressed in the past couple year and gives evidence that large foreign owned financial companies improved their reporting significantly, but smaller and Czech owned companies still lack behind. Additionally, many various standards for CO₂ measurements are used and therefore, difficulty in comparability of reported data remains.

1. Introduction

The European Commission adopted a set of proposals to make the fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels (EU, A European Green Deal, 2021). The Czech Republic is one of the biggest emitters of CO₂ per capita in Europe with 9,8t and although quite a small economy, it is contributing 0.25% to the world's total annual emissions (Agency, 2021). Even though Coal source of CO₂ emissions is rapidly declining since 1980, still more than half of CO₂ emissions come from the coal, partially imported from Russia and Ukraine. The war conflict in Ukraine accelerates the need to move away from Russian Gas, oil and coal as well as significantly reduce consumption and increase the level of local renewable energy sources. EU called up for the "REPowerEU action plan" and stressed the need to formalize the Fit55 as soon as possible (EU, REPowerEU: Joint European action for more affordable, secure and sustainable energy, 2022). Furthermore, there is an existing proposition for Corporate Social Reporting Directive (CSRD) that would ask almost 50 thousand EU companies to comply with the final directive in 2024. Approximately, 1500 companies are to comply in the Czech Republic. CSRD enhances currently valid Non-financial reporting directive (NFRD) on sustainability reporting but extends the scope of the reporting requirements. Financial sector is aware of emissions accounting, as evidenced by the emergence of the range of recommendations and legal proposals within EU Taxonomy. Also, industry organizations as well as the academic papers devoted to these phenomena listed in the next chapter, are closely following the topic. This work is solely concentrating on carbon reporting, and it evaluates CO₂ emissions equivalent tons reporting for major firms of the Czech financial sector. These banks and insurance companies are obliged to

report on carbon emissions based on the Czech law 462/2016Sb paragraph 32f because of EU NFRD. The validity for disclosures is fiscal year starting 1.1.2017. Neither NFRD nor Czech law specifically instruct how the report on environmental disclosure should look like, and although industry standards are being agreed upon nowadays, they are not yet universal. There are several widely used standards like Global reporting initiative (GRI) that is using GHG protocol (GHG Protocol Corporate Standard Revised, 2004) or globally frequently used voluntary disclosure platform CDR database. Companies often refer its disclosure to other formats like UN SDG goals, SASB, IIRC or ISO standards. Given the widespread GHG protocol and initiative, specific Global GHG Accounting and Reporting Standard for the Financial Industry was developed by the Partnership for Carbon Accounting Financials (PCAF) and launched at the end of 2020 to give some more detail on the methodology how banks and insurance companies can handle the reporting focusing on Scope 3 of the emissions reporting that covers vendor environmental evaluation but above all customers businesses' loans and risk insurances (Partnership for Carbon Accounting Financials, 2022). PCAF was inspiration for TaskForce on Climate related financial disclosure (TCFD), which goes beyond a simple CO₂ reporting of the company itself but prepares calculation methods of the climate change exposure for banks and insurance companies (Task Force on Climate-related Financial Disclosures, 2022). While in many cases these institutions, standards, and frameworks are compatible, others are not standardized or organized. (PCAF, 2020) Summing up all the above stated, financial companies are asked more than ever to disclose its environmental risks, their strategy for carbon neutrality target and prepare a strategy for sustainable financing. Next paragraph gives overview on current academic knowledge on carbon disclosure problematique.

2. Literature review

This paper derives the research on carbon reporting from the context of the whole climate change as well as ESG frameworks that are in the middle of academic attention since Kyoto and Paris conferences. However, this paper is limited and therefore concentrates solely on one aspect: disclosure of CO₂ equivalent tons of emissions of the financial companies in the Czech Republic (based on GHG protocol method) and their CO₂ neutrality target disclosure.

Given ESG is quite a complex topic across different disciplines, several research streams were suggested (Gibassier, Michelon, & Cartel, 2020). Not only the wide areas of the research directions attracts academic attention, but researchers also question, whether the understanding of the topic is common (Ascuí & Lovell, 2011) or whether the pathway to meet the goal is correct (Gibassier, Michelon, & Cartel, 2020), (Martineau & Lofontaine, 2019) (Brauch & Spittle, 2021). Given the complexity and multidisciplinary context, there are few valuable works on literature review on GRI (Peters & Wagner, Global Reporting Initiative (GRI) and its Reflections in the Literature, 2015), non-financial information disclosure (Tarquinio, 2022) or on carbon accounting itself (He, Luo, Shamsuddin, & Tang, 2021). The main focus of the literature review relevant for this paper is research done on absolute levels of GHG emissions (Solomon, Solomon, Norton, & Joseph, 2011), (Liesen, Hoepner, Patten, & Figge, 2015) (Liesen, Figge, Hoepner, & Dennis, 2016) (Jung, Herbohn, & Clarkson, 2018) (Faria & Labutong, 2019) (Light & Skinner, 2021). The core assumption in line with the literature findings is that the company can provide data on CO₂ emissions only if it is able to measure it using an existing reliable standard. In other words, as prof. Kaplan says: „...when you can measure what you are speaking about, and express it in numbers, you know something about it. If you cannot measure it, you cannot improve it (Kaplan, 2009).

Given the focus of this paper is the Czech Republic, the main literature inspiration was work of researchers based in the management accounting department, faculty of finance and accounting, Prague University of Economics. The team has been focusing on ESG reporting for the past 15

year. The team's activity resulted in numerous conference papers and journal articles. Above all quantitative analysis on non-financial reporting for the Czech Republic starting with conference paper on large companies CSR reporting (Petera, Wagner, & Bouckova, Analysis of CSR Reporting Practices of the Largest Companies Domi-ciled in the Czech Republic, 2014) and followed with papers on increasing importance and perception related to sustainability by the Czech companies (Petera, Wagner, & Knorová, Perception and Interpretation of Sustainability among the Largest Corporations Established in the Czech Republic, 2016), to more recent works identifying determinants for disclosure (Petera, Wagner, Pakšiová, & Křehnáčová, 2019) to quantifying amounts of disclosed information, including environmental information. (Petera, Dečman, Remlein, & Rep, 2021). The assumption that existing environmental strategy with implemented environmental management system improves environmental reporting and environmental as well as economic performance in Czech and Slovak Republic was confirmed (Petera, Wagner, & Páksiová, The Influence of Environmental Strategy, Environmental Reporting and Environmental Management Control System on Environmental and Economic Performance, 2021). Another relevant conclusion for this work is that sustainability reporting depends on the globalisation level (Horvath, Putter, Dagiliene, Dimante, & Cezary, 2017). Interesting article on Polish banking sector research revealing legislative gaps in carbon accounting (Komarnicka & Komarnicki, 2022). Listed findings of the research on carbon reporting as well as ESG reports claim, there is still a long way to provide a high-quality report in a transparent format and form. The author of this paper investigated to what extent the Czech banks and insurance companies were providing CO₂ emissions disclosure in the past 2 years to bring light into the progress in this area.

3. Data and Methodology

Our sample consisted of 17 Czech Banks and insurance companies. Majority of the banks is foreign owned; 3 small banks are Czech owned and one medium size bank was disposed from the research /licence removed/. All 4 analysed insurance companies are foreign owned. The sample is sufficient for the evaluation of the current state of the carbon reporting in the Czech financial sector given the analysed sample represents more than 80% of the banking market share from the balance sheet value perspective (Česká bankovní asociace, 2022) resp. more than 70% from the insurance market contracts perspective (Vývoj pojištného trhu, 2022)

This analysis intends to manifest the current level of carbon reporting of the financial service sector in the Czech Republic. Quantitative and qualitative content analysis methods were used for this research. Quantitative analysis was used to document occurrences of carbon disclosure data in Czech or English language and within any publicly accessible forms /ESG or any nonfinancial reports, annual financial reports, web pages, press releases/. The search was done for the evidence of any sign of environmental consciousness declared, for Carbon emissions equivalent totals in tons for 2019 and 2020 /Scope 1-3 according to GHG protocol/ deriving from their operations in the Czech Republic and finally, for Carbon neutrality goal disclaimer of the company and Methodology used. 5 companies were interviewed to precise the data collected. Details of all non-coded information useful for any eventual future alternative research are to be available with the author. Inductive development procedure was used for finalizing the data categorization. It was followed by qualitative analysis as a method of examination of data material that would focus on interpretation rather than quantification (Kohlbacher, 2006) . The summarization is to be found in Table 1 in the next chapter.

4. Findings

Findings of this research give a picture of the discourse of the Czech environmental reporting in the financial sector in the past 2 years. As literature review suggested, foreign owned companies provide more often and in better quality ESG disclosures as well as large companies pay attention to ESG (Ali, Frynas, & Mahmood, 2017) (Horvath, Putter, Dagiliene, Dimante, & Cezary, 2017) (Peters, Dečman, Remlein, & Rep, 2021). Also, hand in hand with other empirical research, there are big gaps in the reporting (Alliance for Corporate Transparency, 2021), (EY, 2021).

Czech financial sector represented by the 17 entities in almost all cases mentions environmental consciousness or sustainability in some way and form. However, only 5 of them do report hard data on CO₂e emissions but only 1 discloses neutrality target for their Czech operations fully and 1 partially. One bank recalculates its emissions per customer, another one per employees. Companies in our sample in most cases refer its disclosure to formats like GRI, UN SDG goals or ISO standards, but methodology referred is very wide.

Table 1 Czech financial sector carbon reporting

Czech Financial sector carbon reporting	Total – for year 2020 /2019/
Total number analysed	17 (17)
Final number of companies analysed	16 (16)
Environmental consciousness declaration publicly in any form	14 (14)
• Web incl. foreign owner	13 (13)
• CSR report/ESG report/Non-financial report	5 (4)
GHG protocol provided by the Czech company	5
• Scope 1	5
• Scope 2	5
• Scope 3	3
Carbon neutrality goal set for Czech company level	2
Methodology referred	
• GRI	4
• SDG	3
• Others /ISO, UN.... /	5

Interviews enriched this research by more intensive detail for which however this paper has no space for. E.g., 3 banks representatives believed they are the leaders within the financial sector, and they actively promote environmental reporting through different associations like: Czech banking association, Sustainable Leaders Forum, Business leader's forum and other social platforms. They believe professional platforms are providing framework and best practices for promoting ESG reporting significantly. 3 interviewees confirmed ESG became a very important topic for the top management. None of the interviewees did know the details or did want to share details about non-financial report auditing.

5. Discussion and limitations

This research was mainly focused on qualitative data of CO₂ emissions disclosures of only 17 financial institutions in the CR. Even though the sample was sufficient for the financial sector, it does not answer a question about the state of the ESG reporting for the Czech Republic as such. During the interview with the representatives responsible for CSR, more interesting data was collected as far as CSRD and Czech consumer carbon consciousness, but the limits of this paper does not allow to get into details and future qualitative analysis would be enlarging the topic. Also, larger sample from other industries and public sector would enlighten the situation much more.

Furthermore, the same research might be repeated in the future for this sample to confirm the progress. Therefore, interesting future academic research could focus on CSRD readiness or/and investigate an approach to GHG Scope 3 including Carbon offsets and financing factor of the green governance with EU Taxonomy. Finally, an interesting aspect would be the corporate governance and impact on the organizational hierarchy and responsibilities as already suggested by previous research (Peters, Wagner, & Knorová, Perception and Interpretation of Sustainability among the Largest Corporations Established in the Czech Republic, 2016).

6. Conclusion

This paper documents the status quo of the Czech banks and insurance companies environmental reporting, namely carbon footprint hard data on Scope 1-3 of the GHG Protocol and company CO₂ neutrality goal set. Carbon accounting in the financial sector in Czech Republic is slowly catching up with the western Europe (Alliance for Corporate Transparency, 2021). Largest Czech banks and an insurance company made significant progress within the past 2 years mainly because their holding company provided them with governance and administrative support to provide ESG reporting, but also because legal and social pressures are increasing in the topics around sustainability. Hand in hand with that, industry standards for environmental reporting are slowly worked through and widespread. This study results complemented the knowledge gap on the progress in carbon disclosures of the Czech financial sector.

7. Acknowledgment

This paper is one of the research outputs of the project “Interaction and integration of strategic management accounting and sustainability accounting” supported by the Grant No. F1/46/2021 – Internal Grant Agency of the Prague University of Economics and Business.

8. References

- Agency, E. E. (2021, April 13). CO₂ emissions per capita. Retrieved from EEA greenhouse gases - data viewer: <https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer>
- Ali, W., Frynas, J. G., & Mahmood, Z. (2017). Determinants of CSR disclosure in developed and developing countries: A literature review. *Corporate Social Responsibility and Environmental Management*, pp. 273-294; <https://doi.org/10.1002/csr.1410>.
- Alliance for Corporate Transparency. (2021). Retrieved from 2020 Research Report: http://allianceforcorporatetransparency.org/assets/Research_Report_EUKI_2020.pdf
- Asci, F., & Lovell, H. (2011). As frames collide: making sense of carbon accounting. *Accounting, Auditing & Accountability Journal*, Vol. 24 Issue 8. ISSN: 0951-3574.
- Brauch, M. D., & Spittle, E. (August 2021). Carbon Accounting by Public and Private Financial Institutions: Can We. *Načteno z Columbia Law School*: www.scholarship.law.columbia.edu
- Česká bankovní asociace. (2022). Retrieved from Česká bankovní asociace: www.cbaonline.cz
- EU, C. o. (2021). A European Green Deal. Retrieved from Official web of the European Union: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
- EU, C. o. (2022, March 8). REPowerEU: Joint European action for more affordable, secure and sustainable energy. Retrieved from Press Corner EU commission: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_1511
- EY. (2021, June). Retrieved from Global Climate Risk Disclosure Barometer: https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/assurance/ey-if-the-climate-disclosures-are-improving-why-isnt-decarbonization-accelerating.pdf

- Faria, P. C., & Labutong, N. (2019). A description of four science-based corporate GHG target-setting methods. *Sustainability Accounting, Management and Policy Journal*, pp. Vol. 11 No. 3, pp. 591-612. <https://doi.org/10.1108/SAMPJ-03-2017-0031>.
- GHG Protocol Corporate Standard Revised. (2004, March). Retrieved from Greenhouse gas protocol: <https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf>
- Gibassier, D., Michelon, G., & Cartel, M. (2020, March 9). The future of carbon accounting research: "we have pissed mother nature off, big time". *Sustainability Accounting, Management and Policy Journal*, pp. Vol. 11 No. 3, pp. 477-485. <https://doi.org/10.1108/SAMPJ-02-2020-0028>.
- He, R., Luo, L., Shamsuddin, A., & Tang, Q. (2021, April 6). Corporate carbon accounting: a literature review of carbon accounting research from the Kyoto Protokol to the Paris Agreement. *Accounting Finance*, pp. Volume62, Issue1, 261-298. <https://doi.org/10.1111/acfi.12789>.
- Horvath, P., Putter, J. M., Dagiliene, L., Dimante, D., & Cezary, T. H. (2017, June). Status Quo and future development of sustainability reporting in Central and Eastern Europe. *Journal of East European Management Studies*, pp. 22(2):221-243. DOI:10.5771/0949-6181-2017-2-221.
- Jung, J., Herbohn, K., & Clarkson, P. (2018, May 28). Carbon Risk, Carbon Risk awareness and the Cost of Debt Financing. *Journal of Business Ethics*, pp. 1151-1171. <https://doi.org/10.1007/s10551-016-3207-6>.
- Kaplan, R. S. (2009). Handbook of Management Accounting Research. In K. Bates, Handbook of Management accounting Research (pp. 1253-1269). Emerald group publishing Ltd.
- Kohlbacher, F. (2006, February). The Use of Qualitative Content Analysis in Case Study. *Forum Qualitative Sozialforschung*, pp. Volume 7, No. 1, Art 21.
- Komarnicka, A., & Komarnicki, M. (2022, October 25). Challenges in the EU Banking Sector as Exemplified by Poland in View of Legislative Changes Related to Climate Crisis Prevention. *Energies*, pp. 15(3)(699):1-20 <https://doi.org/10.3390/en15030699>.
- Liesen, A., Figge, F., Hoepner, A., & Dennis, M. P. (2016, August 10). Climate change and asset prices: Are corporate carbon disclosure and performance priced appropriately? *Journal of Business Finance & Accounting*, pp. 35-62 <https://doi.org/10.1111/jbfa.12217>.
- Liesen, A., Hoepner, A. G., Patten, D. M., & Figge, F. (2015, September 21). Does stakeholder pressure influence corporate GHG emissions reporting? Empirical evidence from Europe. *Accounting, Auditing & Accountability Journal*, pp. ISSN: 0951-3574.
- Light, S. E., & Skinner, C. P. (2021). Banks and Climate Governance. *Columbia Law Review*, Vol. 6, No. 6.
- Martineau, R., & Lofontaine, J.-P. (2019, June). When carbon accounting systems make us forget nature: from commodification to refication. *Sustainability Accounting, Management and Policy Journal*, pp. 11(5) DOI:10.1108/SAMPJ-07-2018-0178.
- Partnership for Carbon Accounting Financials. (2022). Retrieved from PCAF: <https://carbonaccountingfinancials.com/>
- PCAF. (18. November 2020). The Global GHG Accounting and Reporting Standard for the Financial Industry. Načteno z Greenhouse Gas Protocol: <https://ghgprotocol.org/global-ghg-accounting-and-reporting-standard-financial-industry>
- Petera, P., & Wagner, J. (2015, June). Global Reporting Initiative (GRI) and its Reflections in the Literature. *European Financial and Accounting Journal*, pp. 13-32. DOI:10.18267/j.efaj.139.
- Petera, P., Dečman, N., Remlein, M., & Rep, A. (2021, May). Non-financial Reporting in Selected European Countries. *European Financial and Accounting Journal*, pp. 73-90. DOI:10.18559/978-83-8211-055-5/05.
- Petera, P., Wagner, J., & Bouckova, J. (2014). Analysis of CSR Reporting Practices of the Largest Companies Domiciled in the Czech Republic. *The International Scientific Conference INPROFORUM*, (pp. 21-27). České Budejovice.
- Petera, P., Wagner, J., & Knorová, K. (2016). Perception and Interpretation of Sustainability among the Largest Corporations Established in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, pp. 1053–1065; DOI: 10.11118/actaun201664031053.
- Petera, P., Wagner, J., & Pákšiová, R. (30. July 2021). The Influence of Environmental Strategy, Environmental Reporting and Environmental Management Control System on Environmental and Economic Performance. *Energies*, stránky 14(15), 4637; <https://doi.org/10.3390/en14154637>.

- Petera, P., Wagner, J., Pakšiová, R., & Křehnáčová, A. (2019, October 30). Sustainability Information in Annual Reports of Companies Domiciled in the Czech Republic and the Slovak Republic. *Engineering Economics*, pp. 30(4):483-495. DOI:10.5755/j01.ee.30.4.22481.
- Solomon, J. F., Solomon, A., Norton, S. D., & Joseph, N. L. (2011, October 25). Private climate change reporting: an emerging discourse of risk and Opportunity? *Accounting, Auditing & Accountability Journal*, pp. Vol. 24 No. 8, pp. 1119-1148 <https://doi.org/10.1108/09513571111184788>.
- Tarquinio, L. (2022, February 18). Assurance of nonfinancial information: A Comprehensive Literature Review. *Non-financial Disclosure and Integrated Reporting*, pp. 353-373.
- Task Force on Climate-related Financial Disclosures. (2022). Načteno z Task Force on Climate-related Financial Disclosures: <https://www.fsb-tcfd.org/>
- Vývoj pojištného trhu. (2022, leden 27). Retrieved from Statistiky dle metodiky ČPA: <https://www.cap.cz/images/statisticke-udaje/vyvoj-pojisteno-trhu/STAT-2021Q4-CAP-CS-2022-01-27-WEB.pdf>

CIRCULAR ECONOMY IN RELATION TO FINANCIAL DATA

Miroslava Vlčková

Faculty of Economics
University of South Bohemia
mvlckova02@ef.jcu.cz

DOI: 10-35011/IDIMT-2022-331

Keywords

Circular Economy, Financial Data, Mann-Whitney U test

Abstract

The circular economy is an essential topic of this time, and in the coming years, it will become an integral part of many businesses. The importance of the circular economy is based on minimising waste raw materials and maximising environmental protection. This paper aims to compare financial indicators for the companies that are affected by the circular economy and companies that are not affected by the circular economy. These indicators were divided into five groups, namely: the area of indebtedness, liquidity, profitability, the area of employment-related indicators and analysis of bankruptcy and solvency models. Significant statistical differences in the indicators of indebtedness, liquidity, and employment-related indicators were found. It was found that companies affected by the circular economy have higher indebtedness. Similarly, these companies have lower liquidity. For the personal cost per employee and average monthly wage, the indicators are higher for the companies that are not affected by the circular economy. The survey shows that it is probably due to more increased investment during the implementation of circular economy elements; the companies affected by the circular economy are more indebted and have higher liabilities, so liquidity is worse. Because of higher costs in depreciation, these companies have a lower profit on the employee.

1. Introduction

The circular economy is characterized by the fact that it is based on the creation of closed production systems where resources are reused, thus making it possible to generate more value over a longer period (Urbinati et al., 2017). Its basic objectives include minimizing the consumption of mainly scarce resources during the production cycle and the use of originally wasted raw materials again in the production process. Part of the circular economy also means the transition to new energy sources. The concept of circular economy is based on changing the current view of production and consumption "Take-Make-Dispose" and focusing more on long-term sustainability.

The process of the implementing elements of the circular economy nowadays seems to be a matter of course and, in a way, as simple reuse of individual resources. However, in the area of the circular economy, there are numerous obstacles that prevent companies from increasing their activity. These include, for example, various administrative processes, regulations, etc. The companies, which

refuse to participate in the circular economy system, perceive administrative demands, financing, investments and cost barriers as the most significant (Garcés-Ayerbe et al., 2019).

2. Literature review

The process of implementation elements of the circular economy nowadays seems to be a matter of course and, in a way, as a simple reuse of individual resources. However, the transition to a circular economy system is a complex process and requires cooperation both between individual internal centres and between businesses. On World Economic Forum was found that currently only 8.6% of the world's companies belongs to the circular economy (WEF, 2020). Such a low percentage is due not only to the complexity of the processes in the area of the circular economy but also to the significant cost-intensiveness of implementing elements of the circular economy. This is confirmed by e.g. Khan et al. (2020) who examine the behaviour of organizations and obstacles in the implementation of a circular system, specifically in the production and consumption of plastics. The study shows that most companies tend to engage in a circular system of production and consumables, but their efforts often fail due to obstacles such as excessively high costs and the convenience of the process in place.

The circular economy is also closely related to sustainability. Blum, Haupt & Bening (2020) say that in the European Union, in addition to material circulation, economic, environmental, and social aspects need to be analyzed in the implementation of circular economy elements. The main objective should therefore not be to build as many circular production systems as possible but rather to ensure economic sustainability while contributing to the sustainable development goals.

Vegter, van Hillegersberg & Olthaar (2020) point out that to measure actual performance in a circular business model, it is necessary to define what performance targets are pursued for all processes. With the decreasing availability of resources, while at the same time the growing demand for well-being from consumers, the development of new economic models capable of improving the efficiency and effectiveness of resource use is needed (Ghisellini, Ripa, & Ulgiati, 2018). The mathematical model for the prediction of future waste-related parameters is proposed by Smejkalová, et al. (2018). They deal with the area of waste management and its development and say that for waste management to work effectively, it is necessary to make a good forecast reflecting the analyzed time frame. When planning waste management, the production forecast and the structure of the waste material are very important. However, the currently available data do not have sufficient informative power due to the short time series and at the same time, there is poor data availability.

In addition to analyzing financial and performance indicators, the size of the companies also needs to be considered. For example, in the Czech Republic, small and medium-sized companies have an important position and are the most widespread group of companies. The attitude of these companies towards the circular economy is important in their participation in the sustainable development goals. Garcés-Ayerbe & et al. (2019) deals with the transition to a circular economy system for European SME's. In the article, the authors examine the practices of the circular economy and analyze in detail the approach of European companies. The involvement of companies in the circular economy system is a gradual process where individual measures must be implemented in companies gradually, from initial control measures to final preventive procedures.

Kuo et al. (2010) found a positive correlation with statistical significance in terms of the company's environmental costs, net income, and economic benefits of environmental protection. Franklin-Johnson, Figge & Cannig (2016) also deal with the development of new indicators for assessing the environmental impacts associated with the circular economy. They analyze a new performance metric, a lifetime indicator that measures the contribution to material retention based on the amount

of time a resource is reused. These performance indicators provide a tool that can be used at the management level to measure the impact of decisions on the durability of renewable materials. Janik & Ryszko (2019) analyze selected indicators and evaluate their role in decision-making processes. Their article presents a comprehensive analysis and comparison of the circular economy indicators available at the micro level.

Urbinati et al. (2020) examine and characterize practices to create and capture value in the circular models and emphasize the need for evidence and recommendations. They show principles that can support the application of circular economy management practices to manufacturing companies.

The Czech Republic, as a part of the circular economy in Europe, is also mentioned in articles that analyze that topic in the European Union. Individual countries are compared when participating in the system of the circular economy. This topic is discussed, for example by Marina & Parisa (2020), who compare the rate of transition of the 28 member states of the European Union to the circular economy. At the same time, it assesses the state of the circular economy in Europe. The main indicators here are the correlation between GDP and strategic elements, which the European Union has identified as obstacles for countries to move to a circular economy system. The analysis identifies strategies that can be considered effective in engaging in the circular economy, even those that have no significant impact on this process. Grdic, Nizic & Rudan (2020), on the other hand, adding that the transition to a circular economy can ensure economic growth and GDP growth even when the use of natural resources is reduced. Fitch-Roy, Benson, Monciardini (2019), on the other side, say that the circular economy cannot be applied to all EU countries due to the fact that some of the measures included in the European Union's package for the transition to a circular system must already have some basis.

3. Methodology

The aim of this paper is to analyze financial data of companies from the Czech Republic and their relationship to implementation of the elements of circular economy and in relation to financial analysis indicators. There were obtained data from 160 companies, while the information was collected by means of questionnaire surveys when a proportional sample of almost 13,000 companies was created to match the distribution in the Czech Republic (from all 14 regions of the Czech Republic). Then these data were linked to the data obtained from the balance sheets and profit and loss' account of individual companies. The companies were divided according to implementation of the elements of the circular economy for research purposes. Subsequently, the individual relationships between financial data and elements of the circular economy were analyzed. The evaluation uses data from 160 companies, for which data were obtained by questionnaire surveys and from balance sheet statements and profit and loss statements from the year 2019. The year 2019 was chosen because in the following years 2020 and 2021, there was a coronavirus crisis, and the data could be affected by this crisis. Of this number of 160 companies and based on the questionnaire survey, 76 companies have implemented the elements of the circular economy, and 84 companies do not have implemented elements of the circular economy.

For analysing, a statistical test Mann-Whitney U test, was used. This test is used to evaluate unpaired experiments when comparing two different samples. It was tested the hypothesis that two variables have the same probability distribution. At the same time, these variables may not correspond to Gaussian normal distribution; it is sufficient to assume that they are continuous. The test involves the calculation of a statistic whose distribution under the null hypothesis is known. The null hypothesis asserts that the medians of the two samples are identical (Freund, Wilson, Mohr, 2010; Budíková, Králová, Maroš, 2010)). Statistically, it is evaluated at a significance level of 0.05 where zero hypothesis $H_0: \mu_1 - \mu_2 = 0$ against alternative hypothesis $H_A: \mu_1 - \mu_2 \neq 0$.

U is then given by:

$$U_1 = R_1 - \frac{n_1(n_1+1)}{2}, \quad (1)$$

where n_1 is the sample size for sample 1, and R_1 is the sum of the ranks in sample 1. An equally valid formula for U is:

$$U_2 = R_2 - \frac{n_2(n_2+1)}{2} \quad (2)$$

The smaller value of U_1 and U_2 is the one used when consulting significance tables. The sum of the two values is given by:

$$U_1 + U_2 = R_1 - \frac{n_1(n_1+1)}{2} + R_2 - \frac{n_2(n_2+1)}{2} \quad (3)$$

Knowing that $R_1 + R_2 = \frac{N(N+1)}{2}$ and $N = n_1 + n_2$, and doing some algebra, we find that the sum is $U_1 + U_2 = n_1 n_2$.

4. Results and discussion

The main aim of this paper is to evaluate the relationship between the implementation of the elements of circular economy and the financial analysis indicators. Financial analysis indicators are analyzed for companies that have implemented elements of the circular economy and for companies that do not have implemented elements of the circular economy. The analysis will take place at five levels: analysis in the area of indebtedness, liquidity, profitability, in the area of employment-related indicators and analysis of bankruptcy and solvency models.

In the next part, 19 indicators were analyzed. In the area of indebtedness, total indebtedness, equity debt ratio, interest coverage, credit indebtedness and loan repayment period in years are analyzed. The Mann-Whitney U test was performed at a significance level of 0.05. The hypotheses $H_0 = x0.50 - y0.50 = 0$ were tested, where it is assumed that the financial indicators in these companies are the same (or remarkably similar) in both groups (Circular economy elements YES or NO) and the hypothesis $H_A = x0.50 > y0.50$, which assumes that the financial indicators in these companies are different. The results are shown in the next table.

Table 1: Mann-Whitney U test analysis of the indebtedness area in relation to the circular economy; Source: own research

Financial indicator	Circular economy NO	Circular economy YES	U	Z	P-value
Total indebtedness	6960	5920	2350	2.8753	0.0040
Equity debt ratio	6848	6032	2462	2.4926	0.0127
Interest coverage	5498	7382	2572	-2.1168	0.0343
Credit indebtedness	6486	6394	2824	1.2557	0.2092
Loan repayment period in years	6360	6520	2950	0.8252	0.4093

In this analysis, a statistically significant difference was found in the values of total indebtedness, equity debt ratio and interest coverage. If we have a look at the graphical representation, we find that the debt ratio is higher for companies that are affected by the circular economy. The higher indebtedness may be due to the fact that these companies have to invest in equipment at the initial stage of the implementation of the circular economy elements. The result for the loan repayment period indicator is also interesting, where there is no statistically significant difference between companies affected and not affected by the circular economy. But as figure 1 shows, the higher

repayment period of loans is for companies that are affected by the circular economy. This is because long-term investments require long-term loans. Indicators of total indebtedness and loan repayment periods are shown in the following figure.

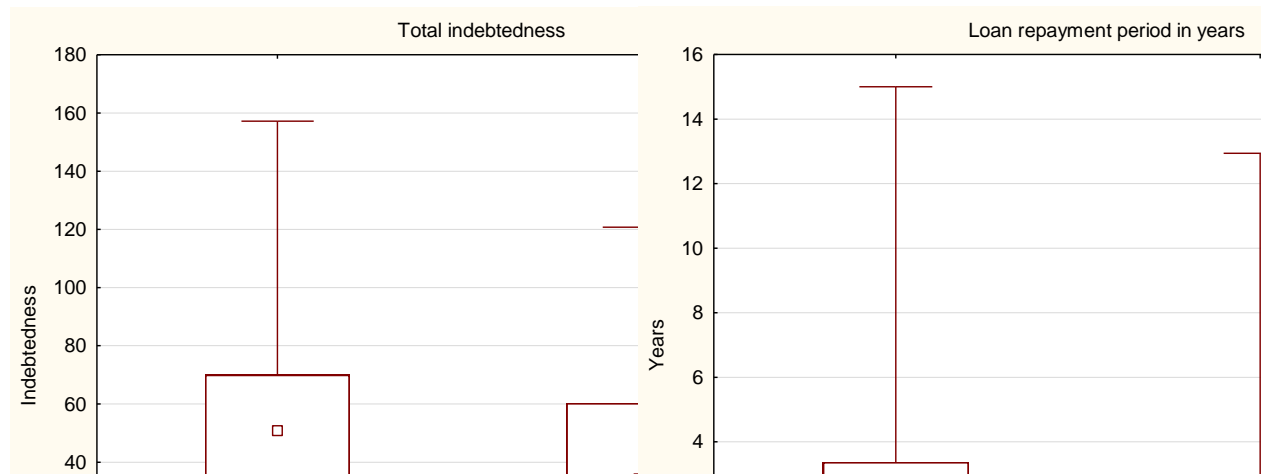


Figure 1: Mann-Whitney U test – total indebtedness (on the left) and loan repayment period (on the right);

Source: Own research

In the area of liquidity, current liquidity, quick liquidity, and cash liquidity are analyzed. The same hypothesis was established, in this case in relation to liquidity, and was tested again at a significance level of 0.05. The results are shown in the next table.

Table 2: Mann-Whitney U test analysis of the liquidity in relation to the circular economy; Source: Own research

Financial indicator	Circular economy NO	Circular economy YES	U	Z	P-value
Current liquidity	5496	7384	2570	-2.1236	0.0337
Quick liquidity	5638	7242	2712	-1.6384	0.1013
Cash liquidity	6142	6738	3168	0.0803	0.9360

This analysis shows a statistically significant difference only in the current liquidity ratio. This indicator informs us how many times a business is able to satisfy a creditor if it turns all current assets into cash at a given moment. The higher the value of this indicator is, the lower the risk of insolvency is. According to the graphic view, it is clear that current liquidity is lower for companies that are affected by the circular economy. This may be linked to the above-mentioned indebtedness and higher levels of liabilities, but it may also be related to the fact that companies that are affected by the circular economy better manage their stocks or the material consumed.

If it would be increased a level of significance to the level of 0.10, then there would be a statistically significant difference for the quick liquidity as well. This value is also higher in the companies that have not implemented elements of the circular economy.

In the area of profitability, return on equity, return on assets, return on long-term capital, and return on sales are analyzed. The same hypothesis was established at this part in relation to the profitability, and it was tested again at a significance level of 0.05.

Unfortunately, at this level of significance, no significant differences were found between companies that are affected and are not affected by the circular economy. Significant differences were not found even when the significance level moved to 0.10.

In the area of employment-related indicators, labour productivity, profit per employee, personnel costs per employee and average monthly wage are analyzed. The same hypothesis was established, in this case in relation to employment-related indicators, and it was tested again at a significance level of 0.05. The results are shown in the next table.

Table 3: Mann-Whitney U test analysis of the employment-related indicators in relation to the circular economy; Source: Own research

Financial indicator (in th. CZK / month)	Circular economy NO	Circular economy YES	U	Z	P-value
Labour productivity	3886	3864	1806	-0.5675	0.5704
Profit per employee	3670	4080	1590	-1.6475	0.0995
Personnel costs per employee	3602	4148	1522	-1.9875	0.0469
Average monthly wage	3990	4525	1644	-2.1605	0.0307

As can be seen from the table, there is a statistically significant difference for two indicators, namely the indicator of personnel costs per employee and the indicator of the average monthly wage. Both indicators are higher for businesses that are not affected by the circular economy. If the significance level is increased to 0.10, the profit per employee indicator would also become a statistically significant difference. This indicator is also higher for companies that are not affected by the circular economy. The higher profit per employee may be due to the fact that companies that are affected by the circular economy, especially in the initial years of the implementation of the circular economy system, have higher demands on investments, i.e., on fixed assets, and thus have higher costs in the form of depreciation, thus also lower profit. The selected indicators, namely profit per employee and average monthly wages, are shown in the following figure.

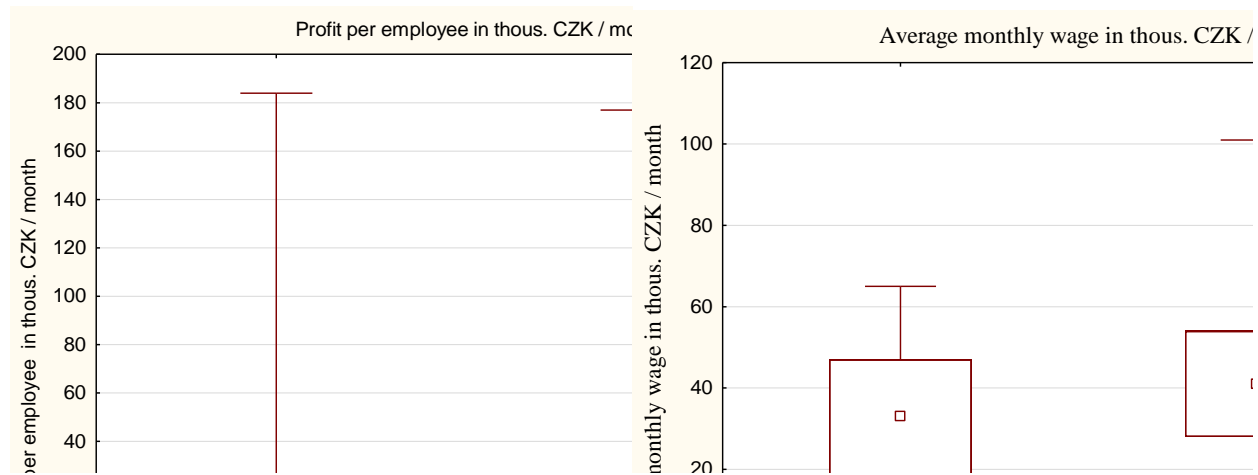


Figure 2: Mann-Whitney U test – profit per employee (on the left) and average monthly wage (on the right);

Source: Own research

And finally, in the area of bankruptcy and solvency models, Taffler's model, Index IN 99 and Quick test are analyzed. The same hypothesis was established and was tested again at a significance level of 0.05.

However, no statistically significant difference was found at this significance level. But when the significance level was shifted to a level 0.10, a statistically significant difference was found in the quick test indicator (with a p-value of 0.0694). According to the graphical view, companies that are affected by the circular economy have higher values in this test. The principle of the quick test is based on the calculation of four ratio indicators that relate to the area of the financial stability and the income situation of the company, and in simple terms, it can be said that the higher the values

the company achieves, the better it prospers. It can therefore be concluded that from a statistical point of view, companies that are affected by the circular economy are better-thriving companies.

Since the topic of the circular economy is also fundamental for future generations, many authors are engaged in the analysis of elements of the circular economy in relation to various indicators, such as financial indicators or economic indicators. Similarly, Scarpellini et al. (2021) have found that, from an economic point of view, the biggest obstacles to investing in the elements of the circular economy are uncertainty about the rate of return, the volume of investment and difficulties in accessing financing for small investors and companies.

Vlčková (2020) analyzed indicators in relation to individual elements of the circular economy, which are backup of plastic packaging, increasing the life of packaging; recycling and reuse of waste; and use of renewable resources. In the analysis of financial indicators and the recycling and reuse of waste element, a significant difference was found in the liability's indicator. When analysing the use of renewable resources element, a difference was found in the fixed assets indicator. In the analysis of the element of backup of plastic packaging, increasing the life of packaging, a significant difference was found in the owner's equity indicator, total assets, operating revenues, and operating costs indicators. All these indicators were lower for companies that have implemented the elements of the circular economy.

For further research, it is possible to recommend an analysis of enterprises affected by the circular economy in relation to financial indicators and in the division of enterprises into manufacturing enterprises, enterprises providing services, and commercial enterprises.

5. Conclusion

This paper primarily deals with the analysis of the relationship between the implementation of the elements of the circular economy and the financial indicators.

This aim was achieved by analyzing financial indicators in the area of indebtedness, liquidity, profitability, in the area of employment-related indicators and analysis of bankruptcy and solvency models. It was found that in the area of indebtedness, companies that are affected by the circular economy have a higher indebtedness, specifically for the indicators of total indebtedness, equity debt ratio, and interest coverage. In the area of liquidity, the statistically significant difference was found only in the current liquidity indicator, when this indicator was higher for companies that do not have implemented circular economy elements in place. For employment-related indicators, differences were found in two indicators, namely personnel costs per employee and average monthly wage. These are lower for businesses that are affected by the circular economy. No significant differences were found in profitability and bankruptcy and solvency models. Overall, it can be stated that, apparently, due to higher investments in the implementation of circular economy elements, companies affected by the circular economy are more indebted have higher liabilities, so liquidity is worse for these companies, and due to higher costs in the form of depreciation, these companies have a lower profit on the employee.

6. References

- Budíková, M., Králová, M., & Maroš, B. (2010). Guide to basic statistical methods. 1st ed. Praha: Grada Publishing.
- Blum, N. U., Haupt, M., & Bening, C. R. (2020). Why "Circular" doesn't always mean "Sustainable". *Resources, Conservation and Recycling*, 162. Scopus. <https://doi.org/10.1016/j.resconrec.2020.105042>.
- Fitch-Roy, O., Benson, D., & Monciardini, D. (2019). Going around in circles? Conceptual recycling, patching and policy layering in the EU Circular Economy Package. <https://ore.exeter.ac.uk/repository/handle/10871/38866>.

- Franklin-Johnson, E., Figge, F., & Canning, L. (2016). Resource Duration as a Managerial Indicator for Circular Economy Performance. *Academy of Management Proceedings*, 2016(1), 11617. <https://doi.org/10.5465/ambpp.2016.11617>.
- Freund, R. J., Wilson, W. J., & Mohr, D. L. (2010). *Statistical methods*. (3rd ed). Amsterdam: Elsevier.
- Garcés-Ayerbe, C., Rivera-Torres, P., Suárez-Perales, I., & Leyva-de la Hiz, D. I. (2019). Is It Possible to Change from a Linear to a Circular Economy? An Overview of Opportunities and Barriers for European Small and Medium-Sized Enterprise Companies. *International Journal of Environmental Research and Public Health*, 16(5), 851. <https://doi.org/10.3390/ijerph16050851>.
- Ghisellini, P., Ripa, M., & Ulgiati, S. (2018). Exploring environmental and economic costs and benefits of a circular economy approach to the construction and demolition sector. A literature review. *Journal of Cleaner Production*, 178, 618–643. <https://doi.org/10.1016/j.jclepro.2017.11.207>.
- Grdic, S. Z., Nizic, K. M., & Rudan, E. (2020). Circular Economy Concept in the Context of Economic Development in EU Countries. *Sustainability*, 12(7), 3060. <https://doi.org/10.3390/su12073060>.
- Janik, A., & Ryszko, A. (2019). Circular economy in companies: An analysis of selected indicators from a managerial perspective. *Multidisciplinary Aspects of Production Engineering*, 2(1), 523–535. <https://doi.org/10.2478/mape-2019-0053>.
- Khan, O., Daddi, T., Slabbinck, H., Kleinhans, K., Vazquez-Brust, D., & De Meester, S. (2020). Assessing the determinants of intentions and behaviors of organizations towards a circular economy for plastics. *Resources, Conservation and Recycling*, 163, 105069. <https://doi.org/10.1016/j.resconrec.2020.105069>.
- Kuo, L., Kevin Huang, S. and Jim Wu, Y. (2010), "Operational efficiency integrating the evaluation of environmental investment: the case of Japan", *Management Decision*, Vol. 48 No. 10, pp. 1596-1616. <https://doi.org/10.1108/00251741011090342>.
- Marino, A., & Pariso, P. (2020). Comparing European countries' performances in the transition towards the Circular Economy. *Science of The Total Environment*, 729, 138142. <https://doi.org/10.1016/j.scitotenv.2020.138142>.
- Scarpellini, S., Gimeno, J. Á., Portillo-Tarragona, P., & Llera-Sastresa, E. (2021). Financial Resources for the Investments in Renewable Self-Consumption in a Circular Economy Framework. *Sustainability*, 13(12), 6838. <https://doi.org/10.3390/su13126838>.
- Smejkalová, V., Šomplák, R., Nevrlý, V., Pavlas, M., 2018. Design and Decomposition of Waste Prognostic Model with Hierarchical Structures, *Mendel Journal series*, 2018 (1), 85-92.
- Vegter, D., van Hillegersberg, J., & Olthaar, M. (2020). Supply chains in circular business models: Processes and performance objectives. *Resources, Conservation and Recycling*, 162, 105046. <https://doi.org/10.1016/j.resconrec.2020.105046>.
- Urbinati, A., Chiaroni, D., & Chiesa, V. (2017). Towards a new taxonomy of circular economy business models. *Journal of Cleaner Production*, 168, 487–498. <https://doi.org/10.1016/j.jclepro.2017.09.047>.
- Urbinati, A., Rosa, P., Sassanelli, C., Chiaroni, D., & Terzi, S. (2020). Circular business models in the European manufacturing industry: A multiple case study analysis. *Journal of Cleaner Production*, 274, 122964. <https://doi.org/10.1016/j.jclepro.2020.122964>.
- Vlčková M. (2020). Analysis of the financial indicators in companies affected by the circular economy. *Inproforum 2020, Proceedings of the 14th International Scientific Conference INPROFORUM, Business Cycles – more than Economic Phenomena*, November 5 - 6, 2020, České Budějovice. Czech Republic, (pp. 64 -69).
- Walker, I. (2010). *Research Methods and Statistics*. 2010 ed. Houndmills, Basingstoke, Hampshire ; New York, NY: Palgrave.
- WEF. (2020). Platform for Accelerating the Circular Economy. Retrieved 11. April 2022 from WEF: <https://www.weforum.org/projects/circular-economy>.

ENVIRONMENTAL REPORTING OF MINING COMPANIES AS PART OF ENVIRONMENTAL POLICY

Ladislava Míková, Petra Rydvalová

Technical University of Liberec

ladislava.mikova@tul.cz, petra.rydvalova@tul.cz

DOI: 10-35011/IDIMT-2022-339

Keywords

Environmental policy, Environmental reporting, Environmental information, Mining company

Abstract

This article compares the environmental information mining companies publish on websites as part of their environmental policy. The article compares the disclosure of information by larger companies with smaller ones using different categories. The central aspect of this research was whether mining companies have an established environmental policy and what tools they use to report the information.

1. Introduction

The need to protect the environment and maintain suitable living conditions for future generations arose in the 1960s 20th century. Environmental disasters have reached such proportions that they have begun to threaten people's lives. Therefore, negotiations are underway on proposals on how to prevent these disasters and address the current global problems. At the moment, the basics of environmental policy are evolving.

Environmental policy is defined at the international level, at the level of localities (states), but above all for companies that significantly impact environmental pollution. Most companies are aware of their negative impact and therefore implement environmental policies in their strategies. Even though the company does not have an established environmental policy (exceptional cases), it is subject to the regulations of the State Environmental Policy of the Czech Republic, which means that it must comply with the relevant prohibitions.

A suitable example of such enterprises is the mining and quarrying sector (CZ-NACE 05-09). Mining activities take place here - black and brown coal (air emissions), landscape destruction and land use (quarries), mining waste management (surface dumps), groundwater contamination, and brownfields. Every year, more than 4,200 billion tonnes of mineral wealth are extracted from the country. That is enough material to build 4,200 Eiffel Towers (estimated to weigh about 10,000 tons). Therefore, the 10 majorities of global mining companies have agreed and united their initiative into the Global Mining Initiative, which aims to respond to growing public complaints and concerns. (Bice, 2016)

In general, a company is beneficial to society. However, it negatively affects its environment because, during its activities, the extraction of scarce and limited natural resources and the exchange of energy and material flows with the environment. In order to reduce the harmful impact on its surroundings, the company is implementing a system of so-called environmental policy. This

is a change in the overall intentions of the organization about its environmental profile officially expressed by senior management. Alternatively, here, the company publicly commits itself to a long-term transformation of the company so that there is no further damage to the environment on its part. As already mentioned, the company's transformation is mainly due to the top management, which is fully acquainted with environmental issues. Subsequently, information about the change in ecological thinking is passed on to individual employees, who are further motivated to participate in environmental protection within the company and their personal lives.

2. Theoretical basics of environmental policy

Every business has a positive or negative impact on the environment, which can lead to positive or negative externalities. Businesses should strive to keep their negative environmental impact to a minimum. The influence of the environment is determined by the nature and number of various substances and energy flows that the company exchanges with the environment. The environmental policy includes the business processes for which the company is responsible. The company is obliged to comply with legislation concerning environmental protection, but on its initiative, it can also include voluntary activities for this protection.

The principles of environmental policy are the essential elements that guide the direction of environmental policy. They are essential for formulating, implementing, and managing environmental policy while helping to make better use of the instruments of this policy and to comply with applicable legislation.

The basic principles of the environmental policy include:

- prevention - Prevention of endangering or damaging the environment by promptly implementing necessary measures.
- precaution - It is not always possible to answer questions about the origin and the subsequent solution of environmental problems. The given activity is prohibited if it is possible to fear possible negative influences reasonably.
- the polluter pays - The polluter is liable to the injured parties (i.e., liability for human or property damage) (Cordato, 2004).

3. Benefits of environmental policy for mining companies

The main benefit of environmental activities for companies and especially for the public is a healthy environment that maintains acceptable living conditions for future generations. The concept of sustainable development is the basis of environmental policy. "Sustainable development reflects a weakening of confidence in the ability of self-regulatory mechanisms of the natural and social world to ensure their further development (existence) in the conditions created by the development of human communities, and the associated idea of the need for managed development." This concept consists of three pillars - economic, environmental, and social - these are interdependent and reinforcing pillars (Maldonado, 2001).

If a company implements its environmental activities beyond the legislative framework, it is possible to characterize several positive benefits:

- Cost savings - waste management, reduction of labor costs, efficient consumption of all resources.
- Reduction of fines - fines exceed state-set limits (Leal, 2004).

- Entering new markets - easier access for companies that comply with environmental policy (Berthelot, 2004).
- Competitive advantage - better environmental image.
- Better communication with investors and the general public.
- Increasing the efficiency of business processes.

Martin Perry (2015) says that several mechanisms have been proposed that link environmental characteristics to market rewards, including in particular:

- Cost reduction - investments that reduce environmental impact by reducing resource consumption and emissions per unit of output while increasing production efficiency. This process is sometimes called ecoefficiency; it reduces the natural resources used in production, products, and services. (WBCSD, 1999).
- Increasing revenue - tackling environmental behavior can stimulate innovation and improve products and services that increase market share or create new demand.
- Better risk profile - a proactive approach to environmental issues reduces the possibility of confrontation with incidents that can lead to prosecution and loss of reputation. A proactive attitude also helps businesses ensure that they are in an advantageous position and quickly adapt to standards and legislative regulations changes.
- Improving reputation - in addition to positive customer feedback, companies can be seen as better for work, as opposed to companies that do not show or report their commitment to minimizing their environmental footprint. Demonstrating environmental responsibility can be a prerequisite for suppliers' involvement in the supply chain. (Epstein, 2008; Esty & Winston, 2009; Perry, 2015)

4. Methodology and data

Based on the research, a database of mining companies in the Czech Republic was created. Natural persons also engaged in mining have been excluded from this database. In 2021, there were 471 mining companies in the database. The companies were further subdivided according to size according to Commission Recommendation 2003/361 / EC of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises. The number of large enterprises predominated in the database (124 pieces), while it was impossible to find their size for 74 enterprises for further classification.

This research focused on studying websites and annual reports because managers decide how their information will be disclosed based on their own decisions. The reason for selecting the website for the study was that it usually contains the sustainability information itself. Of the original number of mining companies, only 35 companies were selected because they are the only ones with websites. The content analysis of the annual reports and websites for the year 2021 took the form of monitoring the sentences of environmental published items. The criteria that had to be published on the website were originally compiled - e.g., the GRI G3 guideline, including the mining sector supplement, SustainAbility.

During the analysis, it was found that the mining companies do not provide any of the above information. In the Czech Republic, mining companies report environmental information through the ISO standard 14001. The study showed that mining companies do not place too much emphasis on environmental reporting.

Therefore, the analysis was performed on 10 large and small foreign companies. Although these companies are more considerable than mining companies in the Czech Republic, they provide much more environmental information. Managers decide how much information should be published in the annual reports. The volumes and characteristics of published information indicate the importance that managers attach to environmental issues.

Because the study mainly had access to the website, the analysis was carried out here. Hackston and Milne (1996) sentences, graphs and tables, and other characteristics were calculated on the website. The analysis by Hackston and Milne (1996) focused on whether the sentences represent good or neutral environmental reports about mining companies. For example, a sentence dealing with the environmental policy was considered neutral. If the company published information about an environmental disaster (e.g., a leak of mine water saturated with uranium residues), it was classified as unfavorable. If the company reported on using new remediation technologies, this was classified as positive disclosure. In this way, 10 mining companies and their websites were analyzed.

5. Result of research

Research shows that large companies publish a large amount of environmental information. The results also show that large mining companies publish more information than small companies. This result was expected because large companies are under more significant pressure from stakeholders. These companies are trying to improve their public relations through environmental information see table 1.

The research also focused on the quality of published environmental information. The comparison proves that large and small mining companies publish environmental issues similarly. Not only is the same number of sentences published, but the same formulas are used.

The research results also show that large mining companies publish statistically significantly better environmental information than small companies. A detailed examination of the website will be the subject of further research.

Table 1: The mining companies' environmental annual report and website disclosures

The average number of sentences	Smaller co. by market cap.		Larger co. by market cap.	
	Mean	Std Dev	Mean	Std Dev
Number of sentences overall				
Environmental disclosure	54.257	63.493	194.879	215.775
Quality scores overall				
Environmental disclosures	88.667	89.010	255.000	285.320
By Good, Bad, and Neutral news from a company's perspective				
Environment - good news	8.250	11.511	17.333	16.439
Environment - bad news	2.325	2.828	11.667	12.388
Environment-neutral news	38.556	54.293	159.778	191.042
By disclosure medium (number of sentences)				
Environment - Annual report	37.875	39.812	114.129	136.873
Environment – Website	17.333	22.669	79.500	85.659

6. Conclusion

This research focused on the environmental policy of mining companies, which should include the provision of environmental information. As the research shows, mining companies in the Czech Republic do not pay enough attention to this issue. Therefore, the analysis was performed on 10 randomly selected foreign mining companies. From the information provided on the website, it can be concluded that the area of environmental information publishing among mining companies has reached a high level. It is not necessary to look for differences between reporting large and small companies because large and small companies report in a relatively uniform way. Further research will focus on formulating criteria and principles that mining companies in the Czech Republic should use for their environmental reporting. The data obtained from studying foreign companies will serve as a model.

7. References

- Berthelot, S., Coulmont, M. (2004). ISO 14000 - a Profitable Investment?. *CMA Management*, 78(7), 36-39. ISSN 1490-4225.
- Bice, S. (2016). *Responsible mining: key principles for industry integrity*. New York, ISBN 978-1-138-78827-5.
- Cordato, R. (2004). Toward an Austrian Theory of Environmental Economics. *The Quarterly Journal of Austrian Economics*, 7(1), 3-16. ISSN 1098-3708.
- Epstein, M. J. (2008). *Making sustainability work: best practices in managing and measuring corporate social, environmental and economic impacts*. Berrett-Koehler Publishers, ISBN 978-1576754863.
- Esty, D. C., Winston, A. S. (2009). *Green to gold: how smart companies use environmental strategy to innovate, create value, and build competitive advantage*. Hoboken, N.J.: Wiley, ISBN 978-0470393741.
- Giménez, L., Casadesús, G. M., Pasola J. V. (2003). Using environmental management systems to increase firms' competitiveness. *Corporate Social Responsibility and Environmental Management*, 10(2), 101-110. ISSN 15353958.
- Maldonado, M. (2000). The democratisation of sustainability: The search for a green democratic model. *Environmental Politics*, 9(4), 43-58. ISSN 0964-4016.
- Perry, M. (2015). *Environmental Policy for Business: A Manager's Guide to Smart Regulation*. 1. New York: Business Expert Press, ISBN 978-1-60649-670-1.
- WBCSD. 2000. *World Business Council for Sustainable Development: Striking the Balance*. London: Earthscan, ISBN 2-940240-45-0.

ANALYSIS OF THE RELATIONSHIP BETWEEN FINANCIAL INDICATORS AS A TOOL FOR OPTIMIZING FINANCIAL HEALTH OF BUSINESSES

Jarmila Horváthová

Faculty of Management and Business
University of Prešov in Prešov
jarmila.horvathova@unipo.sk

Martina Mokrišová

Faculty of Management and Business
University of Prešov in Prešov
martina.mokrisova@unipo.sk

Igor Petruška

Faculty of Management and Business
University of Prešov in Prešov
igor.petruska@unipo.sk

DOI: 10-35011/IDIMT-2022-345

Keywords

Business, Financial health, Indicator, Relationship, Return on sales, Total indebtedness

Abstract

Every business owner wishes to adequately evaluate the financial health of the business. From this point of view, it is important to find out whether the company is able to increase its profit and its value, and what financial health assessment tools it should use to ensure this growth. The aim of the paper is to analyze the relationship between the indicators Return on sales (ROS) and Total indebtedness (TI) in terms of improving the financial health of businesses. A threshold regression model was chosen to investigate the nonlinear relationship between ROS and TI. The paper used the values of financial ratios of 6,993 businesses active in the construction sector. Three models were applied, in particular models with one, two and three cut-off values. The best results were achieved using a model with one cut-off value. At the same time, a nonlinear dependence between TI and ROS in the form of an inverted U (V) was confirmed.

1. Introduction

The success of the business is reflected in its financial situation. Financial analysis evaluates company's financial situation and its development. Financial indicators evaluate individual aspects of the company's financial situation, so for a comprehensive assessment of company's financial situation, it is necessary to examine not only the achieved values of individual indicators, but also

the relationships between these indicators. These relationships between indicators can be investigated using pyramidal systems of indicators, factor analysis or mathematical and statistical models. The aim of the paper was therefore not only to assess the financial health of businesses but also to identify the relationship between the ROS and TI indicators using a threshold regression model. From the profitability indicators, the ROS indicator was chosen. This indicator is less used in empirical studies in the given area. However, our aim was to find out whether there is a relationship between ROS and debt.

Remainder of the paper is structured as follows: Section 2 lists methods of business financial health evaluation with a special emphasize on the examination of the relationship between debt and profitability by various authors. Section 3 describes the data, the analyzed sample of businesses, methods for removing outliers and threshold model. Section 4 lists the results of applied methods. Section 5 summarizes the essential conclusions and presents significant findings and future direction of the research.

2. Evaluation of financial health of businesses

The most common method of assessing a company's financial health is the method of technical analysis, which evaluates the business from an economic point of view on the basis of a detailed study and financial statements analysis (Fisher, 1992). According to many Slovak and foreign authors (Ittner et al., 2003; Dixon et al., 1990; Pavelková and Knápková, 2009; Synek et al., 2007; Petřík, 2009), the most common indicators for measuring the financial health of businesses are financial indicators. At present, the financial health of Slovak business is assessed using three basic methods (Kislingerová et al., 2011): assessment based on a set of indicators, usually from five areas of financial health assessment, namely liquidity, activity, capital structure, profitability and market value. These groups are independent of each other and form a parallel set of indicators. The second method is assessment based on a set of indicators that are arranged in pyramidal systems in which a key and highly synthetic indicator is at the top. One of the most up-to-date pyramidal models was developed in the Czech Republic. It is the INFA model, which represents a system of two opposing pyramids, the core of which is Return on assets (Neumaierová and Neumaier, 2002). The third method uses one aggregate indicator which synthesizes several variables multiplied by a coefficient into a single number. This number represents the value that predicts the company's development in the future.

2.1. Analysis of the relationships between indicators as a tool to increase the financial health of companies

Since financial indicators assess individual aspects of the company's financial situation, a comprehensive assessment of the company's financial situation could be obtained by examining systems of indicators, such as pyramidal systems of indicators. The basic principle of pyramidal systems is a gradual and increasingly detailed decomposition of the indicator, which identifies the relationships between indicators (Knápková et al., 2013). An important prerequisite for the creation of the pyramidal system is the ability of management to interpret financial and economic links between individual indicators. Using a pyramidal system of indicators, it is possible to quantify the intensity of the impact of individual partial indicators on the top indicator and explain the development of the company's financial situation between periods, evaluate differences between actual and planned value of the top indicator, compare the results of indicators with competitors (Sedláček, 2009). Most pyramidal models are based on Du Pont equations, which gradually decompose the top indicator (for example ROA or ROE) into partial indicators in a logical and

deductive way (Zalai et al., 2013). Okruhlica (2013) points to the need to use the pyramidal model of profitability indicators in business practice.

The relationship between individual indicators is also analyzed by factor analysis. In general, it examines the relationship between individual partial indicators and the top synthetic indicator. This analysis is primarily about finding the causes of changes in individual indicators that characterize the financial health of the company, in terms of profitability, liquidity and financial stability. In her study, Jenčová (2016) applied factor analysis of financial metrics of companies in the electrical engineering industry operating in Slovakia.

Another possibility to examine the relationships between indicators is the use of mathematical and statistical methods. From these methods, the threshold regression model was applied (further described in the chapter "Data and methodology"). Threshold regression models are used quite often. They classify the sample according to whether the value of the observed variable exceeds a certain threshold or not (Caner and Hansen, 2004). The threshold regression model was applied in the field of finance in the studies of Hansen (1999), Yeh et al. (2008), Qiu et al. (2010), Dang et al. (2012).

Cheng et al. (2010), Lin and Chang (2011) applied a threshold regression model to examine the impact of debt on business' value. Nemati et al. (2019) used this model to analyze the impact of capital structure on the profitability of companies in Southeast Asia.

Several authors have examined the relationship between debt and return on sales (ROS) in their studies. Rouf (2015) analyzed the relationship between capital structure and company performance. He used total indebtedness and other indicators as a measure of indebtedness, and measured performance using the indicators return on sales (ROS) and return on assets (ROA). Sikveland and Zhang (2020) analyzed the relationship between short-term and long-term debt and the ROS indicator.

3. Data and methodology

The database features all businesses active in the construction sector (SK NACE 41, 42, 43) in the year 2018 with the exception of micro-entities. The number of businesses was 6,993. The data were obtained from Slovak analytical agency CRIF – Slovak Credit Bureau, s.r.o. Construction sector is considered one of the key sectors of the Slovak economy. The share of this sector in GDP was 5.8% in 2020 (ŠÚSR, 2021b). In this year, the share of persons employed in construction in the total number of persons working in the Slovak economy reached 7.56% (ŠÚSR, 2021a). Construction is an important guide of the economic development; it is closely connected with the deviations and movements in the economy. It responds immediately to changes in the economic cycle and has a multiplier effect on the development of other sectors. This means that investment in construction launches the entire chain of demand for goods and services in the related sectors in the country's economy, which is particularly favorable in the areas of economic activity, employment and, retrospectively, the public budget balance (MDVSR, 2019).

A procedure based on probability density estimation was used to remove outliers. The histogram (Cícha, 2010) is considered the simplest estimate of density in one-dimensional space. In it, data is divided into non-overlapping intervals and the number of data in each interval is calculated. The kernel density estimate used in this paper also divides the range of measured data into intervals, thus generating interval center density estimates. However, unlike histograms, the intervals may overlap. It is possible to consider shifting the interval (window) over the entire range of measured data. The second difference is that the kernel density estimate not only calculates the number of observations in the window, but also assigns a weight to each point (a number from 0 to 1),

depending on the distance from the center of the window and calculates these weighted values. The function that determines these weights is called the kernel. Kernel density is independent of the selection of intervals (bins). It can therefore be considered a tool for exploratory data analysis. The area defined at the top by the density curve and at the bottom by the x-axis and the range of observations is equal to 1. The relationship for the calculation of the Kernel density estimate is as follows (1) (Scott, 1992):

$$f_{K(x)} = \frac{1}{nh} \sum_{i=1}^n K\left(\frac{x - x_i}{h}\right)$$

where K is Kernel function, x is the variable for which the kernel density estimate is to be made, x_i represents individual observations, n is the number of observations, h represents bandwidth.

Several functions can be used to represent the kernel density estimate: Biweight, Cosine, Epanechnikov, Gaussian Parzen, Rectangular, Triangular (Stata 2017a). We present the definition of the Epanechnikov kernel function, which was used in this paper (2) (Gyamerali et al., 2019):

$$K|u| = \begin{cases} \frac{3}{4}(1 - u^2) & \text{if } |u| \leq 1, \\ 0 & \text{otherwise,} \end{cases} \quad (2)$$

To determine the relationship between TI and ROS, we used nonlinear threshold models. These models were calculated based on cross-sectional data for the year 2018. The data do not have the properties of normal distribution and they do not suffer from heteroscedasticity. Threshold models can have multiple thresholds, the number of which can be determined by Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC) or Hannan-Quinn Information Criterion (HQIC).

Single threshold model can be written as (3) (Cheng et al., 2010; In Hansen, 1999):

$$v_{it} = \begin{cases} u_i + \beta_1 d_{it} + \varepsilon_{it} & \text{if } d_{it} \leq \gamma \\ u_i + \beta_2 d_{it} + \varepsilon_{it} & \text{if } d_{it} > \gamma \end{cases} \quad (3)$$

where v_{it} represents dependent variable (in our case return on sales), d_{it} (total indebtedness) is the explanatory variable and also the threshold variable, γ is the hypothesized specific threshold value, u_i is a given fixed effect used to express heterogeneity of different companies under different operations conditions, β_1 represents the threshold coefficient in the case that threshold value is lower than γ , β_2 represents the threshold coefficient in the case that threshold value is higher than γ , ε_t is IID error with mean 0 and variance σ^2 , i represents different businesses, t represents different periods.

Observations from the equations (3) are divided into two regions depending on whether the threshold variable d_{it} is lower or higher than the threshold (γ). The regions have different regression slopes β_1 and β_2 . Our aim is to use known data to estimate unknown parameters γ, β, σ^2 .

If there are two thresholds, the model can be modified as follows (4):

$$v_{it} = \begin{cases} u_i + \beta_1 d_{it} + \varepsilon_{it} & \text{if } d_{it} \leq \gamma_1 \\ u_i + \beta_2 d_{it} + \varepsilon_{it} & \text{if } \gamma_1 < d_{it} \leq \gamma_2 \\ u_i + \beta_3 d_{it} + \varepsilon_{it} & \text{if } \gamma_2 < d_{it} \end{cases} \quad (4)$$

where threshold value $\gamma_1 < \gamma_2$. Equations (4) can be extended to multiple thresholds model.

4. Results and discussion

The kernel density estimate was used to determine the distribution of the analyzed data and to identify outliers. In the first stage, businesses with the values of financial ratios ROS (-0.5; 2) and

TI (0; 2) were selected from the set of 6,993 businesses active in the construction sector. 6,426 businesses met this condition.

The number of businesses with a ROS value higher than 0.5 was very low. Therefore, the upper edge of the considered interval was reduced from 2 to 0.5. Similarly, in the case of TI, the number of enterprises with TI over 1.5 was low. Therefore, the upper edge of the considered interval was reduced from 2 to 1.5.

Using the kernel density estimate, businesses that acquired outlying ROS and IT indicators were identified. After these were excluded, the set included 6,165 businesses with the values of indicators in the intervals: ROS (-0.5; 0.5); TI (0; 1.5). The nature of the distribution of the examined values of financial ratios has not changed significantly.

To determine the dependence between the ROS and TI indicators, nonlinear threshold models were used. They were selected using the criteria listed in the chapter "Data and methodology". Total indebtedness was used as a threshold and mode variable. Models with one, two and three cut-off values were compared. Stata 15.1 software was used to calculate the model parameters.

Model with two cut-off values

The minimum BIC value (-2.708×10^4) was reached for two cut-off values (TI): 0.1132 and 0.1501. According to the BIC criterion, the most suitable candidate is a model with two cut-off values, the parameters of which are given in Table 1.

Table 1: Threshold model with two cut-off values; Source: authors

	ROS	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
Region1	TI	0.6465	0.1262	5.12	0.000	0.3990	0.8940
	Coef.	0.0361	0.0075	4.79	0.000	0.0213	0.0509
Region2	TI	1.4266	0.8213	1.74	0.082	-0.1831	3.0364
	Coef.	-0.139	0.1092	-1.27	0.203	-0.3531	0.0749
Region3	TI	-0.1367	0.0054	-25.9	0.000	-0.1474	-0.1260
	Coef.	0.1251	0.0040	31.24	0.000	0.1172	0.1329

For the first and second region the correlation coefficients are positive, i.e. with the growth of TI in these areas, the ROS also grows. If the TI exceeds the threshold value 0.1501, the correlation coefficient changes to negative (-0.1367). In the third region, therefore, with increasing debt, profitability decreases. However, this model has a regression coefficient that is not significant for the second model and confidence intervals for the regression coefficients have a non-zero intersection.

Model with three cut-off values

The minimum value of AIC (-2.715×10^4) and HQIC (-2.714×10^4) was reached for the three TI cut-off values: 0.1132; 0.1501 and 0.3527. Both of these criteria recommend us to use three cut-offs or 4 regions. Therefore, AIC and HQIC are outlined in table 2.

Table 2: Threshold model with three cut-off values; Source: authors

	ROS	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
Region1	TI	0.6465	0.1261	5.13	0.000	0.3992	0.8937
	Coef.	0.0361	0.0075	4.79	0.000	0.0213	0.0509
Region2	TI	1.4266	0.8205	1.74	0.082	-0.1816	3.0349
	Coef.	-0.1390	0.1091	-1.27	0.202	-0.3529	0.0748
Region3	TI	-0.2358	0.0638	-3.69	0.000	-0.3610	-0.1106
	Coef.	0.1409	0.0166	8.46	0.000	0.1083	0.1736
Region4	TI	-0.1518	0.007	-21.00	0.000	-0.1659	-0.1376
	Coef.	0.1382	0.0057	24.20	0.000	0.1270	0.1494

For regions 1 and 2 (where debt is lower), the regression coefficients are positive. If the indebtedness (TI) exceeds the value of 0.1501, the regression coefficients change to negative.

With the growth of TI above this limit, the ROS decreases. However, the model has the same shortcomings as the previous one with two cut-off values. The coefficient for region 2 is insignificant and the confidence intervals for the individual regions are not disjunct.

Model with one cut-off value

For the model with one cut-off value (TI = 0.150169) the values of the information criteria are as follows: $BIC = -2.710 \times 10^4$ a $HQIC = -2.711 \times 10^4$. The parameters of this simple model are given in Table 3.

Table 3: Threshold model with one cut-off value; Source: authors

	ROS	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
Region1	TI	0.2205	0.0878	2.51	0.012	0.0483	0.3927
	Coef.	0.0504	0.0068	7.37	0.000	0.0370	0.063921
Region2	TI	-0.1367	0.00546	-25.04	0.000	-0.1474	-0.1260
	Coef.	0.1251	0.0040	31.18	0.000	0.1172	0.1330

All coefficients are significant and there is no intersection of confidence intervals. We therefore selected this model to describe the relationship between ROS and TI in the construction sector of the Slovak Republic. With the growth of indebtedness, the ROS (a coefficient of 0.2205) also increases up to the value of the threshold variable TI of 0.1501. After exceeding this limit, the impact of TI growth on ROS is negative with a coefficient of -0.1367. Based on the results it can be stated that there is relationship between ROS and TI, but it is not strong, as indicated by the values of the coefficients. This fact can also be seen in Figure 1. Red line in this figure illustrates threshold value.

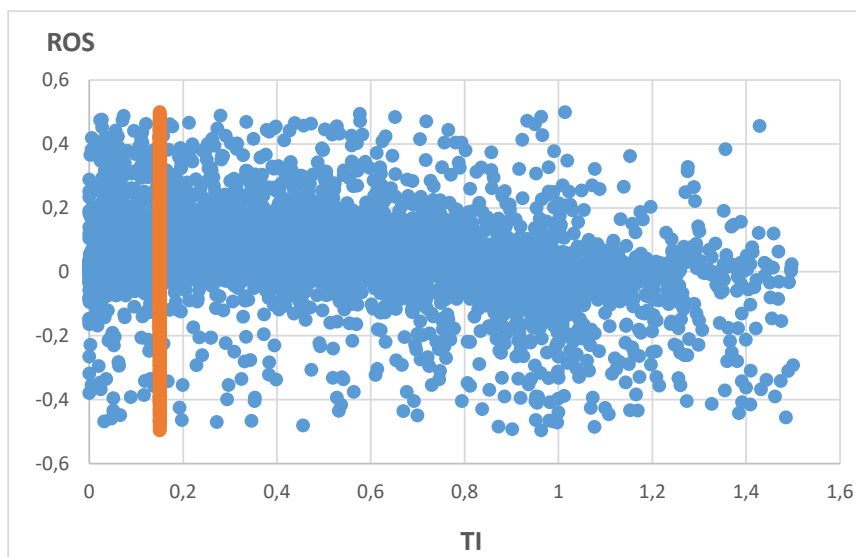


Figure 1 Scatter Plot (ROS, TI); Source: authors

5. Conclusion

The goal of each business is to maximize the profitability. Given the results of the analysis and with a view of achieving the set goal, the management may decide to change production, introduce new products or introduce new business activities which are more profitable. As a result, pyramidal models of the indicators help the businesses make many important decisions. The future of any business and its prosperity depends on a timely analysis and its correct interpretation.

This paper analyzed the relationship between return on sales and total indebtedness of businesses active in the construction industry in the Slovak Republic. Using the kernel density estimate, businesses with outliers were excluded from the data set. Nonlinear threshold models selected using the Bayesian (BIC), Akaike (AIC) and Hannan - Quinn information criteria (HQIC) were then used to determine the dependence. Total indebtedness was used as a threshold variable. Models with one, two and three cut-off values were compared. The model with one cut-off turned out to be the most suitable. Until the debt threshold (0.1501) is reached, the value of the ROS indicator increases. After overcoming this value of indebtedness, the profitability of sales decreases with the growth of TI. Based on it we found out that there is a nonlinear relationship between indebtedness and profitability of sales in the year 2018. Further research will focus on verifying this relationship over a longer period of time and examining the relationship between debt and other profitability indicators, such as return on assets and return on equity. It would be interesting to see how the debt payment period influences these relationships. In managerial practice, this knowledge would enable more precise decisions in the area of capital structure of companies. This finding is also very important in terms of optimizing the financial health of companies.

6. Acknowledgements

The research was prepared within the grant scheme VEGA 1/0741/20 - The application of variant methods in detecting symptoms of possible bankruptcy of Slovak businesses in order to ensure their sustainable development.

7. References

- Caner, M., & Hansen, B. E. (2004). Instrumental variable estimation of a threshold model. *Econometric theory* 20(5), 813-843. <https://doi.org/10.1017/S0266466604205011>.
- Cícha, M. (2010). Plně neparametrický odhad volatility a driftu úrokové sazby PRIBOR 3M. *Ekonomické listy* [online], 4, 20-27. [cit. 2021-11-20]. Available at: https://www.cesvsem.cz/data/data/ces-soubory/ekonomicke_listy/gf_Ekonomicke%20listy_04_2010.pdf.
- Dang, V. A., Kim, M., & Shin, Y. (2012). Asymmetric capital structure adjustments: New evidence from dynamic panel threshold models. *Journal of Empirical Finance* 19(4), 465-482. <https://doi.org/10.1016/j.jempfin.2012.04.004>.
- Dixon, J. R., Nanni, A. J., & Vollmann, J. E. (1990). *The New Performance Challenge: Measuring Operations for World-class Companies*. Dow Jones-Irwin. Homewood.
- Fisher, J. (1992). Use of Non-Financial Performance Measures. *Journal of Cost Management* 6(1), 1-8.
- Gyamerali, S. A., Ngare, P., & Ikpe, D. (2019). Crop yield probability density forecasting via quantile random forest and Epanechnikov Kernel function. [online]. [cit. 2021-11-05]. Available at: <http://ir.mkusu.ac.ke/handle/123456780/4393>.
- Hansen, B. E. (1999). Threshold effects in non-dynamic panels: Estimation, testing, and inference. *Journal of Econometrics* 93 (1999), 345-368. [https://doi.org/10.1016/S0304-4076\(99\)00025-1](https://doi.org/10.1016/S0304-4076(99)00025-1).
- Cheng, Y. S., Liu, Y. P., & Chien, C. Y. (2010). Capital Structure and Firm Value in China: A Panel Threshold Regression Analysis. *African Journal of Business Management*, 4, 2500-2507. [online]. [cit. 2021-11-07]. Available at: <http://www.academicjournals.org/AJBM>.
- Ittner, C., Larcker, D., & Randall, T. (2003). Performance implications of strategic performance measurement in financial services firms. *Accounting, Organizations & Society* 28(7/8), 715-741.
- Jenčová, S. (2016). Využitie pyramídovej sústavy ukazovateľov [The use of the pyramidal system of indicators]. *Finančné trhy* [Financial markets] 14(3). [online]. [cit. 2021-11-05]. Available at: <http://www.derivat.sk/index.php?PageID=2609>.
- Kislingerová, E. et al. (2011). *Nová ekonomika. Nové príležitosti?* [New economy. New opportunities?]. 1 vyd. Praha: C. H. Beck. ISBN 978-80-7400-403-2.
- Lin, F. L., & Chang, T. (2011). Does debt affect firm value in Taiwan? A panel threshold regression analysis. *Applied Economics* 43(1), 117-128. DOI: 10.1080/00036840802360310.
- Knápková, A., Pavelková, D., & Šteker, K. (2013). *Finanční analýza – Komplexní průvodce s příklady* [Financial Analysis - A comprehensive guide with examples]. 2. vyd. Praha : Grada Publishing. ISBN: 978-80-247-4456-8.
- MDVSR. (2019). *Ročenka slovenského stavebníctva 2019* [Yearbook of Slovak Construction 2019]. Ministry of Transport and Construction of the Slovak Republic.
- Nemati, A., Baghani, A., Emamverdi G., Darabi R., & Norollahzadeh, N. (2019). Effect of capital structure on profitability of companies in southeast Asia based on threshold panel regression approach. *Journal of Financial Economics* [online], 13(46), 73-94 [cit. 2021-11-04]. Available at: <https://www.sid.ir/en/Journal/ViewPaper.aspx?ID=682968>.
- Neumaierová, I., & Neumaier, I. (2002). *Výkonnost a tržní hodnota firmy* [Performance and market value of the company]. Praha: Grada Publishing. ISBN 80-247-0125-1.
- Okruhlica, F. (2013). Hodnotenie výkonnosti súkromnej a verejnej spoločnosti z pohľadu vlastníka [Evaluation of the performance of private and public companies from the perspective of the owner]. *Finančný manažér* [Financial manager] 13(3), 22-25.
- Pavelková, D., & Knápková, A. (2009). *Výkonnost podniku z pohľadu finančního manažera* [The performance of the company from the perspective of the financial manager]. 2. vyd. Praha: LINDE. ISBN 978-80-86131-85-6.
- Petřík, T. (2009). *Ekonomické a finanční řízení firmy* [Economic and financial management of the company]. Praha: Grada Publishing. ISBN 978-80-247-3024-0.

- Qiu, T., Zheng, B., & Chen, G. (2010). Financial networks with static and dynamic thresholds. *New Journal of Physics* 12(4). DOI: 10.1088/1367-2630/12/4/043057.
- Rouf, Md. A. (2015). Capital Structure and Firm Performance of Listed Non-Financial Companies in Bangladesh. *The International Journal of Applied Economics and Finance* 9(1), 25-32. DOI: 10.3923/ijaef.2015.25.32.
- Scott, D. W. (1992). *Multivariate Density Estimation: Theory, Practice, and Visualization*. New York: Wiley. ISBN 04-715-4770-0.
- Sedláček, J. (2009). *Finanční analýza podniku [Financial analysis of the company]*. Brno: Computer press, a. s. ISBN 978-80-251-1830-6.
- Sikveland, M., & Zhang, D. (2020). Determinants of capital structure in the Norwegian salmon aquaculture industry. *Marine Policy* 119(4), 104061. <https://doi.org/10.1016/j.marpol.2020.104061>.
- STATA (2017a). Univariate kernel density estimation [online]. [cit. 2021-11-20]. Available at: <https://www.stata.com/manuals13/rkdensity.pdf>.
- Synek, M. et al. (2007). *Manažerská ekonomika [Managerial economics]*. 4. aktualizované a rozšířené vydání. Praha: Grada Publishing. ISBN 978-80-247-1992-4.
- ŠÚSR (2021a). DATAcube – stavebníctvo [DATAcube - Construction] [online]. Bratislava: Statistical Office of the Slovak Republic [cit. 2022-02-14]. Available at: <http://datacube.statistics.sk/>.
- ŠÚSR (2021b). *Ročenka stavebníctva SR 2021 [Yearbook of Construction 2015]*. Statistical Office of the Slovak Republic.
- Yeh, M. L., Chu, H. P., Sher, P. J., & Chiu, Y. C. (2008). R&D intensity, firm performance and the identification of the threshold: fresh evidence from the panel threshold regression model. *Applied Economics* 42(3), 389-401. <https://doi.org/10.1080/00036840701604487>.
- Zalai, K. et al. (2013). *Finančno-ekonomická analýza podniku [Financial and economic analysis of the company]*. Bratislava: Sprint 2 s.r.o. ISBN 978-80-89393-80-0.

SMART TECHNOLOGIES FOR A SUSTAINABLE GREEN WORLD

SMART TECHNOLOGY AND CIRCULAR ECONOMY FOR A GREENER WORLD AND RESILIENT SOCIETY

Erwin Schoitsch

Center for Digital Safety & Security
Austrian Institute of Technology, Vienna
erwin.schoitsch@ait.ac.at

DOI: 10-35011/IDIMT-2022-357

Keywords

Circular Economy, Smart Systems, Systems-of-Systems, Machine Ethics, Society 5.0, Artificial Intelligence, Trustworthiness, Standardization, Digitalization, Green Cities, Green Deal, UN Sustainable Development Goals, Resilient Society

Abstract

Smart technologies are not only drivers of economic and societal disruptive changes – they are a chance to shape our future in a beneficial way as enablers of a sustainable, “green” world. They are a means to support the implementation of the 17 UN SDGs (Sustainable Development Goals) and the European “Green Deal”. The current crisis (climate change, Ukraine war, just to mention a few causes) has shown that our society and economy are not resilient against such critical changes. One of the approaches is to invest much more in circular economy and sustainable modes of production, transport and living, to reduce dangerous dependencies in all industrial and social areas. On the one hand, a severe economic crisis with shortage of essential resources for people worldwide bears risks of social instability and war, on the other hand, mitigation by smart technologies and high automation including autonomous systems bears a considerable risk to democracy, human rights and self-determination as well. European policy has reacted to the challenges of climate change and environmental footprint reduction particularly in context of production, transport, farming and large urban agglomerations – smartness (intelligence) is not only addressing well-being, assisted living and comfort of citizens (keyword “Society 5.0”), but even more sustainability goals in the long term (“Green and Circular Cities”).

1. Introduction – Smart Systems Technology for Green and Circular Economy

Smart (intelligent) systems and technologies are shaping our society and economy, causing disruptive changes. They are not only drivers of innovation and economy, but a chance to shape our future in a beneficial way as enabler of a sustainable Society 5.0 (Japanese Government, 2017, 2018; Hinkelmann, 2022). But if evolving the wrong way around, they may become a considerable threat to human rights, freedom, human independence and democracy. By putting together data, information and control/surveillance functions, and (mis)using them may result in a critical “Big Brother” impact.

The current situation already demonstrates that our society and economy on a global basis are not resilient against critical changes. We have exploited our natural resources in a ruthless manner often just for short term profits and benefits of a few. This situation is encompassed by an

enormous progress in technology, particularly in electronic-based software and systems, including “smart materials”. Particular focus is on the evolutionary development towards integrated large and complex system-of-systems cluster applications, e.g., Smart Cities, Smart Farming, holistic production and mobility solutions (e.g., beyond autonomous vehicles towards optimized shared multi-modal mobility and logistics solutions as a service) overcoming the boundaries of single isolated “systems of interest” (Schoitsch, 2020). The main questions are:

- how to develop intelligent, interconnected cyber-physical systems of systems, the underlying infrastructure (IoT, smart wireless connectivity, AI ecosystem), so that we can guarantee trustworthiness and high acceptance by the citizens,
- how can digital economy systems support a resilient, sustainable and ethically aligned, human-centered society,
- how can we, the people, manage the disruptive changes to be expected, preserving our freedom and rights.

In a digitalized world, safety and security are well established properties, facilitated by standards, qualification/verification techniques and methods. Highly automated systems are challenging beyond the well-established techniques and methods – they have to react in a reasonable manner on unpredictable situations and environments, to take autonomous decisions based on high-level and (even) ethical principles, situation awareness, perception, scene understanding, Artificial Intelligence, Big data, IoT - these are just a few key words.

Even the attacks on human rights, freedom and independence are now much “smarter”, and most of us are often not aware of the degree of surveillance and control, even in our democracies in the so-called “Western World”.

This will impact considerably our lives and lifestyle. Current crisis like Covid-19 lock-downs or the Ukraine war have demonstrated our economic vulnerability because of the dependency on worldwide functioning supply chains, and loss of sufficient access to critical resources (energy, critical materials and components) could lead to social imbalance and instability.

But there are some ideas for mitigation: The Japanese concept of “Society 5.0” is targeted at

"A human-centered society that balances economic advancement with the resolution of social problems by a system that highly integrates cyberspace and physical space."

This is a high-level target for the benefit of people in an advanced economy and society to resolve the challenge of social balance and stability if properly implemented but may not be sufficient if just focused on technology. It must be combined with the goals of a resilient economy as defined by the European Green Deal (European Commission, 2019) and the UN sustainable Development Goals (United Nations, 2015), and the “human centered” aspect has to be supported by the legal (constitutional) environment.

As examples like the movement of “Resilient Cities” (ERCIM, 2021) and “Sustainable Growth” show, smart technologies are a chance to overcome current waste of resources, recycling and reuse sustainable production not only in industry but also in agriculture (smart farming, in large cities even “vertical farming” making large population agglomerates less vulnerable), mobility, work spaces and living spaces (“smart buildings”, “smart homes”). “Business resilience” is also a key objective.

2. The UN Sustainability Goals

On a historic UN summit September 2015, the United Nations General Assembly set the “2030 Agenda for Sustainable Development”, which came into force on 1 January 2016. 193 member states approved the 17 Sustainable Development Goals (SDGs) (United Nations, 2015). This is a commitment for the next fifteen years, to fight hunger, disease, poverty, inequality, and climate change which are real problems that affect millions of people every day, including goals towards a better, sustainable, fair society (social), economy and environment.

This requires a global effort, cooperation, and an understanding that everyone can play a part in moving us forward. These “Global Goals” are a collection of interconnected goals with hundreds of targets and measurement indicators geared toward a date of 2030. The goals are providing a path – what some people refer to as a “Pathway for Humanity” — for any business to harness their power by directing their efforts toward specific global objectives (more details <https://sdgs.un.org/goals>).

The goals themselves to be simple, but powerful, ranging from ending poverty to building sustainable cities. Technologies are key to realize the most important goals for a still growing world population under pressures like resource exploitation and climate change. An overview is provided in Figure 1. The Global Goals are:

SDG 1: No Poverty	SDG 2: Zero Hunger
SDG 3: Good Health and Well-being	SDG 4: Quality Education
SDG 5: Gender Equality	SDG 6: Clean Water and Sanitation
SDG 7: Affordable and Clean Energy	SDG 8: Decent Work and Economic Growth
SDG 9: Industry, Innovation & Infrastructure	SDG 10: Reduced Inequalities
SDG 11: Sustainable Cities and Communities	SDG 12: Responsible Consumption & Production
SDG 13: Climate Action	SDG 14: Life Below Water
SDG 15: Life on Land	SDG 16: Peace, Justice and Strong Institutions
SDG 17: Partnerships for the Goals	



Figure 1: The UN 17 Sustainable Development Goals (“Global Goals”)(Source: <http://greencities.eu/about>)

To monitor and track progress in achieving results towards the SDGs (Sustainable Development Goals), the UN has created a global initiative “Sustainable Development Solutions Network” (European SDSN, 2020). The SDSN methodology (sound metrics, statistical methods, identification of gaps etc.) was audited by the European JRC (Joint Research Center) in July 2019 (European Commission, 2019), the results of which are available as a report. Related regional reports are e.g., the 2020 Europe Sustainable Development Report (ESDR, 2020) including SDG Index and Dashboards, issued by the SDSN and Bertelsmann Foundation.

3. The European Green Deal

The European Commission (EC) has particularly addressed the challenge of Climate Change and Climate Action. In „COM (2019) 640 final“, a communication of the EC to the European institutions (European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions) on “The European Green Deal”, the declared goal is a Europe “Striving to be the first climate-neutral continent” (European Commission, 2019-12-11). It is an ambitious commitment to future generations, identifying

“Climate change and environmental degradation as an existential threat to Europe and the world”.

To overcome these challenges, the European Green Deal will transform the EU into a modern, resource-efficient and competitive economy, ensuring:

- no net emissions of greenhouse gases by 2050
- economic growth decoupled from resource use
- no person and no place left behind

The European Green Deal has an action plan (European Green Deal, 2019) to

- boost the efficient use of resources by moving to a clean, circular economy
- restore biodiversity and cut pollution

The plan outlines investments needed and financing tools available. It explains how to ensure a just and inclusive transition. The EU aims to be climate neutral in 2050. Reaching this target will require action by all sectors of our economy, including

- investing in environmentally friendly technologies,
- supporting industry to innovate,
- rolling out cleaner, cheaper and healthier forms of private and public transport,
- decarbonising the energy sector,
- ensuring buildings are more energy efficient,
- working with international partners to improve global environmental standards,

The EU will also provide financial support and technical assistance to help those that are most affected by the move towards the green economy. This is called the “Just Transition Mechanism”. It will help mobilize at least €100 billion over the period 2021-2027 in the most affected regions. A most important part of this huge effort is dedicated to research towards “clean green technologies” to be developed and implemented throughout Europe, converting economy and society.

4. European Digitization and Standardization towards “Green and Sustainable”

EC Growth, the DG (Directorate General) for Internal Market, Industry, Entrepreneurship and SMEs, considers digital transformation as a major goal of European industry and society, because it is a key element for European growth. Europe can build on its strength in traditional sectors and can take up the potential and challenges of advanced digital technologies. Technologies considered in this context are IoT, big data, autonomous systems, advanced manufacturing, robotics, 3D printing, blockchain technologies and artificial intelligence (European Commission, 2018).

In “My agenda for Europe” of Ursula von der Leyen, the President of the European Commission, is one chapter dedicated to “A Europe fit for the digital age” (Von der Leyen, 2019). It focuses on AI, IoT, 5G, and ethical and human implications of these technologies, empowering people through education and skills, and on protecting ourselves with respect to the risks of these technologies.

Research is a key element to drive digitalization forward. On European level, organizations like AIOTI (AIOTI, 2022), the Alliance for Internet of Things Innovation, which takes care of the IoT aspects in 13 Working Groups, or the industrial associations INSIDE (former: ARTEMIS Advanced Research and Technology on Embedded Intelligent Systems), EPoSS (European Technology Platform for Smart systems Integration) and AENEAS (Association for European Nano-Electronics Activities), which are the private partners in the ECSEL, now KDT, Joint Undertaking, a European PPP (industry-oriented Public-Private Partnership) within Horizon Programmes (EPoSS et al., 2022).

Additionally, DG Growth delivers an annual report on standardization, e.g. the “Rolling Plan on ICT Standardization”, a key pillar in Digitalization, and started a Joint Initiative on Standardization (JIS) http://ec.europa.eu/growth/single-market/europeanstandards/notification-system_en. The same is done by the international standardization organizations ISO and IEC, and their Joint Technical Committee JTC1 (Information Technology), which cover all topics of “Joint interest”, particularly IoT (SC41), AI (SC42), Security (SC27) and Software and Systems engineering (SC7).

CEN/CENELEC has recently published a “Strategy 2030”, as a “Journey towards the UN Sustainable Development Goals (SDGs)” (CEN-CENELEC, 2022). The CEN/CLC strategy has the objective to raise awareness towards CEN/CLC contributions to the SDGs and incite stakeholders to use/consider or recommend CEN and CENELEC work for the implementation of SDG (SDG Mapping, Figure 2).

CEN/CENELEC take actions, e.g., for standards for the climate and signed the London Declaration in 2021 (SDG #13). A Group was founded for eco-design, and in JTC21 a NWIP (New Work Item) was started for “Green and sustainable AI”, considering reduced resource usage directly (electric power requirements) or indirectly (e.g., cooling water for computing facilities). Another example is the commitment to “Gender-responsive Standards” (UNECE declaration in 2019, SDG #5).

Mapping of CEN/CENELEC Standardization activities to SDG (“Strategy 2030”)

(Source: [CEN/CLC Webinar] “Journey towards the UN SDGs”)

Positioning to the five “P”s:

- Partnership (#17)
- Peace (#16)
- People (#1, #2, #3, #4, #5)
- Planet (#6, #12, #13, #14, #15)

- Prosperity (#7, #8, #9, #10, #11)

CEN/CENELEC Mapping Exercise:

- 1195 Standards
- ISO/IEC parallel work embedded
- Mapping tool for download

A similar approach in ISO and IEC:

Looking at a standards website, you will find the SDGs which are affected

Example: ISO TS 5083, Automated Driving Systems: “This Standard contributes to the following SDGs: 4, 7, 8, 9, 11, 13, 15”. <https://www.iso.org/standard/81920.html>



Figure 2: CEN/CENELEC Standards Mapping to topics and “5 P’s” (source: [CEN/CENELEC Webinar])

5. The European Green (Sustainable, Resilient, Circular) Cities Movement

Smart city technologies have been proliferating at a rapid pace for some years now, and the divide between the natural and digital worlds has lessened considerably (ERCIM, 2021, page 4-35). Multiple sensing endpoints located in our environment, offices, homes, devices, and even our body, produce continuous streams of sensor data. The concept of circular economy has entered the mainstream too, and many communities and businesses adopt novel approaches based on circularity. Smartness (intelligence) must address not only the immediate goals of human wellbeing, assisted living and comfort but also, perhaps even more importantly, long-term sustainability, as defined by the 17 UN Sustainable Development Goals (Figure 1) (United Nations, 2015). Relevant Goals are 11 and 13, but also 3, 4, 6, 7, 9, 12 and 17.

“European Green Cities” is a non-profit organization, founded in 1988, that strive to help alleviate the climate crisis, by developing CO₂-neutral cities and neighborhoods across Europe (European Green Cities, 1988). The mission is to contribute to the development of green cities and buildings in a sustainable Europe, by supporting projects of municipalities and citizen-organizations to develop innovative projects within energy transition and mobility, facilitate stakeholder processes, carry out analysis, implementation of best practice, training in sustainable urban development and

dissemination. For details see also (Schoitsch, 2021). Key activities in supporting cities in achieving progress towards the “Green Deal” and “Sustainable development” cover:

- SDGs and holistic urban development, targeting the UN 17 Sustainable Development Goals by developing a baseline, a long-term plan and creating synergies through interdisciplinary knowledge
- Mobility and inclusive environments for all users, especially children, women, elderly people and people with special needs, supporting the green transition towards a more CO₂-neutral mobility system.
- Smart buildings and making buildings more energy efficient (supporting projects)
- Increasing communication and stakeholder engagement (workshops, processes, interdisciplinary understanding, newsletters, web etc.)
- Cooperation in project development, fundraising (EU funding), project management, EU policies and agendas

To ensure knowledge sharing across Europe, the organization also manages the non-profit European Green Cities Network. The network consists of municipalities, social housing organizations, institutions, companies and universities from more than 19 countries. Concrete examples and current projects can be found at <http://greencities.eu/projects>.

6. Machine Ethics - Ethics Guidelines

The impending highly automated and autonomous systems enabled by artificial intelligence (AI) bring with them new challenges and risks. Placing too much trust in, or misusing, machines that make decisions is risky, and the legalities are complex in terms of liability and responsibility. Autonomous systems can be grouped into three broad categories: technical systems that make decisions in “no win” hazardous situations (vehicles in traffic, collaborating robots); decision support systems in governance applications (administration, government, court, staff acquisition, etc.), which may lead to unfair decisions for humans and society; and systems that are open to deliberate misuse by providing information that can’t be proven to be true or fake, potentially influencing elections, public opinion or legal processes to an extent unknown before (ERCIM, 2020, page 4-11).

Of course, there have long been risks associated with technology, with the potential for misinformation, failing algorithms and deliberate deception, but until recently the methodology at least allowed analysis and assessment of the predictable and deterministic algorithms behind the technology. We are now facing a completely different challenge – the age of highly automated and autonomous systems, artificial intelligence (AI) and decision making, whereby human decisions are made by machines through methods such as deep (machine) learning, which are neither “explainable”, nor may necessarily be based on fair, unbiased training sets.

Public acceptance of highly automated and autonomous systems relies on trust in these systems. This is not just a technical issue but also an ethical one, with technology having “big brother” potential and other possible problems as foreseen in science fiction, e.g., Isaac Asimov’s “Three Laws of Robotics”. Asimov’s laws seem reasonable and complete, but although they had to be complemented by an overarching “Zeroth law” (“A robot may not, through inaction, allow humanity to come to harm”), it has been demonstrated (even by Asimov himself) that realistic situations may result in unresolvable conflicts for a robot just because of adhering to this law.

AI technology is being implemented in automated driving, collaborative robots in the workspace, assistive robotic systems, highly automated production, and in management and decision systems in the medical and public service areas, the military, and many other fields. The EC, the European Parliament, the UN, many informatics and computer associations (Informatics Europe, 2018), standardisation groups, the German Ethics Commission for Automated Driving (Federal Ministry, 2017), NGOs, and others, have created guidelines or even certificates for trustworthiness of highly automated systems, AI-systems, ethically aligned design. A new science of “robot psychology” has evolved, that studies the interrelationship of human-robot collaboration and human wellbeing.

One initiative attempting to cover the principles for system designers and developers is the IEEE Global Initiative for Ethical Considerations in Artificial Intelligence and Autonomous Systems (AI/AS) (April 2016, with a document 2019) (IEEE, 2019). It not only identifies and recommends ideas for standards focused on prioritizing ethical considerations in AI/AS (i.e., machine/computer decision making), but also proposes a certificate for “ethically aligned design”.

The City of Vienna was the first city worldwide that earned the IEEE CertifAIEd AI Ethics (AIE) Certification Mark (<https://www.businesswire.com/news/home/20211115005200/en/City-of-Vienna-Earns-IEEE-AI-Ethics-Certification-Mark-Reinforcing-Commitment-to-Digital-Humanism-Strategy>), Nov 15, 2021. Many standardization groups, the EC HLEG group document (European Commission, 2019b), and the German Ethics Commission on Automated and Connected Driving (Federal Ministry, 2017), provide a set of recommendations for AI systems, placing human rights, independence and wellbeing in the centre, independent of economic or demographic attributes, such as age and race. The most recent international contribution to this topic comes from UNESCO as “Recommendations on the Ethics of Artificial Intelligence” (UNESCO, 2021). The main objectives are (citation)

- to provide a universal framework of values, principles and actions to guide States in the formulation of their legislation, policies or other instruments regarding AI, consistent with international law;
- to guide the actions of individuals, groups, communities, institutions and private sector companies to ensure the embedding of ethics in all stages of the AI system life cycle;
- to protect, promote and respect human rights and fundamental freedoms, human dignity and equality, including gender equality; to safeguard the interests of present and future generations; to preserve the environment, biodiversity and ecosystems; and to respect cultural diversity in all stages of the AI system life cycle;

The recommendations are based on “Values” and are following certain “Principles”. Values are:

- Respect, protection and promotion of human rights, fundamental freedoms & human dignity
- Environment and ecosystem flourishing
- Ensuring diversity and inclusiveness
- Living in peaceful, just and interconnected societies

The principles are (1) Proportionality and do no harm, (2) Safety and security, (3) Fairness and non-discrimination, (4) Sustainability, (5) Right to privacy, and data protection, (6) Human oversight and determination, (7) Transparency and explainability, (8) Responsibility and accountability, (9) Awareness and literacy, (10) Multi-stakeholder and adaptive governance and collaboration.

The Recommendation goes into details of actions to ensure accountability, responsibility, transparency and necessary regulations to ensure the rule of law. A set of policy areas is described:

- Ethical impact assessment – this provides guidance to member states, private sector and organizations on introduction of a framework to identify and assess benefits, concerns and risk of (their) AI systems, for mitigation and monitoring measures, etc.
- Ethical governance and stewardship
- Data policy
- Development and international cooperation
- Environment and ecosystems
- Gender, Culture, Education and research, Communication and information
- Economy and Labor
- Health and social well-being

7. Conclusions

The technologically oriented funding organizations and economy-driven policies of the EC have a very positive approach and high expectations concerning the benefits of digitisation of economy, industry and society. The “Green Deal” programme and the human implications of these technologies, empowering people through education and skills, and on protecting against the risks of these technologies, are targeting resilience and sustainability of society and economy (Hinkelmann, 2022). However, we should be aware that many of the achievements could be used against us as well (and some research projects consider this fact already) or lead to wrong decisions because of badly trained or biased AI systems.

Looking at the UNESCO Recommendation, which has been approved by 193 nations of the UN, may make us feel comfortable – but looking around on the world politics and human rights situation, despite almost all countries having approved these recommendations, let us be less sure on the impact of such recommendations and take care and stay alert.

8. Acknowledgements

Part of the work received funding from the EC via Horizon 2020, the ECSEL Joint Undertaking and the partners’ national funding authorities (in Austria FFG (Austrian Research Promotion Agency) on behalf of BMK, The Federal Ministry of Climate Action, Environment, Mobility, Innovation and Technology): Productive4.0 (Grant agreement n° 737459-2), AutoDrive (737469-2), SECREDAS (783119), iDev40 (783163), AfarCloud (783221) and AI4CSM (101007326-2). ADEX (Automated Driving EXaminer) was funded by the Austrian Research Promotion Agency.

9. References

- AIOTI (2022) – Alliance for Internet of Things Innovation, <https://aioti.eu/>
- CEN-CENELEC, (2022), Webinar “Journey towards the UN Sustainable Development Goals – social, economy, environment”, <https://experts.cen.eu/trainings-materials/events/2022/2022-06-02-webinar-sdgs/>
- EPoSS, AENEAS and INSIDE, 2022, ECS-SRIA 2022, Electronic Components and Systems – Strategic Research Agenda 2022,, <https://www.smart-systems-integration.org/publication/update-ecs-sria-2022-final-version>,
- ERCIM News number 122, July 2020, Research & Society Section, “Machine Ethics”, Guest editor Schoitsch, E. (AIT, Vienna), p. 4 – 11, Sophia Antipolis, France, ISSN 0926-4981, <https://ercim-news.ercim.eu/en122>

- ERCIM News number 127, October 2021, Special Theme “Smart and Circular Cities”, Guest editors Schoitsch, E. (AIT, Vienna) and Georgios Mylonas (ISI, Athens), p. 4 – 35, published by ERCIM EEIG, Sophia Antipolis, France, ISSN 0926-4981, <https://ercim-news.ercim.eu/en127>
- European SDSN Network, (2020), “The 2020 Europe Sustainable Development Report (ESDR 2020)”, issued by the SDSN (Sustainable Development Solutions Network) and Bertelsmann Foundation, <https://www.unsdsn.org/sdg-index-and-monitoring> (with further links of other regions)
- European Commission, JRC Technical Reports, (2019), JRC Statistical Audit of the Sustainable Development Goals Index and Dashboards, ISBN 978-92-76-08995-7/ISSN 1831-9424, https://s3.amazonaws.com/sustainabledevelopment.report/2019/2019_JRC_Audit_SDG_Index.pdf
- European Commission, (2018). “Digitising European Industry – Two years after the launch of the initiative”, Brochure March 2018, ISBN 978-92-79-80325-3, doi:10.2759/024187 <https://ec.europa.eu/digital-single-market/en/news/digitising-european-industry-2-years-brochure>
- European Commission (2019-12-11), Communication to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, “The European Green Deal”,
- European Commission (2019b), High-Level Expert Group, “Ethics Guidelines for Trustworthy AI” (Final report April 2019, HLEG AI), Brussels; <https://ec.europa.eu/digital-single-market/en/news/ethics-guidelines-trustworthy-ai>
- European Green Cities (1988), <http://greencities.eu/about> ;
- European Green Deal (2019), Action plan, <https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1596443911913&uri=CELEX:52019DC0640#document2>
- Federal Ministry of Transport and Digital Infrastructure, Ethics Commission on “Automated and Connected Driving – Report June 2017”, Germany; https://www.bmvi.de/SharedDocs/EN/publications/report-ethics-commission-automated-and-connected-driving.pdf?__blob=publicationFile (Summary available in English)
- Hinkelmann, Knut and Gerber, Aurore (Eds), 2022, Proceedings of the Society 5.0 Conference 2022, EPiC Series in Computing, Volume 84, https://easychair.org/publications/volume/Society_5.0-2022
- IEEE (2019) The IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems, “Ethically Aligned Design: A Vision for Prioritizing Human Well-being with Autonomous and Intelligent Systems”, First Edition. IEEE, 2019. <https://standards.ieee.org/content/ieee-standards/en/industry-connections/ec/autonomous-systems.html>
- Informatics Europe and ACM Europe, “When computers decide”, <https://www.acm.org/binaries/content/assets/public-policy/ie-euacm-adm-report-2018.pdf>
- Japanese Government, Cabinet Office (2018), Achieving Society 5.0, https://www8.cao.go.jp/cstp/english/society5_0/index.html
- Japanese Government, (2017). Realizing Society 5.0. https://www.japan.go.jp/abonomics/_userdata/abonomics/pdf/society_5.0.pdf
- Schoitsch, E. (2021). “Trustworthy Smart Autonomous Systems-of-Systems – Resilient Technology, Economy and Society”, IDIMT 2021, Pandemics: Impacts, Strategies and Responses, Trauner Verlag, Linz, Austria, Schriftenreihe Informatik 50, (ISBN 978-3-99062-958-1), p. 377-388,
- Schoitsch, E. (2020). “Towards a Resilient Society – Technology 5.0, Risks and Ethics”, IDIMT 2020, Proceedings, Trauner Verlag, Linz, Austria, Schriftenreihe Informatik 49, (ISBN 978-3-99062-958-1), p. 403-412,
- UNESCO (2021, Nov. 23). Recommendation on the Ethics of Artificial Intelligence, <https://unesdoc.unesco.org/ark:/48223/pf0000381137?3=null&queryId=c5dd8ced-9647-452b-b4d6-92723006496c>
- United Nations, Transforming our World - The 2030 Agenda for Sustainable Development (2015), <https://sustainabledevelopment.un.org/post2015/transformingourworld>
- Von der Leyen, U. (2019). “A Union that strives for more – My agenda for Europe”. <https://www.europarl.europa.eu/resources/library/media/20190716RES57231/20190716RES57231.pdf>

USAGE OF UNMANNED AERIAL VEHICLES FOR DETECTION OF PLANT ANOMALIES

Ivana Čermáková, Roman Danel

Department of Applied Informatics

Faculty of Economics

VSB – Technical University of Ostrava

ivana.cermakova@vsb.cz, roman.danel@vsb.cz

DOI: 10-35011/IDIMT-2022-367

Keywords

UAV, plant anomalies, usage of UAV, detection based on UAV

Abstract

Plant anomalies are one of the key problems in precision agriculture (PA). Nowadays the quickest way to find out and identify areas with anomalies and the reasons for them is to use unmanned aerial vehicles (UAV) mapping. This paper examines the use of UAVs for the detection of plant anomalies in various areas. The main aim is to introduce the possibility of using UAVs for the detection of plant anomalies to maximise crop yield from the monitored area where PA is employed. This paper describes case studies concentrated on this area of interest. In future, research will be focused on comparing infrared (IR) satellite images and UAV images to identify plant anomalies before the plants are above the ground (plant anomalies with seeds and roots).

1. Introduction

Agriculture has been a key part of society since ancient times. With limited land and rising land prices, it is necessary to maximize the harvest from available areas. Precision agriculture (PA) focuses on this issue. PA is a concept of agriculture based on observing, measuring and responding to inter and intra-field variability in crops (McBratney, Whelan & Ancev, 2005). PA uses modern methods that should help with decision-making and monitoring of areas, e.g. a decision support system (DSS). The main aim of PA is to define a DSS for whole-farm management with the consequent aim of optimising returns on inputs while preserving resources. A DSS uses supportive systems/platforms/vehicles, such as unmanned aerial vehicles (UAV), satellites, special harvesters, and special machines and systems (McBratney, Whelan & Ancev, 2005).

UAVs are defined as aerial vehicles flying without pilots (Work Jr & Gilmer, 1976). UAVs are divided into three basic groups (Work Jr & Gilmer, 1976):

- UAV
- remotely piloted vehicle (RPV)
- drone

The general public is familiar with the term UAV, but researchers have divided this into three further terms. RPVs are defined as vehicles piloted and controlled remotely over a long distance,

while UAVs can fly fully autonomously on preprogrammed missions. It is obvious that RPVs are always UAVs, but UAVs do not always have to be RPVs (Fahlstrom & Gleason, 2012). Drones are aerial vehicles with embedded systems; they are a sub-group of UAVs (Fahlstrom & Gleason, 2012). Unmanned aerial systems (UAS) is a term that is currently highlighted. UASs are systems composed of UAVs, control stations and the necessary components for flight. (Úřad pro civilní letectví, 2018).

One of the technical innovations in PA is the use of drones for field imaging to detect crop anomalies.

Detailed images of sown areas have been available for some time through aerial photography and remote sensing. However, satellite images must be ordered in advance, their quality is affected by the weather and they are more expensive.

Drones are suitable for detecting plant anomalies, which allow the repeated imaging of fields from a low height using multispectral cameras. From the captured images, it is possible to detect problems in the examined area by analysing the image and colour changes (Kohout, 2020). For example, we can:

- Detect insufficient irrigation (colour changes of crops not corresponding to the season and age of vegetation)
- Identify plant diseases and pests (especially bacterial and fungal infections)
- Check the condition of treetops (places that cannot be checked from the ground)
- Detect the occurrence of strips of other (unsuitable) soil or rock species in the study area
- Analyse the permeability of the amelioration system
- Detect inaccurate sowing
- Identify crop spraying by sprayer (too large a dose)
- Search for waterlogged places
- Identify the distribution of invasive plants or weeds
- Document crop losses for insurance claims

We can further link the analysis of drone images with the analysis of data obtained from existing public data sources. There are several services (mostly paid) that offer data on soils, geological conditions, climatic conditions, precipitation, areas at risk of floods, forest databases, etc. The services listed in Table 1 are available for the Czechia.

An example of a worldwide paid service is MeteoBlue (<https://www.meteoblue.com>). MeteoBlue offers the long-term measurement of some parameters (precipitation, meteorological conditions, soil etc.), climate forecast, crop climate risk analysis and forecasting and other services. Data from one are available at a cost of about 120 € / year. An example of graphical output from the MeteoBlue service is shown in Figure 1, which depicts crop risk forecasting that monitors and evaluates crop risks based on current seasonal weather, and seven-day and seasonal forecasts. Historical reference periods, such as a year with good or bad growth conditions, may be included for comparison. The crop climate risk analysis diagram supports operational decisions, e.g. when to plant, fertilise or irrigate.

Crop weather risk monitoring and prediction

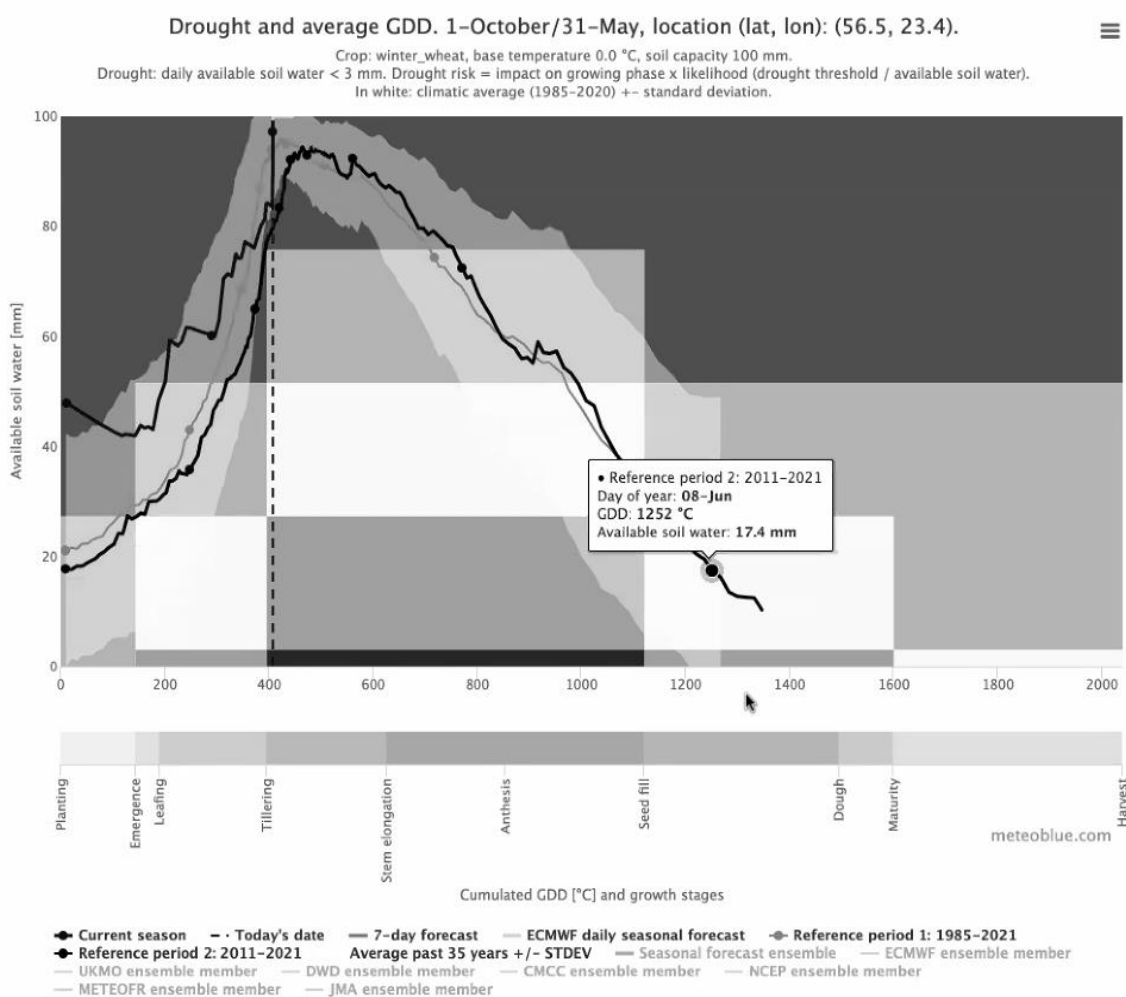


Figure 1. Example of MeteoBlue service output – weather risk monitoring and prediction in a selected location

Table 1 Summary of available data sources in Czechia; Source: Danel & Neustupa, 2016

Data Type	Source
Czech Geological Service (ČGS)	http://www.geology.cz
Czech Administration of Land Surveying and Cadastre (ČÚZK)	ZABAGED - http://geoportal.cuzk.cz
	Real Estate Register http://geoportal.cuzk.cz/geoprohlizec/?wmcid=485
Forest Database	ÚHÚL – www.uhul.cz
	Lesy ČR – www.lesy.cz
	AOPK ČR - www.ochranaprirody.cz ; drusop.nature.cz
DMÚ25	Available on the Geographical Website INSPIRE: http://geoportal.gov.cz/ArcGIS/services/CENIA/cenia_t_podklad/MapServer/WMSServer
Ecological Data	National Geographical website INSPIRE http://geoportal.gov.cz
Natural Sources Information	Nature and Landscape Conservation Agency of the Czech Republic (AOPK)

Data Type	Source
	ČR)
Socioeconomic Source Information	Czech Social Science Data Archive (ČSDA) http://archiv.soc.cas.cz http://medard.soc.cas.cz/
	Czech Statistical Institute (ČSÚ) http://www.czso.cz
	Czech Hydrometeorological Institute (ČHMÚ) - http://hydro.chmi.cz/hydro/ T. G. Masaryk Water Research Institute (VÚV TGM) - http://voda.gov.cz/portal/ POVIS - www.povis.cz Geofond - http://www.geofond.cz

2. Methodology

Vegetation indices are used to identify problematic areas in the crop and the anticipated nature, extent and cause of damage to the vegetation. The most popular are the normalised difference vegetation index (NDVI) and the enhanced vegetation index (EVI).

The NDVI is a simple graphical indicator that can be used to analyse remote sensing measurements, assessing whether or not the target being observed contains live green vegetation. The NDVI is chlorophyll sensitive and is computed as the difference between near-infrared (NIR) and red (RED) reflectance divided by their sum (Formula 1).

$$NDVI_i = (NIR - RED) / (NIR + RED) \quad (1)$$

$NDVI_i$ represents smoothed NDVI observed at time step ‘i’ and their ratio yields a measure of photosynthetic activity within values between – 1 and 1. Low NDVI values indicate moisture-stressed vegetation and higher values indicate a higher density of green vegetation. It is also used for drought monitoring and early famine warning.

The EVI is similar to NDVI and can be used to quantify vegetation greenness (USGS, 2022). However, EVI corrects for some atmospheric conditions and canopy background noise and is more sensitive in areas with dense vegetation. It incorporates an ‘L’ value to adjust for canopy background, ‘C’ values as coefficients for atmospheric resistance, and values from the blue band ‘BLUE’ (Formula 2, G is a gain factor). These enhancements allow for index calculation as a ratio between the RED and NIR values, while reducing the background noise, atmospheric noise and saturation in most cases.

$$EVI = G * ((NIR - RED) / (NIR + C1 * RED - C2 * BLUE + L)) \quad (2)$$

The two vegetation indices complement each other in global vegetation studies and improve upon the detection of vegetation changes. Other indices for examining and detecting plant conditions are NDREI (normalised difference red edge index), NGRDI (normalised green-red difference index) and GNDVI (green normalised difference vegetation index). NDVI and GNDVI were determined to be the most effective vegetation indices for detecting aquatic plants from drones’ images, showing the clearest difference between aquatic plants and the water surface (Song & Park, 2020).

The iterative self-organising data analysis technique (ISODATA) method and the minimum distance method were used for classification in a third case study. The ISODATA algorithm has some further refinements than other algorithms in splitting and merging clusters (Ma, Tan, Chang & Wang, 2011). Clusters are merged if either the number of members in a cluster is less than a certain threshold, or if the centres of two clusters are closer than a certain threshold (Ma, Tan, Chang & Wang, 2011).

The minimum distance method is superior in simplicity and generality of application (Wolfowitz, 1957) on the basis that in many stochastic structures where the distribution function depends continuously upon the parameters and distribution functions of the change variables in the structure, those parameters and distribution functions that are identified can be strongly and consistently estimated by the minimum distance (Wolfowitz, 1957).

3. Case studies

This chapter is divided into three case studies (mainly projects) focused on the detection of anomalies based on UAVs.

3.1. Agrihub project

The Agrihub INSPIRE project (2021-2022) deals with several challenges concerning PA. One of them is the use of drones for crop protection led by Zuzana Palková (SUA, Nitra) and Marcel Konečný (ADDSEN). The mentioned Agrihub challenge aims to design a methodology for identifying problematic areas of a selected crop, based on the measured data from UAVs in the form of images from specialised cameras (capable of scanning in the infrared, red, blue and green wavebands). Consequently, the vegetation indices NDVI and EVI will enable the identification of problematic areas in the crop and then the anticipated nature, extent and cause of damage can be determined. The system determines the coordinates, suggests procedures, methods and dosages, and unmanned devices apply designated substances.

During the preparatory activities for the challenge, several questions arose from the discussions, such as:

- Are the NDVI and EVI methods optimal, or will building reference image databases of the different health conditions of the plants be necessary?
- Is there a real interest for farmers to use drones to diagnose the health and nutritional condition of crops, considering the limitations of using drones?
- What will the business model be for further exploitation of the developed applications?

A hackathon is being prepared to address the issues outlined. The main objectives of the hackathon include more precise specifications of the farmers' needs, possibilities for plant-image database development, and clarification of the business potential of drone utilisation in agricultural practice.

3.2. INVARO project

Drones were also used in the Czech-Polish cross-border cooperation project called INVARO, led by Associate Professor Barbara Stalmachová from the VŠB-Technical University of Ostrava in cooperation with the GIG - Główny Instytut Górnictwa, Katowice, Poland (Main Mining Institute). The project took place from 2016 to 2019 and its goal was to map the spread of invasive plants on the Czech-Polish border and then determine the strategy for preventing further spread. Data on the occurrence of individual plant species were collected using drones and research on the terrain. The spread of invasive plants in the mapped area was modelled using a GIS system based on data in the database. Selected sites were photographed using drones for three consecutive years and changes were evaluated using GIS. The investigated location consists of densely populated and industrial areas, which created problems with imaging, as drones are not permitted to fly over built-up areas. The main output of the project was the *Plan for Reducing the Risks Associated with Invasive Plant Species*. The results of the project and publications created within it are available on the website

<http://invaro.vsb.cz/> [In Czech and Polish]. The summary of the project results was published (Olszewski et al., 2018).

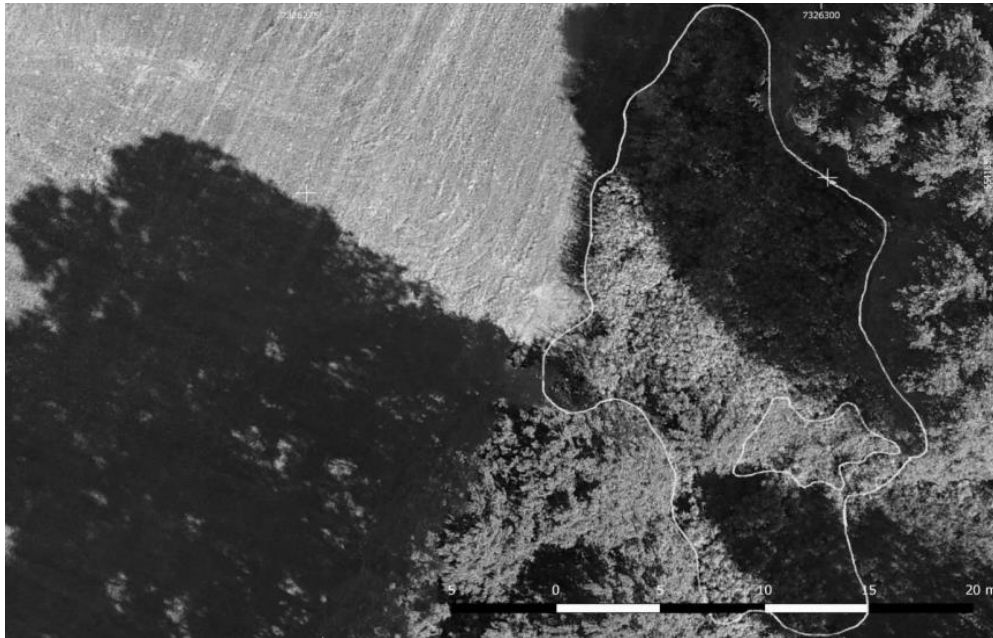


Figure 2. Identification of the area affected by the invasive plant *Impatiens glandulifera* in the Mszana area (Poland, 2017) by drone imaging. [Source: Olszewski & Grabowski, 2019]

3.3. Case study: Koblov

The purpose of the study was to discover the plant anomalies regarding lakes shoreline during the monitored period. The monitored period was between May and September 2021 and the area was observed three times – every two months for visible changes (Figure 3). First, the data was classified and then converted to polygons representing shoreline definition. The data were classified by ISODATA and the minimum distance method. The accuracy of the process is measured with data from real-time kinematic positioning (RTK).



Figure 3. Area of interest during monitoring period [Source: Authors, 2021]

This research did not detect plant anomalies in the area during the monitored period.

4. Discussion

When using a drone to analyse the state of vegetation and identify anomalies, we must consider some limitations and possible problems:

- In the Czech Republic, it is not possible to fly a drone over a populated area or houses
- The height of the air column affects the image analysis. The higher the drone moves, the more colour distortion occurs and subsequent correction is required
- A database of reference images containing known and described anomalies that could be used to evaluate colour changes, is not yet available
- Imaging of the same area over time to monitor changes – due to the nature of the analysed data, the evaluation can take a long time
- The costs for imaging and subsequent evaluation. The weight of the equipment used has an impact on costs (more weight means shorter range)
- The cost of multispectral cameras modified with special mounts for use with drones is CZK 200 to 300 thousand (approximately €10,000)
- The drone is only appropriate for the analysis of smaller areas and detailed evaluation; for larger areas, aerial photography is more suitable (the problem relates to the batteries and their performance with current drones)
- For professional use it is necessary to have a pilot who has passed the tests to perform aerial work

5. Conclusion

The main aim of this paper is to describe the possibility of using UAVs for the detection of plant anomalies to maximise crops from PA-monitored areas. Because PA is one of the key trends in agriculture these days. UAV and images from UAV allow using methods of remote-sensing classification for finding the plant anomalies in various terrains. This method is extremely quick, so the data can be processed in a few hours after the flight. The method provides enough accurate results (based on the sensor on the UAV and the methods used). For studying plant anomalies these methods were used: NDVI, EVI, ISODATA and the minimal distance classifying method. The plant anomalies study contains three case studies/projects: the Agrihub project, the INVARO project and the Koblov case study. In future, the research will focus on using IR UAVs to identify the plant anomalies before the plants appear above the ground (plant anomalies with seeds and roots). The images will be compared with the traditional source of IR images – IR satellites.

6. Acknowledgement

This paper was supported from SGS SP2022/74 grant of VSB – Technical University of Ostrava.

7. References

Danel, R. & Neustupa, Z. (2016). Summary of spatial data sources in the Czech Republic usable for brownfield revitalization projects. International Conference of Brownfields Management and Redevelopment, Ostrava, VŠB-Technical University of Ostrava, Czech Republic.

- Fahlstrom, P. G. & Gleason, T. J. (2012). Introduction to UAV systems, Aerospace series. (4th ed.). John Wiley & Sons.
- Kohout, J. (2020). Praktické využití dronu při monitorování pozemku s pšenicí ozimou. Už první přelet dokázal odhalit problémy [In Czech]. Retrieved April 19, 2022, from <https://www.agroportal24h.cz/clanky/prakticke-vyuziti-dronu-pri-monitorovani-pozemku-s-psenici-ozimou-uz-prvni-prelet-dokazal-odhalit-problemy>
- Ma, Y., Tan, Z., Chang, G., & Wang, X., (2011). A new P2P network routing algorithm based on ISODATA clustering topology. *Procedia Engineering*, CEIS 2011 15, 2966–2970. <https://doi.org/10.1016/j.proeng.2011.08.558>
- McBratney, A., Whelan, B., & Ancev, T., (2005). Future directions of precision agriculture. *Precision Agriculture*, 6, 7–23.
- Olszewski, P., Grabowski, J., Stalmachová, B., Švehláková, H. & Nováková, J. (2018). Risks concerning invasive plant species in an industrial-agricultural community. 18th International Multidisciplinary Scientific Geoconference, SGEM 2018, Albena, Bulgaria.
- Olszewski, P. & Grabowski, J. (2019). Ocena zasobów i zagrożeń związanych z roślinnymi gatunkami inwazyjnymi na terenach transgranicznych [In Polish]. Final conference of the INVARO project, Ostrava, Czech Republic.
- Song, B. & Park, K.H. (2020). Detection of aquatic plants using multispectral UAV imagery and vegetation Index. *Remote Sensing*, 12(3), 387.
- Úřad pro civilní letectví (2018). Úřad pro civilní letectví. Retrieved April 12, 2022, from www.caa.cz
- USGS (2022). Landsat enhanced vegetation index. Retrieved April 12, 2022, from <https://www.usgs.gov/landsat-missions/landsat-enhanced-vegetation-index>
- Wolfowitz, J., (1957). The minimum distance method. *The Annals of Mathematical Statistics*, 28, 75–88. <https://doi.org/10.1214/aoms/1177707038>
- Work Jr, E. A. & Gilmer, D. S., (1976). Utilization of satellite data for inventorying prairie ponds and lakes. *Photogrammetric Engineering and Remote Sensing*, 42(5), 685–694.

BROWNFIELDS OPPORTUNITIES FOR SMART REGIONS

Ivana Čermáková, Roman Danel, Tereza Vašenková

Department of Applied Informatics

Faculty of Economics

VSB – Technical University of Ostrava

ivana.cermakova@vsb.cz, roman.danel@vsb.cz, tereza.vasenkova.st1@vsb.cz

DOI: 10-35011/IDIMT-2022-375

Keywords

Brownfield, smart region, brownfield revitalisation, COBRAMAN

Abstract

'Brownfield' refers to previously developed land with the biggest potential for change in metropolitan areas. It is not necessary to build on 'green land', which can be used differently (e.g. precision agriculture). Brownfield land can be cleaned up and improved for profitable redevelopment. National institutions provide grants for brownfield revitalisation. This paper focuses on the potential for brownfield regeneration in the Czech Republic. A case study focuses on the Moravian-Silesian (Moravskoslezský) region in the Czech Republic. Earlier successful brownfield projects are also examined.

1. Introduction

The term 'brownfield' does not have a uniform definition. Experts dealing with this issue define the term in their own ways. Green (2018) describes brownfields as properties that are abandoned and underused and for which redevelopment is hindered by social and financial complexities. Ahmad et al. (2018) describe brownfields as often consisting of degraded soils with contaminants that contribute enormously to environmental pollution. The Czech agency CzechInvest states that the term brownfield means unused or neglected real estate that might be contaminated. Structures on these sites that were built for industrial, military, agricultural or other purposes cannot be reused without a process of revitalisation (Brownfieldy, 2022).

We classify the concerned areas into five specific types (Tureckova, 2021):

- 'Greenfields' are the exact opposite of brownfields. They are uninhabited and undeveloped land in areas with abundant agricultural land.
- 'Blackfields' are abandoned areas with an excessive level of environmental degradation. Blackfields are mainly the result of mining and industrial use. Increased levels of contamination pose a danger to nature and human life.
- 'Grayfields' represent a type of brownfields that are surrounded by large areas of empty asphalt concrete. This type of land is located in non-functioning public service developments and office parks. Grayfields do not show a high degree of contamination.

- ‘Bluefields’ are characterised by abandoned and disused buildings between the mainland and the water areas (seas, rivers, lakes), such as shipyards, embankments, piers and ports.
- ‘Goldfields’ are ordinary brownfield areas with the potential for profitable investment with a high return. An example of a goldfield is the area of the former Karolina Mine in Ostrava (Czech Republic).

2. National programmes

Brownfield sites cannot be used without prior regeneration. The approach by public authorities towards addressing this issue varies from country to country. In order to successfully regenerate brownfields at the regional level, it is necessary to draw up regional strategies with specific priorities. Brownfield regeneration is a complex process involving various organisations, individuals or entities affected by the brownfields (Klusáček et al., 2018). In the Czech Republic, it is possible to submit a preliminary application to the Regeneration and Business Use of Brownfields Programme, the organisation that supports projects for the revitalisation of former construction sites (Brownfieldy, 2022). The National Recovery Plan, approved by the Czech government, deals with the regeneration of brownfields in the ‘second pillar’ of the Czech Republic’s Recovery and Resilience Plan, the annual budget for which exceeds CZK 3,300 million. The intention is to remove contaminated soil, demolish unused structures and build new green meadows (Physical Infrastructure and Green Transition, 2022).

The Ministry for Regional Development, in cooperation with the CzechInvest agency, manages the official database www.brownfieldy.eu. As of March 1, 2020, the database included 572 localities in the Czech Republic focusing on the 13 regions outside of Prague. It highlights contaminated areas in 7.5% of localities. The areas that are considered brownfields have changed over time. As of the date of publication, the area was 2,325.09 ha in the Czech Republic. The highest number of brownfield localities (80) was recorded in the Ústí Region. The Moravian-Silesian Region (69) was in second place, followed by the South Moravian Region (67). The indicators also showed the types of ownership. The majority of land (65% of brownfield sites) was privately owned, although public ownership overall constitutes only 30% of all land in the Czech Republic. The remaining 5% is a combined type of ownership. Selected data focused mainly on industrial, agricultural and civic brownfields (Turečková et al., 2021).

The website www.brownfieldy.eu also provides information about the following programmes and grants: Regeneration and Business Use of Brownfields, Smart Parks for the Future; Státní Fond Podpory Investic (SFPI); Brownfields; Revitalisation of Old Mining Areas for Non-Agriculture Use; OP PIK – Real Estate; Operační program životního prostředí (OPŽP); Development of the Countryside; Integrated Regional Operations Programme (IROP); Support for the Resumption and Development of the Countryside; and the Expanse Programme (Brownfieldy, 2022).

The Smart Parks for the Future Programme focuses on the development of existing industrial zones for improving infrastructure, including measures to reduce the negative impacts of climate change, regenerate brownfield sites and redevelop smaller business parks in places considered to be of high societal importance for change.

SFPI funds may be used for the following purposes:

- the removal, partial removal, repair, alteration or extension of a building that is part of an area with an old construction load and is not an underground structure, road, railway, waterway, fencing, retaining wall or engineering network;

- the removal, partial removal, repair, modification or other alteration of an underground structure that is part of an area with an old construction load;
- the removal, partial removal, repair or other alteration of equipment that is part of an area with an old construction load;
- carrying out construction, including equipment, on land with an old construction load;
- landscaping in areas with old construction load;
- the removal or partial removal of roads, railways, waterways, utilities, fencing or retaining walls that are located in an area with an old construction load;
- building, locating or modifying a utility network, purpose-built road, sidewalk, street lighting, benches, rubbish bins and other elements of urban infrastructure; and retaining walls or fencing in an area with an old construction load;

The aid can also be used for the purchase of an area with an old construction load or part of it, if this area is to be revitalised. The SFPI Programme is divided into calls for proposals. Two calls have already been successfully evaluated and awarded, and the deadline for the third call was on 2 May 2022 (Brownfieldy, 2022).

OP PIK - Real Estate Programme is also divided into calls. Six calls have already ended (Call 1, Call 2, Call 3, Tourist Trade Call, Coal Regions Call and Support After Twister Call). No call is currently open.

The OPŽP Programme aims to protect and improve the quality of the environment in the Czech Republic. The programme awarded nearly €2.637 billion from the Cohesion Fund and the European Regional Development Fund over the period 2014–2020. The Operational Programme Environment 2014–2020 followed the Operational Programme Environment 2007–2013. The programme focuses on municipalities and cities, research and scientific institutes, businesses, individuals and non-profit organisations (Brownfieldy, 2022).

The Development of the Countryside Programme aims to restore, preserve and improve ecosystems dependent on agriculture through agri-environmental measures (Brownfieldy, 2022), as well as investments for competitiveness and innovation of agricultural enterprises and support for the entry of young people into agriculture and landscape infrastructure. The programme also supports the diversification of economic activities in rural areas in order to create new jobs and increase economic development. The programme document was approved for the period 2014–2020 and followed the Rural Development Programme of 2007–2013. The programme comprises five priority areas related to the promotion of competitiveness in all types of agricultural activity throughout the country and the promotion of innovative agricultural technology practices and sustainable forestry management, especially concerning real estate (Brownfieldy, 2022):

- investment in agricultural holdings;
- forestry infrastructure;
- start-up projects for young farmers;
- investment to support energy from renewable sources;
- investment in non-agricultural activities.

IROP aims to find solutions to a wide range of societal problems and to provide tools to redress regional economic disparities (Brownfieldy, 2022). The following calls are particularly suitable for brownfield regeneration:

- revitalisation of selected monuments within the Culture Programme;
- energy savings in apartment buildings within the Insulation Programme;
- constructions projects connected with the construction and modernisation of primary schools within the Education Programme;
- construction and reconstruction of real estate within the Social Integration Programme concerning social infrastructure;
- construction of IRS stations and their education and training centres within the IRS (Internal Revenue Service) Programme.

Support for the Resumption and Development of the Countryside Programme supports the renewal and development of municipalities with less than 3,000 inhabitants to increase the quality of life and improve the attractiveness of municipal spaces. The implementation of this sub-programme will support the dynamic and balanced development of municipalities in the Czech Republic. The sub-programme presupposes the participation of local residents and civic associations in the renewal and development of municipalities in accordance with local traditions. Two calls were already completed.

The Expanse Programme provides financial support to small and medium-sized companies (Brownfieldy, 2022). Support is provided through preferred loans for financing projects focused on starting and developing these businesses.

3. Case study: Moravian-Silesian region

The Moravian-Silesian region provides two main websites with brownfields information. The first focuses on the city of Ostrava (county seat). The website is called ‘Brownfieldy Ostrava’, and it is supported by the city administration. Three significant brownfields projects were recently approved by the city in Karolina, Hrušov and the Dolní Vítkovice area.

Karolina (coal mine and coke plant) has been revitalised and rebuilt as a new city district with flats and a commercial area. Hrušov (an industrial quarter of Ostrava) was originally for workers’ housing for nearby companies and became a brownfield due to a flood in 1997. After solving ownership and legislative problems, the Ostrava district of Hrušov is to be transformed into the Contera Park Industrial Area with an area of 140,000 m² at a cost of CZK 1 billion.

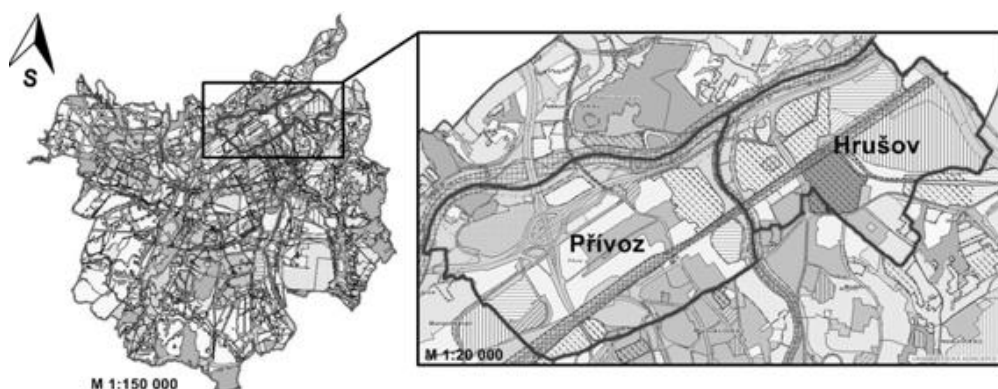


Figure 1. Localisation of Hrušov within Ostrava city [Source: www.mapy2.ostrava.cz & Haasová L., 2018]

The Dolní Vítkovice area, formerly a blast furnace, steelworks, a coal mine and a coal preparation plant, has been rebuilt as a technical monument and a unique educational, cultural and social centre (DOV, 2022). The gas storage in the Dolní Vítkovice area was revitalised and converted into a

concert hall. Part of the complex serves as an interactive technical museum. In 2023 DOV will welcome its one millionth visitor.



Figure 2. Dolní Vítkovice – the original state of the brownfield site in 1998 and the location of the site behind Ostrava city centre (the area behind the cathedral) [Source: Authors]

The second website (Brownfieldy v Moravskoslezském kraji) is focused on the entire region. The main purpose of this website is to inform about current brownfields in the region and finished projects (Brownfieldy v Moravskoslezském kraji, 2022).

Many brownfields in the Moravian-Silesian region have been revitalised, but there are still many places that are unchanged. It is hoped that with new support for brownfield programmes, rebuilding will continue.

The international project COBRAMAN (Cobraman, 2012) lasted from 2008 to 2012 as a cooperation of universities, municipalities and private entities focusing on brownfields and strategies for their reuse. VŠB TU Ostrava, as a partner of the Cobraman project, mainly dealt with information support for brownfields management. One of the project outputs was a database of brownfield revitalisation projects containing the inventory of significant successful and unsuccessful brownfields revitalisation projects (Danel, Čermáková & Chlopeký, 2021).

In recent years, the Cobraman database has been supplemented by inventories of local brownfields (mainly from Moravian-Silesian region) based on a master's course 'European School for Brownfield Redevelopment', which has been taught at the VŠB-Technical University of Ostrava since 2014. Thanks to the activities of its students, a detailed inventory of the Vítkovice, Hrušov and Přívoz districts of Ostrava was conducted, followed by the towns of Havířov and Frýdek Místek.

A separate task for the information support of brownfields revitalisation is to envision the appearance of the sites after the revitalisation process. A 3D-landscape visualisation was developed by Assoc. Prof. Zdeněk Neustupa, who combined data using GIS, CAD and 3DMax software. This method was successfully used in the Moravian-Silesian region for modelling and visualisation of terrain previously used for coal mining (Danel et al., 2014). The plan is to further develop this methodology for use in virtual reality demonstrations.

4. Conclusion

Brownfields and their revitalisation are one of the priorities of regional development programmes. This paper provides an overview of national programmes for brownfield reuse and an evaluation of them. A case study focuses on one region (Moravian-Silesian region). The study covers the most

important projects of brownfields revitalisation in the region and their objectives. Based on this information, it seems that the trend for brownfields regeneration will increase with the support of the state and other institutions.

5. Acknowledgement

This paper was supported from SGS SP2022/74 grant of VSB – Technical University of Ostrava.

6. References

- Ahmad, N., Zhu, Y., Ibrahim, M., Waqas, M., & Waheed, A. (2018). Development of a standard brownfield definition, guidelines and evaluation index system for brownfield redevelopment in developing countries: The case of Pakistan. *Sustainability*, 10(12), 4347. <https://doi.org/10.3390/su10124347>
- Brownfieldy. (n.d.). CzechInvest. Retrieved 24 April 2022, from <https://www.czechinvest.org/cz/Sluzby-pro-municipality/Nemovitosti-pro-podnikatelske-ucely/Brownfieldy>
- Brownfieldy v Moravskoslezském kraji. (n.d.). Retrieved 27 April 2022, from <https://brf-msk.cz/#zregenerovane>
- Cobraman. (2012). Brownfield regeneration management: From education to practice – Final brochure. http://www.cobramance.eu/Portals/0/CM%20newsletter/Cobraman%2006_Newsletter_%20FINAL%20brochure.pdf.
- Danel, R., Čermáková, I., & Chlopečký, J. (2021). Information support for brownfield revitalisation projects and other tasks in environmental areas. 14th International Conference on Strategic Management and Its Support by Information Systems – SMSIS 2021, VŠB-TU Ostrava, Czech Republic, 58–66.
- Danel, R., Neustupa, Z., Lacková, E. & Urbancová, L. (2014). An information system for the support of land-use solutions for areas affected by mining activities in the region of Upper Silesia. 14th SGEM GeoConference on Informatics, Geoinformatics and Remote Sensing – SGEM 2014, Bulgaria, 19–26.
- DOV – Dolní Vítkovice. (n.d.). Retrieved 6 June 2022 from <https://www.dolnivitkovice.cz/en/>
- Fyzická infrastruktura a zelená tranzice. (n.d.). Retrieved 25 April 2022, from <https://www.planobnovy.cz/fyzicka-infrastruktura-a-zelena-tranzice>
- Green, T. L. (2018). Evaluating predictors for brownfield redevelopment: Lecture notes from the 2nd ERCOFTAC summer school held in Stockholm, 10–16 June 1998. *Land Use Policy*, 73, 299–319. <https://doi.org/10.1016/j.landusepol.2018.01.008>
- Klusáček, P., Alexandrescu, F., Osman, R., Malý, J., Kunc, J., Dvořák, P., Frantál, B., Havlíček, M., Krejčí, T., Martinát, S., Skokanová, H., & Trojan, J. (2018). Good governance as a strategic choice in brownfield regeneration: Regional dynamics from the Czech Republic. *Land Use Policy*, 73, 29–39. <https://doi.org/10.1016/j.landusepol.2018.01.007>
- Ostrava. (n.d.). Brownfieldy. Retrieved 27 April 2022 from <https://www.ostrava.cz/cs/podnikatel-investor/nemovitosti/brownfieldy>
- Turečková, K., Nevima, J., Duda, D., & Tuleja, P. (2021). Latent structures of brownfield regeneration: A case study of regions of the Czech Republic. *Journal of Cleaner Production*, 311(127478) 00–12, <https://doi.org/10.1016/j.jclepro.2021.127478>
- Tureckova, K. (2021). Specific types and categorisations of brownfields: Synthesis of individual approaches. *Geographia Technica*, 16(2), 29–39. https://doi.org/10.21163/GT_2021.162.03

AUTONOMOUS VEHICLES AS A MANAGEMENT CHALLENGE - MEETING CONFLICTING INTERESTS

Richard Antonín Novák, Tomáš Sigmund, Lucie Böhmová

Prague University of Economics and Business

richard.novak@vse.cz, sigmund@vse.cz, lucie.bohmova@vse.cz

DOI: 10-35011/IDIMT-2022-381

Keywords

Autonomous vehicles, benefits, CATWOE, digital economy, risks, management, stakeholder's groups

Abstract

In this article we attempt to identify the risks and benefits related to autonomous vehicles, find the crucial stakeholders and define their perspectives. We were inspired by the Checkland's soft system methodology and his CATWOE analysis. We conclude that the essences of the perspectives must be found, their contradictions defined and then a mutual acquaintance of the stakeholders' perspective is a way to overcome the differences. For such an approach the stakeholders must be motivated.

1. Introduction

The rapid development of digital technologies brings new management challenges to address. The impending introduction of autonomous vehicles (AVs) into mainstream operations and the economy appears to present one of the biggest challenges associated with managing the digital economy (Bagloee, et. al., 2016; Sousa, et. al., 2018). Based on the systematic literature review (SLR) following the PRISMA scheme searching on AVs benefits and risks that we summarize below; it shows very conflicting opinions regarding the AVs implementation into daily operation. We see great importance in solving the AV management problem because we believe that the approach to solving this challenge will serve as a fundamental example for solving many other AI-based challenges.

The benefits of AV tend to include based on our SLR:

- Reduction of traffic accidents & Public health & Economical benefits, (Martínez-Díaz a Soriguera, 2018; Sparrow a Howard, 2017; Fleetwood, 2017; Bagloee et al., 2016; Nyholm a Smids, 2016; ...)
- Traffic efficiency, (Bagloee et al., 2016; Sparrow a Howard, 2017; Martínez-Díaz a Soriguera, 2018)
- Vehicle fleet reduction, (Bagloee et al., 2016; Sparrow a Howard, 2017; Martínez-Díaz a Soriguera, 2018)
- Higher personal mobility, (Sparrow a Howard, 2017; Martínez-Díaz a Soriguera, 2018)
- Time sparing, (Gogoll a Müller, 2017; Sparrow a Howard, 2017; Martínez-Díaz a Soriguera, 2018)

- Reduction of pollution and environmental impact, (Gogoll a Müller, 2017; Martínez-Díaz a Soriguera, 2018)
- Space consumption reduction, (Gogoll a Müller, 2017; Sparrow a Howard, 2017)
- Less non-driving hours per vehicle (Sparrow a Howard, 2017)

Among the risks of AV the following are mainly referred based on our SLR:

- Decision making in unavoidable accidents, (Nyholm a Smids, 2016; Contissa, Lagioia a Sartor, 2017; Himmelreich, 2018; Keeling, 2020)
- Liability for traffic accidents, (manufacturer, duty to intervene, „strict liability“ vs shared/full) (Hevelke a Nida-Rümelin, 2015)
- Transition phase from private towards shared transportation, (Martínez-Díaz a Soriguera, 2018)
- Sprawl of urban areas and increase in commutation, (Martínez-Díaz a Soriguera, 2018)
- Labor market modification, (Martínez-Díaz a Soriguera, 2018; Taeihagh a Lim, 2019)
- Prohibition of human driving, (Sparrow a Howard, 2017)

Based on the literature search conducted, it can be stated that there is a strong consensus among the professional community regarding the benefit identified as point *i*, *Reduction of traffic accidents & Public health & Economical benefits* that can be in more detail explained as the following:

- *Reduction of traffic accidents & Public health* is taking into account that 90% of accidents derive from human errors that are expected to be reduced to a minimum (Koopman and Wagner, 2017; Gear 2030, 2017).
- *The Economic benefits* are taking into account that AVs technologies could have significant economic net benefits due to crash reduction (including direct cost savings and associated roadway congestion), enabling greater mobility for the disabled and elderly, decreasing congestions, and improved fuel economy due to more efficient driving (Anderson et al., 2014).
- *Furthermore*, the autonomous (driverless) car market was valued by the Mordor Intelligence report (Mordor, 2022) at USD 22.22 billion in 2021, and it is expected to reach USD 75.95 billion by 2027 while registering a CAGR of 22.75% during the forecast period 2022-2027. Based on the more aggressive surplus scenario of the A.T.Kearney (Roemer, 2022) the market of self-driven cars will grow between 2025 and 2035 with CAGR of 50%, and will completely change the business models in public transportation where car will be no more a product but a service purchased in driving minutes and provided by “new taxi” service providers established from the AV technology leaders such as Uber, Google, Tesla, VW, BMW, Toyota among others. Today it is not yet clear which of these companies will become the new taxi providers, but it is clear that some of them have a better starting point than other players in the market.

We can summarize that no other benefit or risk listed above, apart from point *i*, *Reduction of traffic accidents & Public health & Economical benefits* has such a strong consensus in the expert community on its unambiguity. The other benefits and risks can thus be seen more as different perspectives of different opinion groups shaping a range of derivative managerial and ethical dilemmas.

We will not address the dilemmas arising from the conflict of benefits and risks of AVs in this paper, but will focus on managerial issues, which we define as the following research questions:

- Why does the society plan to introduce AV into the economy? And can the introduction of AV be avoided?
- Do we know the impacts of introducing AVs into the economy at the time of decision making? How does the society estimate that the decision to introduce AV will be made?
- Which interest group will benefit from the introduction of AVs and are AVs beneficial to society as a whole or just a few interest groups? And is there a strong consensus in society as to whether it is a good idea?

2. Methods

We have used a systematic literature review summarized in the introduction party as an early assessment of information of AV subject area using the PRISMA scheme (Liberati, et al. 2009). The review was performed in the time period of September to November 2021 and the keywords were: benefits, risks, autonomous vehicles, self-driven cars.

We used the WoS, Scopus and Google Scholar databases as data sources. If some arguments regarding AVs were present in multiple sources, then we retained those sources that had the most citations themselves as part of the SLR duplication removal.

Records identified (both through database searching and other sources) $n = 117$. We removed 76 sources in the screening process mainly because of duplication removal. The number full text articles assessed for eligibility was 41. The number of resources included in the synthesis and referred to in the article is 21, respecting their impact and relevance to the title of the article.

The result part of our paper is based on logical methods such as analysis vs synthesis, induction vs deduction, abstraction vs concretization. We have primarily inspired by the Soft Systems Methodology (SSM) based on Peter Checkland to address the research questions, but we didn't follow his steps strictly.

In our paper we examine the specific SSM technique called CATWOE, which focuses on defining necessary elements that together constitute a human activity system from a certain perspective. This perfectly fits to our focus on viewing AVs from different Interests & Stakeholders' group. This mnemonic word CATWOE stands for: Customer, Actor, Transformation, Weltanschauung, Owner and Environmental constraints, (Bergvall-Kåreborn, et. al., 2004).

„CATWOE came about as a combination of intuition, real world experience and also a desire to take into account the wisdom gleaned at that time in formal systems thinking.”

(Smyth and Checkland, 1976).

3. Results

Following the SSM and CATWOE methods applied to the managerial challenge of Autonomous vehicles and approaching the conflicting interests of different stakeholders we will go quickly through 7 stages of SSM: 1, Unstructured description of the problem situation, 2, Rich Picture as the problem situation visualization, 3, Root definition of relevant system elements, 4, Conceptual model, 5, Comparison of Model (4) with Rich picture (2), 6, Definition of feasible and desirable changes, 7, Action to solve the problem or improve the situation.

We will apply CATWOE to SSM stage 3 (root definition) to find and solve managerial challenge related to the: *people, processes and environment* that are in are named in CATWOE as 6 elements: *Customers, Actors, Transformation process, Worldview, Owner, Environmental constraints*.

Unstructured description:

We consider as done in the introduction part of this paper. We identified the key stakeholders and their perspective on AV: AV manufacturers, AV users: companies and individuals (rich and poor, skilled and unskilled, technophobic and geeks), technological companies, financial institutions, state authorities.

3.1. Rich picture visualization

See below the Figure 1 followed by the SSM CATWOE method:

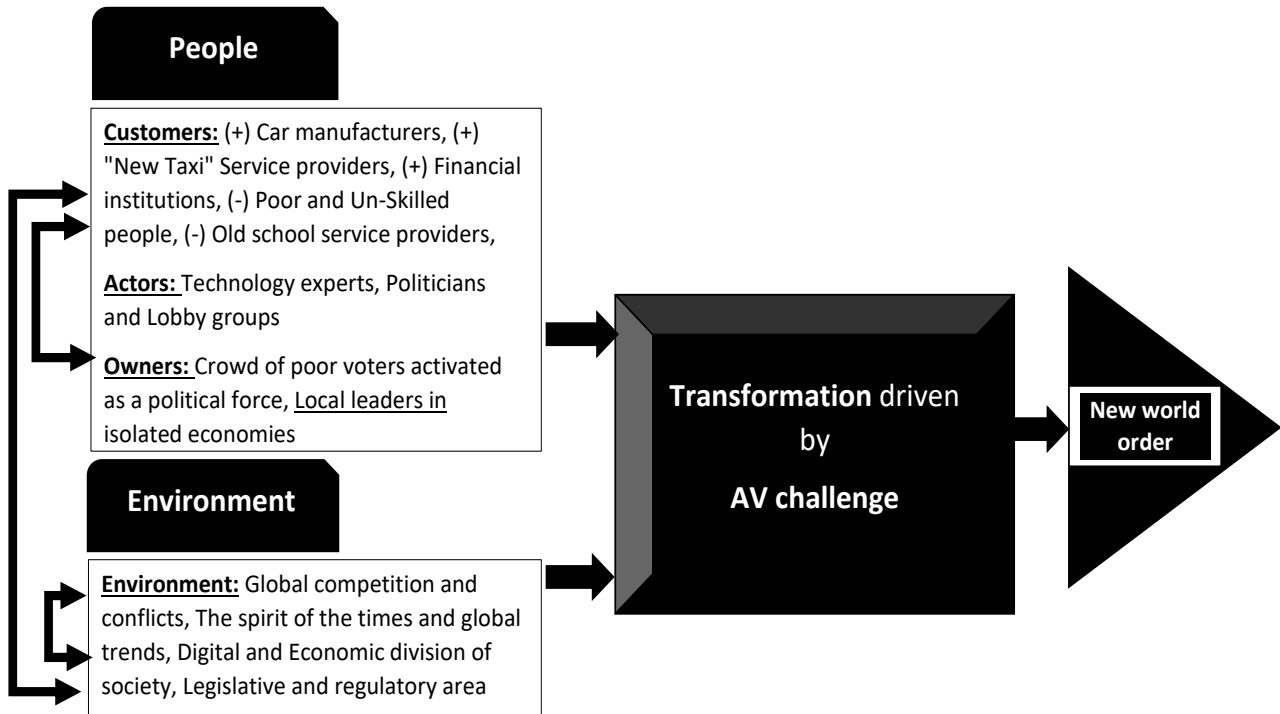


Figure 1. Simple rich picture

The analysis of the causal factors leading to the final managerial and policy decision is shown in the table below using the CATWOE method. We selected the transport as the crucial worldview from which the introduction of autonomous cars should be perceived. However, there are other perspectives mentioned in the benefits and risks related to AV. We can think of reduction of accidents, smoother and quicker transport, hacking, loss of control over the vehicle etc.

Table 1 General CATWOE

CATWOE Element Area	Specific Element (CATWOE)	Examples
Customer 1	(+) Car manufacturers	Ford, BMW...suppliers
customer 2	(+) "New Taxi" Service providers	Uber, Google, Tesla, VW, BMW...
customer 3	(+) Financial institutions	FinTech, InsureTech, Companies
customer 4	(-) Poor and UnSkilled people	the benefits are not felt and the risks fall most heavily on them
customer 5	(-) Old school service providers	Petrol stations, Inflexible car services...
Actor 1	Technology experts	AI, Data specialists...
Actor 2	Politicians and Lobby groups	US Government, EU Parliament, Automotive lobby
Owner 1	Crowd of poor voters activated as a political force	Populist and extremist parties
Owner 2	Local leaders in isolated economies	Butan, North Korea
Transformation 1	(input) Motives of stakeholders	Gain profit, Control others, Desire to make the world a better place for all
Transformation 2	(input) Risks	Liability for traffic accidents, Labor market modification...
Transformation 3	(output) A new world and social order	Rentism, Socialism, Extremism, Communism (Frase, 2016)
Transformation 4	(process) Public debate and decision-making in society	Elections, professional conferences, guild and legislative bodies
World-view 1	Benefits	Reduction of traffic accidents & Public health & Economical benefits...
Environment 1	Global competition and conflicts	China vs US vs EU vs Russia
Environment 2	The spirit of the times and global trends	Faith in AI as salvation, Environmental changes
Environment 3	Digital and Economic division of society	AI literacy, Asset concentration
Environment 4	Legislative and regulatory area	GDPR, Digital Services Act

CATWOE definitions are as follows (Smyth & Checkland, 1976): Customer - who would-be beneficiaries or victims of the system; Actor - person or persons who would perform the transformation process; Owner - the person who can stop the transformation; Transformation - processes some input to output; worldview - describes what makes the transformation meaningful; Environment - represents constraints that are taken as given.

On the basis of the SLR and the occurrence of the searched keywords and the number of their citations, we considered the following elements (marked in yellow) in the Table 1 to be essential:

- Motives, values, cultures, power relations, legitimacy of stakeholders – as the fundamental input to the Transformation process
- Public debate and decision-making process in society – as the Transformation process
- Benefits, losses, risks and potentials – describing what makes the AV implementation as meaningful
- The spirit of the times and global trends – representing constraints that are given now

We have identified the element Motives of stakeholders as the root-cause with the following rationale coming from psychological, social science and how they currently view importance of motivations and emotions in human and crowd decision making process.

“Over centuries of psychological thought there have been diverse conceptualizations of the relations among cognition, motivation, and emotion—or what Hilgard (1980) referred to as the "trilogy of mind." A theory of emotion is, in effect, a theory of how motivation and cognition produce emotions in adaptationally relevant encounters,” (Lazarus, 1991).

We shouldn't simply motivate stakeholders to support AV. We should motivate them to understand and consider other's perspective (democratic approach) which can lead to the change of their original dissenting perspective and they will start to support the introduction of AV in some limits. On the other hand, the supporters of AV should also understand the perspective of those refusing AV.

We can learn from LeBon's theory of the crowd (2017) about the motivation of the crowd. He claims that the crowd determines the trajectory of history, that individuality disappears in the crowd, that crowds can be easily influenced with affirmation, repetition, and contagion. We should consider that when influencing the crowd to support the balanced opinion respecting all stakeholders' perspectives. All stakeholders including the general public must be informed about the perspective of other stakeholders. It will be very difficult as issues related to AV include technological, legal, financial, environmental and ethical issues which in addition to that all can't be exactly and in detail predicted.

The following picture shows an application of our theory to the worldview on the AV as a new taxi. A lot of similar perspectives and transformations must be identified and all stakeholders must be acquainted with them and a compromise must be looked for. Even here the motivation to learn from others must be supported.

Table 2 CATWOE of the AV as a new taxi

CATWOE	CATWOE element
Worldview 1: New Taxi	
Customer 1 (+)	Person asking for transport
Customer 2 (+)	Car manufacturer
Customer 3 (+)	Taxi service provider
Customer 4 (-)	Driver
Customer 5(-)	Poor people
Customer 6 (+)	Financial institutions
Transformation	Transport
Environment	Legal and technical environment; ethical issues are crucial; interest groups
Environment 2	The spirit of the times and global trends
Environment 3	Digital and Economic division of society
Environment 4	Legislative and regulatory area
Owner	State; taxi service provider
Actor	Taxi service provider
Actor	Technology experts

3.2. Definition of changes

We must find a wide forum where all these issues will be discussed. All perspectives must be respected and a compromise must be found. For such a democratic approach a motivation must be established. Then the following step consists in the definition of the perspectives, their respective CATWOE and analysis of the most problematic conflicts between them.

4. Discussion

At the beginning of our paper, we defined a broad field for research defined by research questions 1-3. In trying to apply the systemic approach to solve the managerial problem of AV commissioning, we narrowed the scope of the paper to the effort of partially answering question 3, i.e. to name the risks and benefits of AV from different perspectives and to suggest a way to resolve the conflicts between the interests of different stakeholders. To address this question, we used the CATWOE methodology within the SSM framework (P. Checkland).

We are so intrigued by the breadth and depth of AV issues that we are planning and opening further research in the areas defined by the two questions originally mentioned, but unresolved in our paper:

- Why does the society plan to introduce AV into the economy? And can the introduction of AV be avoided?
- Do we know the impacts of introducing AVs into the economy at the time of decision making? How does the society estimate that the decision to introduce AV will be made?

5. Conclusion

The introduction of autonomous cars is a complicated problem that combines many perspectives. We attempted to identify its risks and benefits and find the relevant stakeholders and their perspectives that will be affected. We conclude that both before and during the implementation many perspectives must be respected to find an acceptable solution.

6. Acknowledgement

This paper was prepared with the support of the project VŠE Praha 13/2021, IG409011

7. References

- Anderson, J. M., Nidhi, K., Stanley, K. D., Sorensen, P., Samaras, C., & Oluwatola, O. A. (2014). Autonomous vehicle technology: A guide for policymakers. Rand Corporation.
- Bagloee, S. A., Tavana, M., Asadi, M., & Oliver, T. (2016). Autonomous vehicles: challenges, opportunities, and future implications for transportation policies. *Journal of modern transportation*, 24(4), 284-303.
- Bergvall-Kåreborn, B., Mirijamdotter, A., & Basden, A. (2004). Basic principles of SSM modeling: an examination of CATWOE from a soft perspective. *Systemic Practice and Action Research*, 17(2), 55-73.
- Contissa, G., Lagioia, F., & Sartor, G. (2017). The Ethical Knob: ethically-customisable automated vehicles and the law. *Artificial Intelligence and Law*, 25(3), 365-378.
- Fleetwood, J. (2017). Public health, ethics, and autonomous vehicles. *American journal of public health*, 107(4), 532-537.
- Frase, P. (2016). *Four futures: Life after capitalism*. Verso books.
- GEAR 2030, (2017) Ensuring that Europe has the most competitive, Innovative and sustainable automotive industry of the 2030s and beyond: The Report of the High Level Group on the Competitiveness and Sustainable Growth of the Automotive Industry in the European Union
- Gogoll, J., & Müller, J. F. (2017). Autonomous cars: in favor of a mandatory ethics setting. *Science and engineering ethics*, 23(3), 681-700.

- Hevelke, A., & Nida-Rümelin, J. (2015). Responsibility for crashes of autonomous vehicles: An ethical analysis. *Science and engineering ethics*, 21(3), 619-630.
- Himmelreich, J. (2018). Never mind the trolley: The ethics of autonomous vehicles in mundane situations. *Ethical Theory and Moral Practice*, 21(3), 669-684.
- Checkland, P., & Poulter, J. (2020). Soft systems methodology. In *Systems approaches to making change: A practical guide* (pp. 201-253). Springer, London.
- Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., ... & Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Journal of clinical epidemiology*, 62(10), e1-e34.
- Keeling, G. (2020). Why trolley problems matter for the ethics of automated vehicles. *Science and engineering ethics*, 26(1), 293-307.
- Koopman, P., & Wagner, M. (2017). Autonomous vehicle safety: An interdisciplinary challenge. *IEEE Intelligent Transportation Systems Magazine*, 9(1), 90-96.
- LeBon, G., & Nye, R. A. (2017). *The crowd*. Routledge.
- Martínez-Díaz, M., & Soriguera, F. (2018). Autonomous vehicles: theoretical and practical challenges. *Transportation Research Procedia*, 33, 275-282.
- Mordor Intelligence (2022). Autonomous (Driverless) Car Market - Growth, Trends, COVID-19 Impact, and Forecast (2022 - 2027). <https://www.mordorintelligence.com/industry-reports/autonomous-driverless-cars-market-potential-estimation>
- Nyholm, S., & Smids, J. (2016). The ethics of accident-algorithms for self-driving cars: An applied trolley problem?. *Ethical theory and moral practice*, 19(5), 1275-1289.
- Roemer, M. (2022). How automakers can survive the self-driving era. Kearney. <https://www.kearney.com/automotive/article?/a/how-automakers-can-survive-the-self-driving-era>
- Smyth, D. S. & Checkland P. B. (1976). Using a Systems Approach: The Structure of Root Definitions. *Journal of Applied Systems Analysis*, 5 (1), 75-83.
- Sousa, N., Almeida, A., Coutinho-Rodrigues, J., & Natividade-Jesus, E. (2018, March). Dawn of autonomous vehicles: review and challenges ahead. In *Proceedings of the Institution of Civil Engineers-Municipal Engineer* (Vol. 171, No. 1, pp. 3-14). Thomas Telford Ltd.
- Sparrow, R., & Howard, M. (2017). When human beings are like drunk robots: Driverless vehicles, ethics, and the future of transport. *Transportation Research Part C: Emerging Technologies*, 80, 206-215.
- Taeihagh, A., & Lim, H. S. M. (2019). Governing autonomous vehicles: emerging responses for safety, liability, privacy, cybersecurity, and industry risks. *Transport reviews*, 39(1), 103-128.

A PROPOSED X.800-BASED SECURITY ARCHITECTURE FRAMEWORK FOR UNMANNED AIRCRAFT SYSTEM

Abdelkader Magdy Shaaban, Oliver Jung, Christoph Schmittner

Center for Digital Safety & Security

AIT Austrian Institute of Technology, Vienna

abdelkader.shaaban@ait.ac.at, oliver.jung@ait.ac.at, christoph.schmittner@ait.ac.at

DOI: 10-35011/IDIMT-2022-389

Keywords

Cybersecurity, Security Services, Security Mechanisms, Potential Threats

Abstract

Cybersecurity is considered to be one of the most challenging topics when developing cyber-physical systems. One typical example are weak security protection measures that can have a severe impact in many applications domains. The aviation domain and Unmanned Aircraft Systems are in particular vulnerable since they usually come with several wireless interfaces but only with limited processing power. Successful cyberattacks can have a multitude of negative consequences. A hijacked Unmanned Aerial Vehicle can potentially harm people or damage infrastructure. Network cybersecurity presents multiple sets of applicable protection mechanisms and security services for each network layer to ensure the full consideration of security issues. Therefore, in this work, we propose a security architecture framework that combines the security recommendations outlined in ITU-T X.800 with a threat modelling approach. This helps to classify the existing potential threats and define the applicable security mechanisms and services that can protect our system model against multiple cyberattacks.

1. Motivational Background

Unmanned aerial vehicles (UAVs) are becoming essential to our smart green world in multiple civil application domains. Their cost-effective and simple and easy handling makes them ideal for surveillance tasks, emergency services, smart farming, smart logistics and transport, smart cities and buildings, environmental monitoring, etc. UAVs require a secure communication channel to communicate with other connected system components (e.g., other UAVs, ground control stations, satellites, etc.) and accomplish a particular mission. However, addressing security issues in the Unmanned Aircraft System (UAS) is considered one of the challenges when establishing a secure system infrastructure. The lack of security protection measures in the UAS system design could lead to unexpected consequences. For example, the loss of integrity of the firmware of a Control Unit could constitute a safety impact for the UAVs and lead to other implications when it is flying over a populated area. Furthermore, cybersecurity is essential in the UAS domain because it aims to secure communication channels among all connected points in the UAS system model to ensure sufficient protection for securing data and critical components from different attack vectors (Shaaban, Jung, & Fas Millan, 2022).

In the field of network cybersecurity, the International Telecommunication Union (ITU-T) X.800 standard defines a collection of security services and methods for the Open Systems Interconnection (OSI) model to ensure that each network layer has appropriate protection against a variety of cyber threats. For each layer of the communication architecture, X.800 specifies security services and mechanisms that can be used for protection, starting from the Physical Layer (layer 1) up to the Application Layer (i.e., layer 7). The purpose of security services is to ensure that systems or data flows are appropriately protected from unauthorized access. Moreover, defined security policies can be considered as security mechanisms that should be enforced to meet the goals defined by the policies. These techniques could be utilized for various purposes, including the prevention, detection, and even recovery of a specific security issue (ITU, 1991).

For system protection threat modelling has become an essential method that helps determining potential cyber threats in a system, including risk management and mitigation measures. The Austrian Institute of Technology AIT (<https://www.ait.ac.at/en/>) developed an automated threat modelling approach that can be applied in multiple application domains, such as Automotive, Internet of Things (IoT), Cyber-Physical Systems (CPS), UAVs, etc. The tool aims to determine the propagation of cyber-attacks throughout a technological system based on a system model, a threat database, and security attributes applied to each system component.

This work presents a security framework for the UAS domain that evaluates all the known security vulnerabilities in a system model and determines which application security mechanisms based on X.800 should be implemented to mitigate the cyber risks in numerous. We first investigate which system components and related security information shall be defined to build a secure UAS application. The framework evaluates all applied security details in the system model by employing a threat analysis to identify and prioritize existing security vulnerabilities and developing a straightforward approach for identifying security mechanism to address these weaknesses. A collection of security recommendations provided by the X.800 will outline which security services shall be utilized by the UAV to address existing security issues. This work focuses on a multi-purpose UAV that could be used in multiple civil applications.

2. Structure of the Proposed Security Framework

The proposed security framework aims to investigate all applicable security details by applying a risk analysis to determine whether security mechanisms are applicable for addressing existing security issues. A set of security services shall be outlined to ensure adequate security protection is in place for the system and for data exchanged between multiple connected nodes in the network.

Figure 1 illustrates the structure of the proposed framework, which includes a set of recommended mechanisms in the UAS system design. As shown in the diagram above, the UAS system model is specified in the middle, and it contains all the system components with related security attributes. The threat analysis approach evaluates all the security attributes that have been implemented to ensure the effective mitigation of cyber threats. THREATGET considers a wide range of potential threats based on the state-of-the-art, which applies a set of rules to the proposed UAS model and determines any possible cyber incident propagating through the system network. The rule engine plays an essential role in automating the risk analysis process. On the righthand side, a set of mechanisms is defined as a security process for detecting, preventing, or recovering the UAS model from cyberattacks. A security service is defined (i.e., left-hand side) as a communication service or processing activity designed to improve the security of a system to process or transfer information.

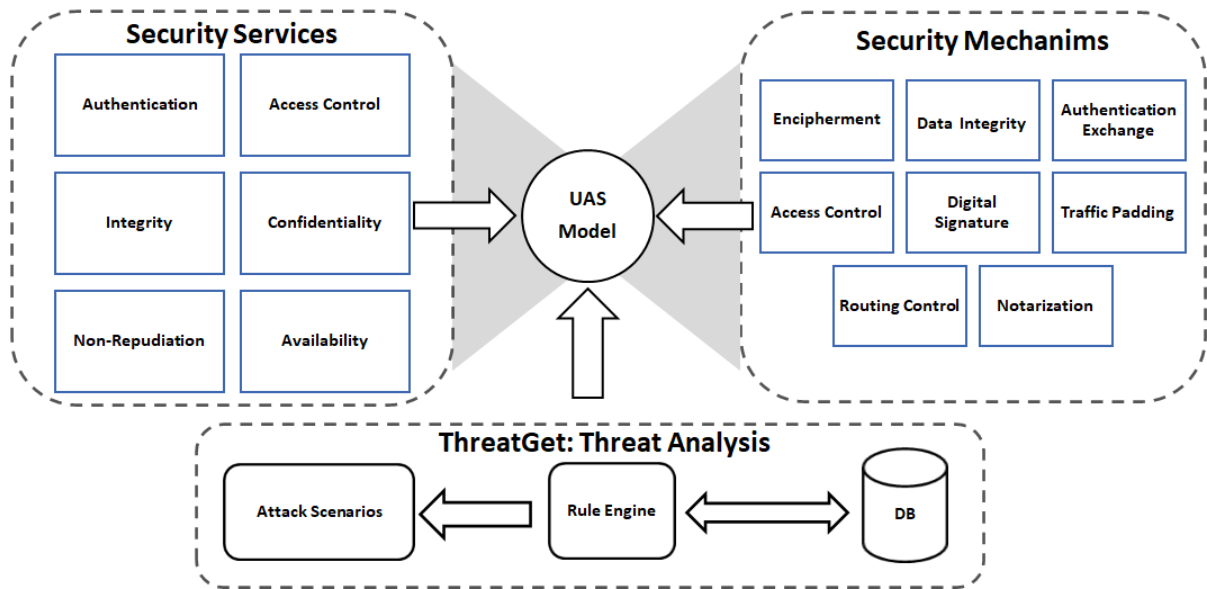


Figure 1. The Proposed Security Framework

2.1. Threat Analysis

The risk analysis plays a significant role in identifying and determining the exact cybersecurity issues in the UAV system model, leading to different types of potential cyber threats (Shaaban et al., 2022). Within the scope of the Horizon 2020 project Labyrinth (<https://labyrinth2020.eu>), we investigate related cyberattack scenarios in the UAV domain based on the state-of-the-art in order to consider a wide range of potential cyber threats in this domain. Therefore, we build a comprehensive threat database containing a wide range of previously investigated potential threats in the UAV domain. In order to automate the threat analysis process, we used the THREATGET threat modelling tool to perform threat analysis and investigate all security vulnerabilities in a UAS system model (Abdelkader Magdy & Christoph, 2020). The tool has a built-in rule engine that examines all components, communication channels, and relevant security details to determine security vulnerabilities in the system model. An example of a UAS model is illustrated in Figure 2.

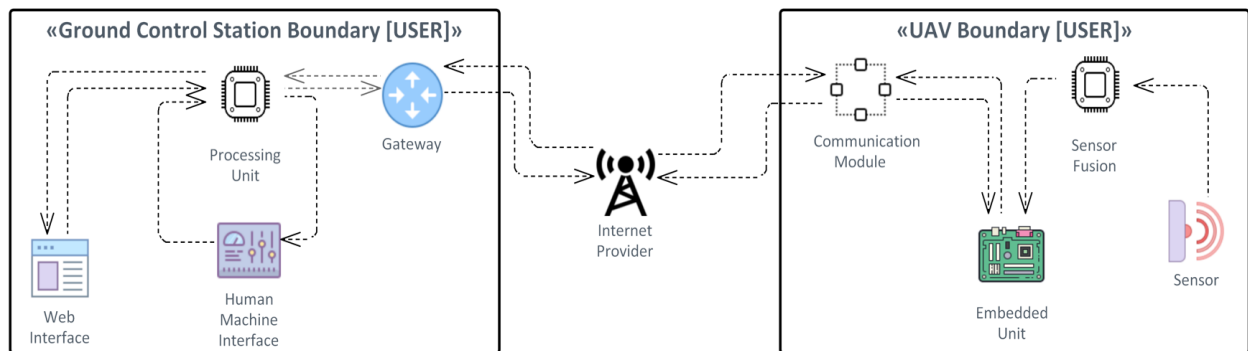


Figure2. A Modeled Structure of a UAS Example using THREATGET

This example shows a simplified representation of a structured UAS diagram modeled using the THREATGET tool. As shown in this diagram, the UAV comprises interconnected components such as a sensor, embedded control unit, and communication module; all these components are defined within a trusted boundary that defines the UAV perimeter. The Ground Control Station (GCS), depicted on the left-hand side of the diagram, has full control over the UAV. The GCS consists of a network device and a human interaction interface, as well as a web application for

controlling and monitoring the operation of the UAV's flight path and trajectory. The Internet service provider, which provides services for the Internet connection between the UAV and the GCS, is also illustrated in the diagram.

In order to detect security weaknesses and potential cyber hazards that could lead to unexpected adverse impacts such as unauthorized control of the UAV while flying over a populated zone, we conduct threat analysis to the system shown in the example diagram in 2. The results of the THREATGET analysis reveal the security vulnerabilities that exist in our system model and provide an understanding of the primary security problems that require additional security consideration. The threat analysis carried out using THREATGET identifies 76 potential threats. In accordance with the STRIDE approach (Shostack, 2014), the tool automatically maps these threats to one of the six major categories (i.e., **S**poofing, **T**ampering, **R**epudiation, **I**nformation Disclosure, **D**enial of Service, and **E**levation of Privilege), where each of these categories has an impact against a particular security measure, as discussed in (Abomhara et al., 2015); a summary of THREATGET's outcomes is defined in Table 1.

Table 1 STRIDE Model with Rate of the Identified Threats by THREATGET

STRIDE	Description	Violation	Detection Rate
Spoofing	Gain unauthorized access through a false identity	Authentication	15
Tampering	Intending to adjust data by an unauthorized manner	Integrity	22
Repudiation	Denying an action that a legal/illegal user performs.	Non-Repudiation	0
Information Disclosure	Disclose sensitive data by an unauthorized method.	Confidentiality	3
Denial of Service	Affect the availability of a specific service or system.	Availability	24
Elevation of Privilege	Unauthorized user claims that have a higher privilege.	Authorization	12

As shown in the table, each STRIDE category has a specific security target intended to be violated by the attacker. The detection rate represents the number of threats identified by THREATGET according to the STRIDE classifications. For example, 15 threats are determined by THREATGET classified as spoofing, whereas only three are classified as information disclosure. However, there is no repudiation violation identified by the tool. However, in a more complex UAS model, more threats will be identified, and repudiation could also be detected. In the following section we will present the different security services and related mechanisms as stated by X.800 to define appropriate measures for identifying, preventing, or recovering from any of the identified cyber-attacks. In addition, security services will be discussed that are used to improve the security of system data and the transmission of information among various interconnected nodes over a wide range of the UAS system components.

2.2. Security Mechanisms

X.800 defines multiple security mechanisms as a collection to deliver security services for the OSI model. The following is how these mechanisms are defined in (ITU, 1991) (Stallings, 2007):

- **Encipherment:** It is a method of protecting the confidentiality of data by first encrypting it in a not readable format and then decrypting it so that an authorized party may handle it.
- **Digital Signature:** The alteration of data via cryptography or adding extra data to a sensitive one helps prevent data from being forged by providing recipients with evidence of the data's integrity.
- **Access Control:** It provides access rights to resources.

- **Data Integrity:** It guarantees the integrity of data units or data streams.
- **Authentication Exchange:** Its purpose is to ensure an entity's identity through information exchange.
- **Traffic Padding:** The insertion of random bits into a data stream makes it impossible for an unauthorized third party to analyze the data.
- **Routing Control:** In the event that a breach of security is suspected, particular physically secure pathways must be chosen for specific data.
- **Notarization:** To ensure that specific data flow characteristics are maintained, it is essential to depend on a trustworthy third party to achieve a task.

2.3. Security Services

Services are a set of services supplied by a protocol layer of communication systems. These services ensures that a sufficient level of security is maintained for the system, or the data being exchanged. It categorizes these services into six categories and then divides them into fourteen specific services (Stallings, 2007). These services are defined as follows (ITU, 1991):

- **Authentication:** The authentication service is the one in charge of making sure that the communication is authentic:
 - **Peer Entity Authentication:** It utilizes during the setup of a connection or the data transmission phase.
 - **Data Origin Authentication:** This authentication service, which confirms the origin of a data unit, could be implemented in applications such as electronic mail, which do not require any prior communication setup to be established between the communicated terminals.
- **Access Control:** It is the capacity to restrict and govern access to host systems and applications via communication channels between devices. This capability is referred to as "access control." Access control models come in a variety of types, including Role-Based Access Control (RBAC), Discretionary Access Control (DAC), Mandatory Access Control (MAC), and Attribute-Based Access Control (ABAC), as discussed in (Magdy, Mohamed, Quirchmayr, & Schikuta, 2017).
- **Confidentiality:** The term "confidentiality" refers to the protection of transferred data from being disclosed inappropriately by unauthorized parties (IEC, 2019). According to X.800, there are different types of confidentiality (ITU, 1991).
 - **Connection Confidentiality:** This protects all user data on a connection.
 - **Connectionless Confidentiality:** This is defined to protect the confidentiality of all users accessing a single data block.
 - **Selective-Field Confidentiality:** This confidentiality service secures specific fields within a user's data on a connection or within a single data block.
 - **Traffic-Flow Confidentiality:** This service protects any data based on the observation of the data flow.
- **Non-Repudiation:** This aims at preventing either the sender or the recipient from denying transmitting data. Therefore, when a message is conveyed, it is feasible for the recipient to prove that the claimed sender of the message sent it (ITU, 1991). As described in (ITU, 1991), two types of non-repudiation are defined:

- **Non-repudiation Origin:** Proofs that a particular sender sent the data.
- **Non-repudiation Destination:** Proofs that a receiver obtained the data.
- **Integrity:** The guarantee that the data received is identical to the data that an authorized party sent. X.800 defines different types of this service (ITU, 1991):
 - **Connection Integrity with Recovery:** It protects user data and attempts to recover any incorrect data.
 - **Connection Integrity without Recovery:** It only detects any breach of data integrity but does not attempt to a recover action.
 - **Selective-Field Connection Integrity:** Provides the integrity of specified fields within the user data of a data block transmitted across a connection
 - **Connectionless Integrity:** Protection of the integrity of a single connectionless data block, which can be achieved by detecting changes in the data.
 - **Selective-Field Connectionless Integrity:** This aims at protecting a single connectionless data block by detecting changes.
- **Availability:** System or resource is available when an authorized system entity demands it.

2.4. Arrangement of Security Mechanisms

As the OSI reference model mandates a layered approach for communications ITU-T X.800 mandates a layered approach for security. Cybersecurity threats exists for each of the layers just like security mechanisms that are provided for each of the layer. However, as can be seen in Figure 1, not each of the layers is not reasonable to provide each of the security services on each of the layers.

Security services usually add overhead to the user data in communication systems. Thus, particularly in domains with scarce resources like UAVs the selection of security mechanisms needs to be carefully considered. Authentication, integrity, and non-repudiation services consume computing resources and add additional packet headers containing digital signatures or cryptographic check sums. Encipherment also uses computing resources. It does not add additional packet headers, but resources are required for the associated key management.

Implementing security mechanisms on several layers would support the defense in depth principal where in case security on one layer fails it is still provided by another layer. X.800 points out that a specific security service is provided by several layers if the impact on general communication security is different on each of the layers. One key aspect that needs to be taken into account when considering the different OSI layers is that layer 1 to layer 3 are only established hop-by-hop e.g., between a user equipment and a router. End-to-end connections are only established on layer 4 onwards. In the following we briefly elaborate on the decisions for providing security on different layers (ITU, 1991).

Peer entity authentication is considered useful on layer 3 and 4 where authentication on layer 3 provides support for routing while layer 4 authentication can be done in an end-to-end manner between peer entities before establishing a session. Peer entity authentication should be supported by the application layer.

Data origin authentication can be provided on layer 3 hop-by-hop and on layer4 end-to-end. It can also be supported by layer 7.

Depending on the purpose access control mechanisms can be employed on layer 3, layer 4 and layer 7. On layer 3 they would control access to sub-networks and on layer 4 an end-to-end basis. On layer 7 the access to applications can be controlled.

Non-repudiation is supported by layer 7 only and requires interaction with layer 6 when using digital signatures.

Integrity of user data without error recovery is considered most important for our application domain. This can be provided by layer3, layer 4 and layer 7. Layer 3 supports integrity for the sub-network domain while layer 4 supports where communications is ceased in case of an attack or packets are discarded. On layer 7 integrity is provided with support of mechanisms on layer 6.

Confidentiality can be provided by all layers but layer 5 where it does not provide any benefits over supporting it on other layers. Encipherment on layer 1 can provide complete confidentiality of a physical connection and can support traffic flow confidentiality. However, end-to end confidentiality can only be provided by layer 4 and above. Layer 7 can provide confidentiality by collaborating with layer 6.

2.5. Security Services and Mechanisms with THREATGET Outcomes

According to THREATGET's outcomes, multiple cyber-attacks are identified for our proposed UAS example (i.e., Figure 2). For this reason, this section examines certain selected potential threats detected by THREATGET and matches which suitable security mechanisms to prevent, recover, or handle cyberattacks, are required to provide a specific security service. Table 2 represents the security mechanisms selected for each identified threat to provide a particular security service.

Table 2 Proposed Applicable Security Mechanisms and Services for Selected Potential Threats

Threat	STRIDE	Security Mechanisms	Security Services
Multi-protocol attacks	S	Authentication Exchange	Authenticity
Compromise communication everywhere	T	Encipherment	Data Integrity
Security breach of GCS may lead to the UAV attack	E	Access Control	Access Control

The table includes some selected threats that are identified by THREATGET in order to match between the violation of security properties by each threat and related security mechanism for actual security service. The proposed framework aims to establish a mapping between all security breaches due to the propagation of potential threats with applicable security mechanisms and services. For example, the threat "Security breach of GCS may lead to the UAV attack", violates the authorization for a particular system component; therefore, this threat is classified as elevation of privilege according to the STRIDE mode. Then the applicable security services that shall be applied to the affected component is the Access Control because its grantee to give the control of the UAV by legitimate personal only. In addition, another attack scenario such as the "Compromise communication everywhere", this cyber threat aims at making the data link is entirely out of control from the legitimate ground control station (Lattimore, 2019). Also, threat such as "Multi-protocol attacks", is another malicious way that an attacker could compromise the communication protocols between the various components of the system architecture by either eavesdropping or faking the identity, as described in (Javaid et al., 2012), therefore, the Authentication Exchange shall be applied here as discussed in Section 2.2, in order to maintain the authenticity of the communication.

3. Outlook & Discussion

This work introduces a security framework for the UAS domain that combines security mechanisms and services provided by X.800 with the threat modeling approach to determine which measures shall be applied to address potential cyber threats. The work presents the following:

- The THREATGET tool is utilized to describe a UAS model with all relevant security details and investigate all the interconnected components to identify potential threats that could be propagated from any vulnerable point in the system model.
- A set of application security mechanisms described by X.800 to prevent, detect, and even recover from a specific security issue.
- A set of security services are defined to describe security policies based on the previously discussed mechanisms.
- The paper presents the violations of security measures in a UAS model and includes a set of security mechanisms proposed to address security threats that THREATGET identifies to provide a particular security service.

The future extension of this work will include automat this process by building a knowledge representation model that includes outcomes from the THREATGET tool and automatically building an inference automation approach to determine the applicable security mechanisms and services for addressing these cyber threats.

4. Acknowledgment

This work is accomplished as a part of the LABYRINTH project. The project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 861696.

5. References

- Abdelkader Magdy, S., & Christoph, S. (2020). THREATGET: NEW APPROACH TOWARDS AUTOMOTIVE SECURITY-BY-DESIGN. In IDIMT-2020 digitalized economy, society and information management (pp. 413–419). Retrieved 2020-10-02, from <https://idimt.org/wp-content/uploads/2020/07/IDIMTproceedings2020.pdf>
- IEC. (2019, Feb.). IEC 62443 - Security for industrial automation and control systems - part 4-2: Technical security requirements for IACS components (Tech. Rep.). International Standard.
- ITU. (1991, March). Security architecture for open systems interconnection for CCITT applications (ITU-T Recommendation X.800) (Tech. Rep.).
- Javaid, A. Y., Sun, W., Devabhaktuni, V. K., & Alam, M. (2012). Cyber security threat analysis and modeling of an unmanned aerial vehicle system. In 2012 ieee conference on technologies for homeland security (hst) (pp. 585–590).
- Lattimore, G. L. (2019). Unmanned aerial system cybersecurity risk management decision matrix for tactical operators (Tech. Rep.). NAVAL POSTGRAD-
- UATE SCHOOL MONTEREY CA. Magdy, A., Mohamed, A. B., Quirchmayr, G., & Schikuta, E. (2017). Towards a security and privacy protection model for semantic query engines. In Proceedings of the 19th international conference on information integration and web-based applications & services (p. 198–207). New York, NY, USA: Association for Computing Machinery. Retrieved from <https://doi.org/10.1145/3151759.3151776> doi: 10.1145/3151759.3151776

- Shaaban, A. M., Jung, O., & Fas Millan, M. A. (2022). Toward applying the iec 62443 in the uas for secure civil applications. In P. Haber, T. J. Lampoltshammer, H. Leopold, & M. Mayr (Eds.), *Data science – analytics and applications* (pp. 45–52). Wiesbaden: Springer Fachmedien Wiesbaden.
- Shostack, A. (2014). *Threat modeling: designing for security*. Wiley. (OCLC: ocn855043351)
- Stallings, W. (2007). *Cryptography and network security: Principles and practice.*, 743.

CHALLENGES AND TRENDS IN SOFTWARE DEVELOPMENT

MIGRATION FROM MONOLITHIC TO MICROSERVICE ARCHITECTURE: RESEARCH OF IMPACTS ON AGILITY

Josef Doležal, Alena Buchalcevo^á

Department of Information Technologies
Faculty of Informatics and Statistics
Prague University of Economics and Business
xdolj12@vse.cz, alena.buchalcevova@vse.cz

DOI: 10-35011/IDIMT-2022-401

Keywords

Monolithic architecture, microservice architecture, agile software development, Scrum

Abstract

In recent years, the microservice architecture has been gaining popularity in software development and is replacing the monolithic architecture. The migration process from monolithic to microservice architecture is achievable more easily for software development companies that successfully adopted the agile approach. Aim of the paper is to identify the benefits and challenges of migrating from monolithic to microservice architecture from the agile software development approach perspective. The research is based on data gained in a software company successfully practicing the Scrum framework.

1. Introduction

In the monolithic architecture, all functionality is encapsulated into one single application, so any part cannot be executed independently and parts are tightly-coupled (Ponce et al., 2019). This type of architecture no longer meets the needs of scalability and rapid development (Tapia et al., 2020).

Microservice architecture represents a distributed approach where all application modules are microservices, i.e., independent processes interacting via messages. These services are highly decoupled and are enabled for frequent deployment as per user requirements. Microservices can be implemented using various programming languages or databases (Sarita & Sebastian, 2017).

Microservice architecture is not suitable for every use case, and its implementation can be challenging. However, the popularity of microservices is rising, mainly because of its ability to solve maintenance problems and limited scalability of monoliths (Dragoni et al., 2017).

It seems like microservices fit into agile frameworks perfectly, as smaller teams can focus on individual services (Taibi et al., 2017). The nature of microservices increases software agility because each microservice becomes an independent unit of development, deployment, operations, versioning, and scaling (Jamshidi et al., 2018). However, some outcomes from practical experience argue that if the development process is still a waterfall and software development practices and technologies like DevOps or Docker are not embraced, there could be problems in the development and maintenance of microservices (Kranc, 2017).

There is a lot of studies dealing with different aspects of the migration from monolithic to microservice architecture (Kazanavičius & Mažeika, 2019; Mazlami et al., 2017; Blanch, 2022; Taibi et al., 2017; Fowler & Lewis, 2014), however they do not examine the impact of the migration process on software development agility. Hence, this paper aims at filling this gap and analyzes the impact of migration from monolithic to microservice architecture on agility in a small agile software development company.

The paper is organized as follows. Section 2 discusses the theoretical background. Section 3 presents the research methodology. Section 4 then describes the results. Finally, Section 5 presents the conclusions.

2. Background

In this section the basic concepts of monolithic architecture, microservice architecture, agile software development, Scrum, and the migration from monolithic to microservice architecture are explained.

2.1. Monolithic Architecture

Monolithic architecture represents a traditional way of creating software. The monolithic application is a software in which different components (such as authorization, business logic, notification module, etc.) are combined into a single program developed on a single platform (Gos & Zabierowski, 2020). It is a single unit, which usually consists of a client, a server-side monolithic application, and a database (Figure 1). All the functions are served and managed in one unit.

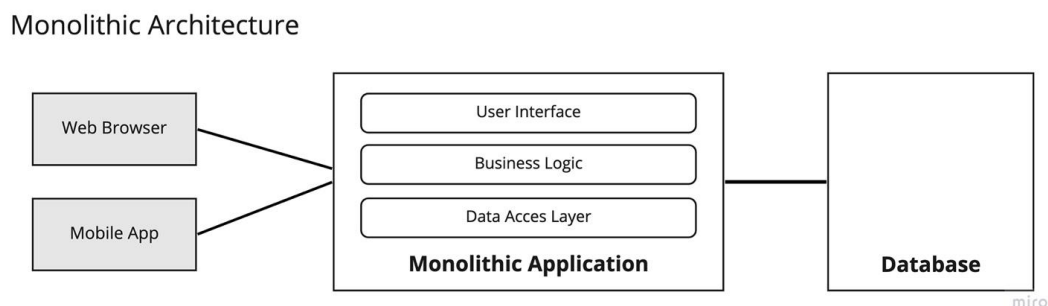


Figure 1. Monolithic Architecture (Kazanavičius & Mažeika, 2019)

Monolithic systems tend to have typically one large codebase. Whenever developers want to upgrade a specific aspect of the system, they must modify the entire application. So, because of the system's unified nature, every minor change affects the whole system (Insights, 2021). For a small team at the founding stage, it is recommended to start with a monolithic architecture, as it is difficult to manage, e.g., microservices with only 2-4 people. Similarly, the monolithic architecture is recommended when developing an unproven product or a proof of concept.

Other benefits that monolithic architecture brings include (Richardson, 2019):

- Ease of development. Monolithic architecture is better known and easier to implement.
- Relatively simple deployment. The entire application or system is uploaded as a single file, so complicated deployment is not needed.
- Easy testing and error tracing.

- Fast performance during the initial stages.
- Easier management. It's easier to set up, monitor, log, test, and deploy one solution than several separate units.

As for the disadvantages of monolithic architecture, the most important ones include (Lytvynenko, 2021):

- Poor scalability. Monolithic applications are easier to manage when they are small, but as it expands and employs new functions, it becomes more difficult to understand and scale.
- Poor stability. A problem in one module can crash the entire application due to the nature of the architecture.
- It can be more difficult to understand. Especially for new team members, it can be challenging to understand a huge monolithic system. With the growth of the application size, this problem gets worse.
- Minor changes are more complicated to implement. The whole system must be deployed even for minor fixes, which is inefficient.
- Future issues with speed. Deployment and launch time increase as an application grows.
- The monolithic application has a single tech stack. The process of implementation of new technology becomes highly complicated.
- Reliability. One error can possibly break down the entire system. This is one of the main disadvantages of monolithic architecture.

Although modern trends are pushing software companies to make their choice in favor of popular microservice architecture, monolithic architecture still has its benefits. However, when the application tends to become more complicated, the monolithic structure grows, becoming a large, hard to manage and scale piece of software.

2.2. Microservice Architecture

According to Lewis and Fowler (2014), the term microservices was first discussed at a May 2011 software architecture workshop to present a new architectural approach. Microservices are being employed by more and more companies around the world now, thanks to the results they are providing in software development processes (Baškarada et al., 2020).

Microservice architecture builds applications as sets of independently deployable units that represent entities of a particular business or mission domain. As we can see in Figure 2, the client part can be represented by a web browser or mobile application that communicate with the microservice providing a presentation layer. This User Interface microservice communicates with number of other microservices that provide the business logic.

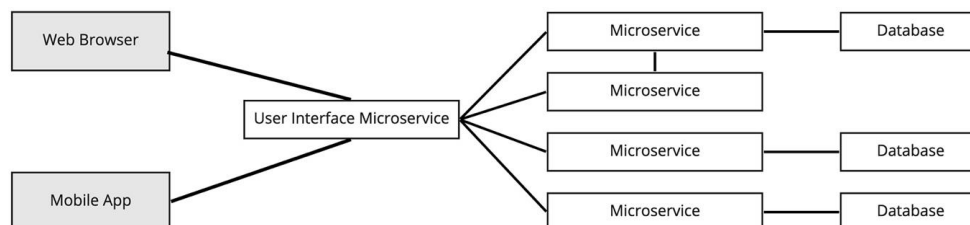


Figure 2. Microservice Architecture (Kazanavičius & Mažeika, 2019)

For example, an e-shop system may include microservices that handle transactions associated with customers, invoices, basket, payments, etc. All data/information associated with each of these entities belongs to its respective microservice. A microservice that needs information outside the boundaries of its own entity (e.g., the warehouse service needs a customer's address) must get it from the corresponding microservice (Ponce et al., 2019).

While there is no precise definition of microservice architecture, there are certain common characteristics around the organization of business capability, automated deployment, intelligence in the endpoints, and decentralized control of languages and data (Fellah & Bandi, 2021).

The most discussed reasons to start with microservice architecture are (Salah et al., 2016):

- **Microservices scalability.** Due to the system of individual microservices, the system as whole is flexible and capable of expanding. Including horizontal scaling – if one microservice experiences a significant load, it's the only one that needs a boost.
- **Performance.** Microservices-based solutions, if organized well, can outperform monolithic ones, especially when more complex software is involved.
- **Greater stability.** An application can run even if some of its microservices malfunction (fault isolation). This results in reduced downtimes.
- **Better security.** The relative isolation of microservice units typically means that attacks and data breaches will be more complicated to carry out on a system-wide scale.
- **Easy to introduce new technologies to the product** - each microservice can use different technology based on business, not technical requirements.
- **Error-proof.** Like the security, the microservice architecture allows establishing a boundary between certain parts of the system. This helps prevent unwanted mistakes – namely, connecting parts that shouldn't be connected. It also prevents tight couplings between the parts that should be linked.
- **Simplified onboarding.** Newcomers can jump on a specific microservice and immediately get into work, so they do not need to examine the entire system.

When considering the adoption of microservice architecture, it is necessary to take into account the disadvantages it brings (Lytvynenko, 2021):

- **Operational overhead.** Microservices are typically deployed on their own containers (docker) or virtual machines, which means lots of handling. These tasks should be automated with container fleet management tools. Independent deployment of each microservice is not effective.
- **Complicated deployment.** Large number of stand-alone services and connections between them require a more significant effort from developers to deploy the application.
- **High initial cost.** Complying hosting infrastructures, as well as skilled development teams to maintain the services, are expensive.
- **Complicated debugging.** It is necessary to trace the source of an error, which can become a challenge when an application consists of a variety of microservices, with each having its own set of logs.
- **Greater resource consumption.** Microservices architecture often requires not only more effort but more development time and manpower, which may not suit some companies.

- Complicated testing. Of course, a more complex system consisting of disparate services created using different tech stacks requires a more thorough approach to testing. Running a few automated scripts through the entire system will have no effect in such a situation.

2.3. Migration from Monolithic to Microservice Architecture

In general, there are two strategies how to migrate legacy monolithic software to microservice architecture. The first one is rebuilding, which means developing a new application. The second one is modernization, i.e., refactoring of the old application. Not all monolithic applications can be easily refactored to microservice architecture. Sometimes it is more economically beneficial to rebuild the application from scratch instead of to refactor it (Kazanavičius & Mažeika, 2019). As reasons speaking for building a new application we can state: (1) applications are built using very old languages and databases; (2) applications have a poor design, etc.

A key challenge in the process of migration is the extraction of microservices from existing legacy monolithic code bases. Identifying components of monolithic applications that can be turned into cohesive, standalone services is a tedious manual effort that encompasses the analysis of many dimensions of software architecture views and often heavily relies on the experience and know-how of the expert performing the extraction (Mazlami et al., 2017).

Because microservice architecture is a relatively new style and no widely approved way of doing migration exists, different organizations use different migration patterns and techniques (Blanch, 2022). According to Ponce, Márquez, and Astudillo (2019) we can name the Model-Driven approach, which uses design elements as input (using Domain-Driven Design), the Static analysis approach, which require the source code as input, and the Dynamic analysis approach, which analyze the system functionalities at runtime.

The microservice architecture adoption often brings challenges. Taibi et al. (2017) state the complexity to decouple from a monolithic system, the migration and splitting of data in legacy databases, and communication among services as the main issues. People's attitudes and minds are another reason speaking against migration, followed by concern for the lack of return on investment in the long run. According to Fowler & Lewis, (2014) there is a high overall cost associated with decomposing an existing system to microservices and it may take many iterations.

2.4. Agile Software Development

An agile approach to software development has become very popular in the last ten years. It is represented by various methods, frameworks, and approaches that are based on values and principles of the Agile manifesto (Beck et al., 2001). Agile approach concentrates on a collaboration of teams, which are self-organized and cross-functional.

Without a doubt, the most popular agile framework is Scrum (Digital.ai, 2021). Scrum defines three roles Product owner, Scrum master and Developers. Product owner is responsible for representing the customer's best interest and has the ultimate authority over the final product. Scrum master is a facilitator, responsible for arranging the daily meetings, improving team interactions, and maximizing productivity. Developers are the people in the Scrum team that develop products using so-called Sprints. Sprints are cycles of work, typically one to four weeks each. At the start of each Sprint, within the Sprint planning meeting a cross-functional team selects items from the Product backlog and this way agrees on what they believe they can deliver within the Sprint (Sprint backlog). Every day the team meets to briefly inspect its progress and adjust the next steps needed to finish the work remaining (Daily Scrum). At the end of the Sprint, the team members review the Sprint with stakeholders (Sprint review) and obtain feedback that can be incorporated in the next iteration. The purpose of the Sprint retrospective is to plan ways to increase quality and

effectiveness for the next Sprint. Scrum emphasizes a working product at the end of the Sprint that is integrated, fully tested, and potentially shippable (Product increment) (Deemer et al., 2012; Schwaber & Sutherland, 2020).

3. Research Method

The main goal of this paper is to analyze the migration from monolithic to microservice architecture with emphasis on agile values of the Scrum framework. For this purpose, the following research questions were formulated:

RQ1: What are the benefits and drawbacks of the migration from monolithic to microservice architecture from the Product owner's perspective.

RQ2: What are the benefits and drawbacks of the migration from monolithic to microservice architecture from the Scrum master perspective.

RQ3: What are the benefits and drawbacks of the migration from monolithic to microservice architecture from the Developer's perspective in an agile team.

To find answers to questions above, we decided to conduct a qualitative research based on semi-structured interviews (Wholey et al., 2010) with people from Scrum teams involved in the migration process. The following questions were prepared for interviews:

Q1: How has the migration from monolithic to microservice architecture affected your role in the software development process?

Q2: How has the migration from monolithic to microservice architecture affected the traditional Scrum ceremonies, namely Sprint planning, Sprint review, Daily Scrum, and Sprint retrospective?

Q3: Have there been any changes to Scrum artifacts like Product backlog, Sprint backlog, Product increment or Definition of Done connected to the migration from monolithic to microservice architecture?

Q4: How has the migration from monolithic to microservice architecture improved or worsened the agile development process?

The research was conducted in a small software company providing logistics solutions. Company began the process of migrating from monolithic to microservice architecture about two years ago. There are three development teams in the company that have been using an agile approach to software development, specifically the Scrum framework, for six years.

The data collection took place in February 2022. In total, four interviews were conducted, participants were one Product owner, one Scrum master, and two Developers.

The first part of the interview was structured, while the second part was not structured to obtain more detailed information. Each interview lasted about 40-60 minutes. The outputs were written down. Although various aspects of migration from monolithic to microservice architecture were discussed during interviews, in this paper we focus on those related to agility. Specifically, we focus on benefits of the migration from monolithic to microservice architecture, disadvantages of the migration, impact of the migration on Scrum events and Scrum artifacts from the Product owner's, Scrum master's and Developer's perspective.

4. Research Results

In this section the results of the research in a small software development company are presented structured based on individual research questions.

4.1. The Impacts of Migration to Microservice Architecture on the Product Owner Role

In general, the Product owner role was noticeably affected by the migration from monolithic to microservice architecture. As one who represented the interests of the customer and the product the Product owner placed emphasis primarily on increasing the frequency of software deliveries. The move to microservice architecture has significantly improved the continuous delivery process. New functionality has not been deployed to the customer in fixed deployment cycles as before, not even at the end of each Sprint, but continuously within a Sprint. The delivery to the customer has been defined as a condition for the User story completion and has been incorporated into the Definition of Done. The increased frequency of deployments has led to more frequent interactions with the customer and therefore increased agility.

Another important change that led to faster software delivery was the simplification of development parallelization. Teams could work on different services in parallel without worrying about inter-service dependencies.

Concerning Scrum ceremonies, the Product owner mentioned the biggest changes in the Sprint planning. With microservice architecture it was easier to structure development by features than by components, which among other things, also helped in communication with stakeholders.

As for Scrum artifacts, the Product backlog was mentioned by the Product owner specifically. The breakdown of the application into smaller parts has led to an increase in the number of User stories. On that account several User stories were aggregated into larger units called Features.

The Product owner, like other participants, also pointed out the increase in complexity of both the software development and the related processes.

4.2. The Impacts of Migration to Microservice Architecture on the Scrum Master Role

Compared to Product owner, Scrum master stated smaller number of changes caused by migration from monolithic to microservice architecture. The Scrum master mainly mentioned communication and coordination among teams and a need for higher team member's motivation.

Scrum master emphasized that breaking the application into smaller independent units simplified the distribution of application responsibilities among teams and helped to achieve the team's cross-functionality. It also reduced the issues related to dependencies among teams, which has led to increased efficiency.

Moreover, the Scrum master pointed out that ability to define Sprint goals more precisely has increased the team member's motivation during the Sprint. The Scrum master also mentioned the complexity of the transition to microservice architecture.

As for Scrum ceremonies and Scrum artifacts, the Scrum master has not observed major changes from his point of view. In particular, the Sprint retrospective was addressed in more detail, although according to the Scrum master remained unchanged.

4.3. The Impacts of Migration to Microservice Architecture on the Developer Role

Naturally, the technological aspects of migration from monolithic to microservice architecture dominated the outputs of the interviews with developers. They did not hide the challenges that accompanied the migration process. They stressed that issues related to deployment, operation, and monitoring should not have been underestimated. Furthermore, DevOps concept and associated automation of processes was marked as crucial. It was necessary to meet the higher requirements for knowledge, experience, and technical proficiency of the development team.

On the other hand, microservices made it easier for development teams to manage their work, and lower risks associated with creating new functionality. Adding or replacing individual microservices was much easier than redeploying the whole monolith.

The increased technological independence associated with migration from monolithic to microservice architecture was perceived positively. However, the possibility of developing microservices in whatever technology and still achieving service integration and interoperability has not been fully used yet. The main reason was the fear of introducing non-standard or rare technologies that other developers would not be able to cover if needed.

A major benefit was presented in relation to the reduction of inter-team dependencies, which had caused considerable problems before the migration.

In relation to Scrum events, the most important change was perceived within the Sprint planning and Backlog refinement meeting.

As for Scrum artifacts, the most important presented change was the update of Definition of Done rules for User stories, which helped to increase the frequency of software deliveries in line with the principle of Continuous delivery.

4.4. Summary of the Impacts of Migration to Microservice Architecture

In this section results of the conducted interviews are summarized from the perspective of the Product Owner, the Scrum Master, and the Developer. In Table 1 perceived benefits of the migration from monolithic to microservice architecture are outlined with the indication of which role the particular benefit has perceived. Table 2 depicts perceived disadvantages of the migration process again with the indication of which role the particular benefit has perceived. Then, Scrum events mentioned by individual roles as affected by migration from monolithic to microservice architecture are presented in Table 3, while Scrum artifacts with the indication of which role the particular artifact has mentioned in Table 4.

Table 1. Perceived benefits of the migration from monolithic to microservice architecture from the point of view of the Product Owner, the Scrum Master, and the Developer.

Perceived benefit of the migration from monolithic to microservice architecture	Product owner	Scrum master	Developer
Increased frequency of software deliveries	x		x
Increased number of iterations with the customer	x		
Development parallelization	x		x
Team motivation		x	x
Cross-functionality of teams		x	x
Lower risk of adding new functionality	x		x
Increased technological independence and agility			x
Lower inter-team dependencies	x		x
Easier communication with stakeholders	x		

Table 2. Perceived disadvantages of the migration from monolithic to microservice architecture from the point of view of the Product Owner, the Scrum Master, and the Developer.

Perceived disadvantage of the migration from monolithic to microservice architecture	Product owner	Scrum master	Developer
Need for higher knowledge and experience of developers		x	x
High costs of the migration process	x		x
Need for deployment automation			x
More complicated monitoring			x
More complicated logging			x
More complex Product backlog	x		x

Table 3. Scrum Events affected by migration from monolithic to microservice architecture from the point of view of the Product Owner, the Scrum Master, and the Developer.

Scrum event	Product owner	Scrum master	Developer
Sprint planning	x		x
Daily scrum			
Sprint			x
Sprint review	x		x
Sprint retrospective			

Table 4. Scrum artifacts affected by migration from monolithic to microservice architecture from the point of view of the Product Owner, the Scrum Master, and the Developer.

Scrum artifact	Product owner	Scrum master	Developer
Product backlog	x		x
Sprint backlog			
Increment		x	x
Definition of Done		x	x

5. Conclusion

The aim of the paper was to investigate the impact of migration from monolithic to microservice architecture focusing on software development agility. The research was conducted in the environment of a small software development company that has been following the Scrum framework. In this context, limitation of the paper should be mentioned. The number of participants was not high as the research was conducted in only one software company. Therefore, the validity of the research output can be influenced by the specifics of a local environment.

The findings show that migration from monolithic to microservice architecture had an impact on all roles of the Scrum framework and the associated processes. The most affected by the changes was the Development team, followed by the Product owner. The Scrum master was the least affected one.

Faster and more frequent deliveries of valuable features to customers, and an increase in the frequency of development iterations are perceived as the main benefits concerning development agility. Other described contributions supporting agility include reduced risks associated with frequent delivery of new functionality, more straightforward parallelization of development, increased developer motivation associated with clearer sprint goal setting, reduced cross-team dependencies, and easier management of the application scope.

As for Scrum ceremonies most changes were described for Sprint planning and Backlog refinement meeting. Mostly affected Scrum artifacts were Product backlog and Definition of Done.

Mostly mentioned challenge was the increase of complexity introduced by microservice architecture. This placed higher demands on knowledge and experience of developers. It was stressed that the deployment process, operational issues, and advanced monitoring should have been considered. Moreover, the DevOps concept and the associated automation was emphasized as critical for acceleration of development, testing, packaging, and deployment of microservice-based applications.

6. Acknowledgment

This work was supported by an internal grant funding scheme (F4/35/2022) administered by the Prague University of Economics and Business.

7. References

- Baškarada, S., Nguyen, V., & Koronios, A. (2020). Architecting Microservices: Practical Opportunities and Challenges. *Journal of Computer Information Systems*, 60(5), 428–436. <https://doi.org/10.1080/08874417.2018.1520056>
- Beck, K., Beedle, M., van Bennekum, A., Cockburn, A., Cunningham, W., Fowler, M., Grenning, J., Highsmith, J., Hunt, A., Jeffries, R., Kern, J., Marick, B., C. Martin, R., Mellor, S., Schwaber, K., Shuterland, J., & Thomas, D. (2001). Manifesto for Agile Software Development. <https://agilemanifesto.org/>
- Blanch, R. (2022). Microservices: Strategies for Migration in a Brownfield Environment. Medium. https://medium.com/@rhettblanch_48135/microservices-strategies-for-migration-in-a-brownfield-environment-6c14335a8069
- Deemer, P., Benefield, G., Larman, C., & Vodde, B. (2012). A Lightweight Guide to the Theory and Practice of Scrum. Ver, 2, 2012.
- Digital.ai. (2021). 15th Annual State Of Agile Report | Digital.ai. <https://digital.ai/resource-center/analyst-reports/state-of-agile-report>
- Dragoni, N., Giallorenzo, S., Lafuente, A. L., Mazzara, M., Montesi, F., Mustafin, R., & Safina, L. (2017). Microservices: Yesterday, Today, and Tomorrow. In M. Mazzara & B. Meyer (Eds.), *Present and Ulterior Software Engineering* (pp. 195–216). Springer International Publishing. https://doi.org/10.1007/978-3-319-67425-4_12
- Fellah, A., & Bandi, A. (2021). Microservice-based Architectures: An Evolutionary Software Development Model. CAINE 2020. The 33rd International Conference on Computer Applications in Industry and Engineering, 75, 41–48. <https://doi.org/10.29007/1gx5>
- Fowler, M., & Lewis, J. (2014). Microservices. [Martinfowler.Com. https://martinfowler.com/articles/microservices.html](https://martinfowler.com/articles/microservices.html)
- Gos, K., & Zabierowski, W. (2020). The Comparison of Microservice and Monolithic Architecture. 2020 IEEE XVIth International Conference on the Perspective Technologies and Methods in MEMS Design (MEMSTECH), 150–153. <https://doi.org/10.1109/MEMSTECH49584.2020.9109514>
- Insights. (2021, September 7). Monolith vs Microservices: Everything You Need To Know. Insights. <https://bambooagile.eu/insights/monolith-vs-microservices/>
- Jamshidi, P., Pahl, C., Mendonça, N. C., Lewis, J., & Tilkov, S. (2018). Microservices: The Journey So Far and Challenges Ahead. *IEEE Software*, 35(3), 24–35. <https://doi.org/10.1109/MS.2018.2141039>
- Kazanavičius, J., & Mažeika, D. (2019). Migrating Legacy Software to Microservices Architecture. 2019 Open Conference of Electrical, Electronic and Information Sciences (EStream), 1–5. <https://doi.org/10.1109/eStream.2019.8732170>
- Kranc, M. (2017). Thank you for not adopting microservices. *SD Times*. <https://sdtimes.com/agile/thank-not-adopting-microservices/>

- Lytvynenko, O. (2021). Monolithic vs Microservices architecture: What's the difference and which to choose? CodeIT. <https://codeit.us/blog/monolithic-vs-microservices-architecture>
- Mazlami, G., Cito, J., & Leitner, P. (2017). Extraction of Microservices from Monolithic Software Architectures. 2017 IEEE International Conference on Web Services (ICWS), 524–531. <https://doi.org/10.1109/ICWS.2017.61>
- Ponce, F., Márquez, G., & Astudillo, H. (2019). Migrating from monolithic architecture to microservices: A Rapid Review. 2019 38th International Conference of the Chilean Computer Science Society (SCCC), 1–7. <https://doi.org/10.1109/SCCC49216.2019.8966423>
- Richardson, C. (2019). Microservices Pattern: Monolithic Architecture pattern. Microservices.Io. <http://microservices.io/patterns/monolithic.html>
- Salah, T., Jamal Zemerly, M., Yeun, C. Y., Al-Qutayri, M., & Al-Hammadi, Y. (2016). The evolution of distributed systems towards microservices architecture. 2016 11th International Conference for Internet Technology and Secured Transactions (ICITST), 318–325. <https://doi.org/10.1109/ICITST.2016.7856721>
- Sarita, & Sebastian, S. (2017). Transform Monolith into Microservices using Docker. 2017 International Conference on Computing, Communication, Control and Automation (ICCUBEA), 1–5. <https://doi.org/10.1109/ICCUBEA.2017.8463820>
- Schwaber, K., & Sutherland, J. (2020). Scrum Guide. <https://scrumguides.org/scrum-guide.html>
- Taibi, D., Lenarduzzi, V., & Pahl, C. (2017). Processes, Motivations, and Issues for Migrating to Microservices Architectures: An Empirical Investigation. IEEE Cloud Computing, 4(5), 22–32. Scopus. <https://doi.org/10.1109/MCC.2017.4250931>
- Taibi, D., Lenarduzzi, V., Pahl, C., & Janes, A. (2017). Microservices in agile software development: A workshop-based study into issues, advantages, and disadvantages. Proceedings of the XP2017 Scientific Workshops, 1–5. <https://doi.org/10.1145/3120459.3120483>
- Tapia, F., Mora, M. Á., Fuertes, W., Aules, H., Flores, E., & Toulkeridis, T. (2020). From Monolithic Systems to Microservices: A Comparative Study of Performance. Applied Sciences, 10(17), 5797. <https://doi.org/10.3390/app10175797>
- Wholey, J. S., Hatry, H. P., & Newcomer, K. E. (2010). Handbook of Practical Program Evaluation. John Wiley & Sons.

DOES AGILE MANAGEMENT CONTRIBUTE TO THE OVERALL SATISFACTION OF THE PROJECT?

František Hašek, Hana Mohelská

Faculty of Informatics and Management
University of Hradec Králové
frantisek.hasek@uhk.cz, hana.mohelska@uhk.cz

DOI: 10-35011/IDIMT-2022-413

Keywords

Agile, Agile project management, Pulse meeting

Abstract

Over the past two decades, agile project management has been adopted by a large number of organizations to increase project efficiency. Agile methods were initially applied in the software development industry for small project teams following the Agile Manifesto principles and later spread to many other industries. Many studies describe agile methodologies, their threats, benefits for teams and society as a whole, the ability to respond to rigid projects and much more. Still, there are not enough resources for empirical research comparing the success of agile and traditional projects. This study aims to determine whether the use of agile methodologies in project management impacts the overall satisfaction of projects. The study tested this on data obtained from the Pulse meeting, which is used to assess the status of projects at two-week intervals. Almost 1,300 records on the status of a large Czech manufacturing company's 60 most significant IT projects were tested using the Chi-square test. Paper compared the overall status of agile and traditionally managed projects. These findings suggest that the projects that use agile methods have significantly better overall status. Therefore, it can be stated that implementing agile management has a significant benefit. Further, directions for future research are discussed.

1. Introduction

With the increasing intricacy and complexity of projects, it was necessary to find a method that should be developed during the project, widely applicable and respond quickly to the required changes according to the feedback (Malik et al., 2019). Agile approaches to managing software projects have their roots in the Agile Manifesto, which was developed as a counterpart for classical waterfall development in the Snowbird, Utah, USA (Williams, 2010). These classical approaches are cumbersome, cannot respond to fast changes, and are often unable to meet deadlines. Traditional project management is very limited in today's complex and rapidly changing business world. The traditional plan-driven top-down approach is inflexible and can hardly respond to changing customer requirements (Bergmann & Karwowski, 2019). The traditional requirements of time, cost and quality have to be extended by other indicators - the scope and satisfaction of stakeholders. Compared to traditional approaches (e.g. waterfall), the agile method brings benefits in a continuous design, flexible range of projects, considerable interaction with the client and better organization of the project team.

Agile approaches are based on five essential priorities (Beck et al., 2001):

- Individuals and interactions over processes and tools.
- Working software over comprehensive documentation.
- Customer collaboration over contract negotiation.
- Responding to change over following a plan.

Implementing this methodology is a worldwide trend, especially in IT companies where agile management is deployed with long-term success compared to traditional waterfall approaches (Muhammad et al., 2021). However, agile methodology has positive effects on IT projects and everywhere where dynamics and flexibility are necessary. It is possible to use it for large projects, only for individual parts of the small projects and also in the fields that are not even close to software development like research, teaching or services. The main benefits in other sectors are mainly teamwork, flexibility and productivity (Gustavsson, 2016).

Several agile methods have emerged, and all are characterized by the fact that self-organizing teams work on projects in which new roles are created that may not be directly related to the employee hierarchy in the company. An example of an agile method is SCRUM. It improves the iterative and incremental approach provided by object-oriented software. The development team works together to achieve a common goal. It gives flexibility and allows us to respond to initial and additional software development requirements (Schwaber, 1997). One of the other methods is XP (Extreme Programming), a development discipline based on the values of simplicity, communication and strong feedback. An essential element of XP is the client, which is the team's centre. All common activities are taken to an extreme (source code revision, constant testing, short iterations) (Lindstrom & Jeffries, 2004).

Agile project management brings many benefits, for example, it enables effective project management even if the persons involved are not experienced experts but novices (Serrador & Pinto, 2015). Agile principles are fundamental truths, a direction that does not change much over time. Most users use a hybrid agile methodology and adjust agile principles according to specific requirements (Williams, 2010). There is generally not the best methodology for project management, each has its advantages and disadvantages. Each project needs a specific approach and a selection of appropriate methods for its specifics, some projects may be unsuitable for deploying an agile approach. These are, for example, organizations with a large number of teams and staff or projects with a huge budget (Alsaqqa et al., 2020). Many companies are implementing these principles gradually, in parts, and are becoming increasingly agile (Abrahamsson et al., 2003).

The analyzed data come from nearly two years of monitoring sixty IT projects using the Pulse meeting method. It is a lean deviation management methodology that has its origin in the Swedish automotive industry, from where it was gradually extended to other countries and industries. The name comes from the analogy of an examination where a doctor measures a patient's pulse to determine his health condition. Similarly, managers use Pulse meeting to find out what the state of the company's projects is. Its principle is concise Pulse meetings, where the deviations are visualized using traffic-coded magnets on whiteboards called Pulse board (Kaya et al., 2014). Pulse meetings at regular intervals (for example, once every two weeks) make it possible to indicate and solve crucial problems in time. Initially, the Pulse meeting was only offline, but the online version brings benefits like communication, data storage, data history backtracking capabilities and others. This method was introduced in 2003 by Scania (Kaya et al., 2014). Still, there is not enough literature to date on this effective method, and most of the information comes from the company's internal sources. During the Pulse meeting, employees will meet at a Pulse board for a short time, update the project's current status and describe it in a few sentences. The Pulse meeting evaluates

the monitored parameters in green, yellow and red. Aspects that are not deviating are marked in green. Yellow indicates the risk of deviation, and red indicates deviation. If necessary, after the Pulse meeting, possible solutions to the problems are discussed (Volkswagen AG, 2022).

The basic ideas of agile methodology are clear, logical and seemingly beneficial. However, there is still a lack of sufficient papers dealing with the empirical comparison of agile and non-agile projects. Therefore, this paper aims to verify whether agile project management is more beneficial than traditional project management approaches. The data obtained from Pulse meetings will be used for comparison, where it is recorded, among other things, whether the project is managed by a traditional waterfall approach or agile and the overall satisfaction of these projects. Specifically, it is a question of determining whether IT projects organized by agile have a better overall status rating than projects managed in the traditional way (waterfall).

2. Data and Methodology

All data are obtained from the IT department of a Czech company operating in the manufacturing industry. The company has more than 250 employees, and its annual turnover is more than 50 million euros, so it belongs to the category of large companies (European Commission. Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs., 2019). The data is obtained from the Pulse meetings table, where basic data on projects are recorded every two weeks, such as project phase, overall status and more (the company does not wish to publish further information). Data from individual Pulse boards were aggregated into one table and subsequently reduced by projects monitored for a month or less. Only sixty of the most significant projects of at least 250 man days are used for the purpose of this paper. A total of 1298 records were obtained describing the overall status of the agile projects and projects managed traditionally. More detailed information about projects cannot be published at the company's request.

The purpose of this paper is to find out whether agile projects in real use have higher overall status values. The best way to evaluate it is by comparing the overall status of agile and non-agile projects recorded by Pulse meetings. Overall status summarizes the status of individual parts of projects and is recorded at regular bi-weekly intervals on the Pulse board. For this purpose, the most suitable method is the Chi-square test. The Chi-square test is based on a comparison of observed (empirical) and expected frequencies, thus determining whether there is any relationship between the state of overall satisfaction and the project management method (in this case, agile and non-agile management) (Rabušic et al., 2019). The prerequisites for this test have been met. The following hypotheses were established for this test.

H0: There is no difference in the overall status of agile-managed and non-agile-managed projects.

H1: There is a difference in the overall status of agile-managed and non-agile-managed projects.

3. Results

This article focuses on an empirical comparison of the overall statuses of agile and non-agile projects in the IT department of the manufacturing company. This paper used all the available data from the Pulse meetings. After clearing data from almost 60 projects, 1298 project progress records remained, of which 628 were agile-managed projects and 670 were non-agile-managed projects. The statistics did not include projects whose status was recorded in pulse meetings for less than a month.

Table 1: Overall status crosstabulation

Agile implementation		Overall status			
		Red	Yellow	Green	Total
Non-agile	Count	65	374	231	670
	Adjusted Residual	1,6	3,5	-4,5	
Agile	Count	45	290	293	628
	Adjusted Residual	-1,6	-3,5	4,5	
Total		110	664	524	1298

Table 1 outlines the descriptive statistics of the data set from Pulse meetings, and these are the traffic lights overall status of agile and non-agile managed projects. Adjusted residuals in Table 1 describe how significant the differences are between actual and expected frequencies. The adjusted residual values indicate that green agile projects (projects running without deviation) have significantly higher adjusted residual values than expected values. Therefore, as part of overall satisfaction, these projects are significantly more often marked in green which means fewer deviations and a better course of the entire project life cycle.

Table 2: Pearson Chi-square

	Value	Df	Asymptotic Significance
Pearson Chi-Square	20,261	2	<0,001

Table 2 describes the result of the Chi-square test. Hypothesis tests were performed using IBM SPSS software. The Chi-square test results is a p-value of $p < 0.001$. At the level of significance $\alpha = 0.05$, H_0 is rejected. There is a difference in the overall status of agile and non-agile projects. This article verifies the effectiveness of implementing agile methodologies in large projects using empirical analysis of the overall statuses of projects in the IT department. These results suggest that agile project management has a statistically significant positive effect on the overall status of projects.

4. Conclusion

Agile project management methods are largely implemented across industries. These changes in project management are caused by higher market dynamics, which reduces the time needed for bringing a product to the market (time-to-market cycle) (Thesing et al., 2021). Implementing agile management seems beneficial and logical, but there is still a lack of publications addressing the real benefits of agile management for large projects. This paper examined whether the status of projects managed using the agile approach is better than projects managed using the traditional waterfall approach. Data from all projects come from the IT department of a large Czech manufacturing company. All data comes from the management tool Pulse board, which, in this case, monitors and evaluates key project indicators in three states. Aspects not deviating are marked in green; yellow indicates the risk of deviation, and red indicates deviation. For this article, projects have been divided into agile-driven and traditional-driven projects. Preliminary descriptive statistics showed that overall satisfaction of an agile project is better with a lower number of deviations. The subsequent Chi-square test confirmed this fact, and it is, therefore, possible to declare that the course of agile projects is less problematic than other projects, and there is a lower number of deviations.

Furthermore, other studies show that implementing agile methods brings favourable aspects to agile projects, especially for the project manager, the project team or the new product development process (Conforto et al., 2014). These outputs support the findings of Serrador & Pinto (2015), who found that the level of agility used in the projects has a statistically significant impact on efficiency,

stakeholder satisfaction and perception of overall project performance. However, the authors obtained data from many companies, which could lead to inconsistencies in the data and deviations in the evaluation methodology in individual companies, this research focused on data from one large company, so it is likely that project evaluation should be consistent.

The findings of this research provide interesting results in using agile methods in practice, but this research has certain limitations. For example, the company does not wish to publish more detailed information about projects, such as what agile management methods are applied. Data is entered manually by individual project managers, and there may be slight subjective deviations. Another limitation is the Pulse meeting, which is an effective tool for top managers but does not provide more detailed data. Another direction of research can be more detailed metrics, such as meeting delivery deadlines, satisfaction with the delivered product, satisfaction of team members etc.

5. Acknowledgement

The paper was written with the support of the specific project 6/2022 grant "DETERMINANTS OF COGNITIVE PROCESSES IMPACTING THE WORK PERFORMANCE" granted by the University of Hradec Králové, Czech Republic.

6. References

- Abrahamsson, P., Warsta, J., Siponen, M., & Ronkainen, J. (2003). New Directions on Agile Methods: A Comparative Analysis.
- Alsaqqa, S., Sawalha, S., & Abdel-Nabi, H. (2020). Agile Software Development: Methodologies and Trends. *International Journal of Interactive Mobile Technologies (iJIM)*, 14(11), 246. <https://doi.org/10.3991/ijim.v14i11.13269>
- Beck, K., Beedle, M., Bennekum, A. van, & Cockburn, A. (2001). Manifesto for Agile Software Development. <https://agilemanifesto.org/>
- Bergmann, T., & Karwowski, W. (2019). Agile Project Management and Project Success: A Literature Review. In J. I. Kantola, S. Nazir, & T. Barath (Ed.), *Advances in Human Factors, Business Management and Society* (Roč. 783, s. 405–414). Springer International Publishing. https://doi.org/10.1007/978-3-319-94709-9_39
- Conforto, E. C., Salum, F., Amaral, D. C., da Silva, S. L., & de Almeida, L. F. M. (2014). Can Agile Project Management be Adopted by Industries Other than Software Development? *Project Management Journal*, 45(3), 21–34. <https://doi.org/10.1002/pmj.21410>
- Gustavsson, T. (2016). Benefits of Agile Project Management in a Non-Software Development Context: A Literature Review. *Project Management Development – Practice and Perspectives*.
- Kaya, O., Catic, A., & Bergsjö, D. (2014). Exploring the Possibilities of Using Image Recognition Technology to Create a Hybrid Lean System for Pulse Methodology. *Procedia Computer Science*, 28, 275–284. <https://doi.org/10.1016/j.procs.2014.03.035>
- Lindstrom, L., & Jeffries, R. (2004). Extreme Programming and Agile Software Development Methodologies. *Information Systems Management*, 21(3), 41–52. <https://doi.org/10.1201/1078/44432.21.3.20040601/82476.7>
- Malik, R. S., Ahmad, S. S., & Hussain, M. T. H. (2019). A Review of Agile Methodology in IT Projects. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3351064>
- Muhammad, U., Nazir, T., Muhammad, N., Maqsoom, A., Nawab, S., Fatima, S. T., Shafi, K., & Butt, F. S. (2021). Impact of agile management on project performance: Evidence from I.T sector of Pakistan. *PLOS ONE*, 16(4), e0249311. <https://doi.org/10.1371/journal.pone.0249311>
- Rabušic, L., Mareš, P., & Soukup, P. (2019). *Statistická analýza sociálněvědních dat (prostřednictvím SPSS) (2., přepracované vydání)*. Masarykova univerzita.

- Serrador, P., & Pinto, J. K. (2015). Does Agile work? — A quantitative analysis of agile project success. *International Journal of Project Management*, 33(5), 1040–1051. <https://doi.org/10.1016/j.ijproman.2015.01.006>
- Schwaber, K. (1997). SCRUM Development Process. In J. Sutherland, C. Casanave, J. Miller, P. Patel, & G. Hollowell (Ed.), *Business Object Design and Implementation* (s. 117–134). Springer London. https://doi.org/10.1007/978-1-4471-0947-1_11
- Thesing, T., Feldmann, C., & Burchardt, M. (2021). Agile versus Waterfall Project Management: Decision Model for Selecting the Appropriate Approach to a Project. *Procedia Computer Science*, 181, 746–756. <https://doi.org/10.1016/j.procs.2021.01.227>
- Williams, L. (2010). Agile Software Development Methodologies and Practices. In *Advances in Computers* (Roč. 80, s. 1–44). Elsevier. [https://doi.org/10.1016/S0065-2458\(10\)80001-4](https://doi.org/10.1016/S0065-2458(10)80001-4)

A SINGLE CASE STUDY ON PRODUCT OWNER ACTIVITIES IN SAFe: PRELIMINARY RESULTS FROM FOCUS GROUP GATHERINGS

Daniel Remta

Department of Information Technologies
Faculty of Informatics and Statistics
Prague University of Economics and Business
xremd03@vse.cz

Matthew McLaughlin

Faculty of Business, Justice and Behavioral Sciences
Charles Sturt University, Bathurst
mmclau08@postoffice.csu.edu.au

DOI: 10-35011/IDIMT-2022-419

Keywords

Product Owner, Activities, Large-scale Agile, SAFe, Enterprise Software Development, Agile

Abstract

Agile work organization methodologies are popular with companies focused on software development regardless of their size. In large-scale environments, Agile with associated roles is often tailored. This tailoring is projected into the large-scale agile frameworks, among which the Scaled Agile Framework is the most popular. As one of the challenges with Scaled Agile Framework adoption, satisfying the requirements of the Product Owner role was identified. However, any empirical research on the Product Owner's function in SAFe is scarce. This paper presents the preliminary results from the single-case study on Product Owner role activities in Scaled Agile Framework. During this study, the focus group consisting of 7 Product Owners generated a list of 62 activities they are regularly involved with. Results indicate that Product Owner's duties and responsibilities in SAFe seems to be only partially aligned with the existing knowledge but doesn't provide enough data to understand the day-to-day Product Owner activities.

1. Introduction

With a history of over 20 years on the market, the so-called Agile approach to software development is no news to organizations (Gustavsson et al., 2022). The organizations focused on software development typically operate in a dynamically changing and developing environment. Hence, the ability to quickly respond to market changes and emerging opportunities is a must for organizations to compete and thrive (Knaster & Leffingwell, 2020). The various Agile approaches aim to facilitate this flexibility. The term "Agile" refers to iterative and incremental practices stemming from a set of values and practices guiding modern approaches to software development (Gustavsson et al., 2022). At first, Agile was designed for small, collocated, and self-organizing

teams, but the success of various agile methods in small projects inspired companies to adopt Agile in large-scale projects and organizations (Uludag et al., 2021). To help organizations adopt Agile and its practice, various frameworks for scaling Agile emerged (Vaidya, 2014). The frameworks are still based on the original agile methods, such as Scrum (Schwaber & Sutherland, 2020), but the original concepts and roles are adjusted. The reflections of the role adjustments are visible in the most popular framework for scaling agile, the Scaled Agile Framework (SAFe) (digital.ai, 2021). When a large-scale agile framework is implemented, original roles defined with agile methods are tailored, and new roles are often introduced, such as product managers or architects (Remta & Buchalcevova, 2021).

In our paper, we focus on the Product Owner role, which has been identified to play a crucial role in the success of projects in large-scale environments (Dikert et al., 2016). Remta and Buchalcevova (2021) described the difference in the scope of activities expected to be performed by the Product Owner role in the Scaled Agile Framework (SAFe) when compared to the role outside this framework. However, these findings were based only on the existing research papers and SAFe description and were not supported by any empirical research. In this paper, we aim to provide an empirical view on the role by the conduction of research on the Product Owner role in a selected company that follows SAFe. A single case study using the online focus group (Richard et al., 2021) as the data collection method was selected as the research method and conducted in a multinational enterprise software development company. The goals of this paper are (1) to provide an overview of the activities performed by the Product Owners in the selected organization so that their management better understands the scope of their activities (2) Compare the results from (1) with existing theoretical findings.

The paper is organized as follows. Following the introduction, Section 2 provides an overview of the existing research on the Product Owner's role in a large-scale environment. In Section 3, the research method and context of the study are presented. Section 4 contains the results from the conducted study. Then, Section 5 concludes the paper with a discussion and a summary of key take-aways.

2. Background

Many organizations use large-scale agile frameworks that come with pre-defined coordination practices and tools to improve the efficiency of software development processes (Gustavsson et al., 2022). Despite existing criticism for the risk of delimiting autonomy for a single team (Alqudah & Razali, 2016), SAFe is the most popular large-scale agile framework (digital.ai, 2021). SAFe provides prescriptive guidelines to implement enterprise-scale Lean-Agile development (SAFe, 2020). There are existing challenges with adopting the framework (Dikert et al., 2016). Putta et al. (2018) stated that staffing the right Product Owner is one of the major challenges when adopting SAFe.

2.1. Product Owner

The Product Owner role originates from Scrum (Schwaber & Sutherland, 2020), the first agile process introduced in the 1990s (Sutherland & Schwaber, 1995). Three roles were defined within the process: Product Owner, Development Team, and Scrum Master. In Scrum, the work is done in iterations of 1–4 weeks called Sprints, each aiming to deliver a potentially releasable product increment. Every increment contains implemented functionality to meet requirements selected by the Product Owner, who is accountable for maximizing the value of the product resulting from the Development Team's work and for effective Product backlog management. When a large-scale agile framework is implemented, new roles are introduced, such as those of product managers or

architects, and the original concept of the Product Owner role changes (Remta & Buchalcevova, 2021).

2.2. Existing research on Product Owner in Large-Scale Environment

Bass and Haxby (2019) conducted 46 interviews with eight companies to explore how the Product Owner's role in meeting the needs of large-scale geographically distributed software projects. It was concluded that the scope of activities goes beyond the capacity of one person acting as a Product Owner on a large scale. None of the companies included in the research practiced SAFe. Berntzen et al. (2019) indicated that coordination between the Product Owner role and the team leader role is key for high-quality communication, knowledge sharing, and updates about goal attainment with the teams. Their analysis of Product Owner showed that (1) coordination varies depending on the context of each Product Owner (type of team, experience, preferences), (2) a focus on high-quality communication changes coordination over time, and (3) unscheduled coordination enables high-quality communication (Berntzen et al., 2019). Gustavsson et al. (2022) described that implementing SAFe limited the ability to choose which features to implement and that Product Owners divide features between teams without involving the developers, and therefore limit the team's autonomy. However, the focus of the study was on the team's autonomy, not the Product Owner's role. Unger-Windeler et al. (Unger-Windeler et al., 2019) did a mapping study on Product Owners in the industry. They concluded that the Product Owner's role in large-scale projects is clearly defined as a group effort, and the Product Owner's management and leadership responsibilities remain unanswered. Remta and Buchalcevova (2021) analyzed the Product Owner roles specifics in SAFe. They identified a significant difference in the scope of activities expected to be performed by the Product Owner role in SAFe to the original concept of the Product Owner's role. SAFe clearly distinguishes between the Product Manager and Product Owner and distributes the activities among the roles. The results in the study (Remta & Buchalcevova, 2021) were derived from the existing research papers and available description of SAFe (SAFe, 2020) and had no empirical part. Overall, empirical research on the Product Owner role in SAFe is scarce. This paper contributes to reduce this gap.

3. Research Method

This section describes the selected research method and the overall process of the study conduction. Then, the study context is described, and the information about the participants is provided. As the key research method, a single case study was selected. Case studies are used in order to investigate contemporary phenomena in their natural context and allow the researcher to obtain findings through the analysis in depth of typical or special cases and thus understand how the phenomena interact with the context (Runeson & Höst, 2008). To collect the data and evidence a focus group was created. The group collaborated throughout multiple iterations to generate inputs for our study. It resulted in a slightly modified process for conducting the case study, initially described by Runeson & Höst (2008).

3.1. Case Study Context

The study was conducted in an organization that is part of a multinational corporation with more than 20 000 employees. The organization has been in operation since the 1970's and was acquired by this corporation in 2018. The examined Value Stream has followed SAFe (SAFe, 2020) since 2017. The focus group was assembled from Product Owners working in a division that delivers mainframe software. They specifically focus on Operations and Automation software. Most products are represented by on-premise software sold to customers with licenses and support. The

typical customer is a large multinational corporation or government agency. Leadership, teams, and even team members within one team are distributed mostly in the Czech Republic and the United States of America. There were 7 Product Owners participating in the study. The Product Owners were asked to participate in the study through their management while the participation was voluntary. Table 1 provides the background information about each participant, namely: Number of months participant is acting as Product Owner; number of teams participant is collaborating with; total number of team members from these teams; number of products the participant is responsible for; years of the participant experience in the field; and participant previous job role.

Table 1 - Research Participant's Background

PO id	Months in the role	Teams	Members	Products	Years in the field	Previous role
A	34	6	32	4	11	Product Owner
B	132	2	18	2	38	Director, Software Engineering
C	18	2	11	1	23	Product Manager
D	9	1	10	2	15	Test Operations Engineer
E	60	2	17	2	10	Quality Assurance
F	84	2	12	2	11	Business Systems Analyst
G	36	2	15	2	13	Program Manager

3.2. Study Design

The objectives of the case study were defined as follows:

- Objective 1 - Provide an overview of the activities performed by the Product Owners in the selected organization so that their management better understands the scope of their activities.
- Objective 2 – Compare the results from Objective 1 with existing theoretical findings.

3.3. Data Collection

The data were collected from December 2021 to March 2022 and emerged from the focus group. All the group communications and gatherings happened online. As the video conferencing tool, Google Hangouts were used. The additional tools to support the collaboration and record the results selected by the participants were Google Sheets (online spreadsheet editor) and MindMup 2.0 (online mind-map editor). The data collection process was divided into four steps. Steps 1-3 were done as the group activity. The meetings were time-boxed to 60 minutes each. Then, Step 4 was completed individually by each participant.

1. Kick-off meeting – The goal of the study was explained to the participants; the planned process of the study was explained; participants selected the tools to collaborate.
2. Group brainstorming – The Product Owner activities were identified and recorded in MindMup 2.0; MindMup remained open for individual contributions until the next meeting;
3. Group refinement – Identified activities with the similar meanings were merged, and categorized into various areas; All activities were transcript into the Google sheet with a short description of each activity;
4. Marking the activities – Every Product Owner selected the responsible role for each identified activity.

3.4. Data Analysis

First, we analyzed in detail the list of activities and their categories that emerged from the focus group. Then, these raw data presented in Figures 1 and 2 in Section 4, were compared with the existing research on the Product Owner role in large-scale environment described in section 2. We have created a series of notes and memos directly into the sheet with data that emerged from focus group, with intention to ease the comparison. The main areas of interest were: clustering of the Product Owner role (Bass & Haxby, 2019); real product ownership (Remta & Buchalcevova, 2021); leadership and management tasks (Unger-Windeler et al., 2019); work with features (Gustavsson et al., 2022). This part of the process was conducted manually without any automation or special software tools.

3.5. Reporting

We provide the complete list of the activities as they were identified, categorized, and described by the focus group without any editing of the content in section 4. The results of our initial Data Analysis are discussed in section 5.

4. Results

The focus group of 7 Product Owners generated a list of 62 activities regularly conducted within development teams in the environment where the Scaled Agile Framework is implemented and divided them into nine areas. Figures 1 and 2 represent the heat map of the Product Owner's responsibility for conducting the activities that the focus group identified. The meanings of used abbreviations are as follows: PO – Product Owner; SM – Scrum Master; EM – Engineering Manager; A – Architect; DT –Development Team; ? – Responsible role not identified

ID	Area	Activity	Description	A	B	C	D	E	F	G
1	Agile Activities	Daily Scrum	Run the daily standup meeting	SM	SM	SM	SM	SM	SM	SM
2	Agile Activities	Sprint Planning	Select the backlog items to consider to for the following sprint	PO	PO	SM	PO	PO	PO	SM
3	Agile Activities	Retrospective	Run the sprint retrospective	?	SM	SM	SM	SM	SM	SM
4	Agile Activities	Accepting User Stories	Accept user stories as complete	PO	PO	PO	PO	PO	PO	PO
5	Agile Activities	Accepting TC Stories	Accept Technical Currency stories	PO	PO	A	PO	PO	EM	PO
6	Agile Activities	Accepting EE Stories	Accept Engineering Excellence stories	PO	EM	A	PO	PO	EM	PO
7	Agile Activities	Accepting Defects	Accept Defects as fixed	DT	PO	?	PO	PO	?	EM
8	Agile Activities	Sprint Review	Organise Internal sprint review every sprint	?	PO	SM	?	SM	PO	PO
9	Agile Activities	Product Showcase	Organise demonstration of product state e.g. new release, new capabilities	PO	PO	PO	PO	PO	PO	PO
10	Agile Activities	Solution Review	Organise contribution to solution wide demo to External Customers, demonstrating new solution value, WIP etc.	PM	PM	PO	PO	PO	PM	PM
11	Agile Activities	Feature Accepting	Review feature meets aims and change state to done	PO	PO	PO	PO	PO	PO	PO
12	Agile Activities	Manage Risks	Document and track risks, working with discrete owners	?	PO	?	PO	?	?	PO
13	Agile Activities	Manage Internal Milestones	Document and track team milestones which may be used at other levels	PO	PO	PO	PO	?	PO	PO
14	Agile Activities	Establish Team Capacity	Maintain sprint velocity numbers to account for team availability and historical results	SM	SM	SM	SM	SM	SM	SM
15	Agile Activities	Innovation Week Planning	Encourage and facilitate team's Innovation Week participation	?	EM	A	?	PO	?	A
16	Product Strategy & Direction	Product Roadmapping	Contribute to roadmap and present back to teams	PM	PM	PM	PM	PM	PM	PM
17	Product Strategy & Direction	Manage Release Milestones	Identify, create, track and report on deliverable milestones	PO	PO	?	PM	PM	PM	PO
18	Dev Team Activities	Organize Knowledge Transfer	Present and measure value for backlog inclusion.	EM	EM	A	EM	EM	EM	EM
19	Dev Team Activities	Definition of Done	Establish and maintain the working agreement within the team that defines implicit properties of the work done state.	?	SM	SM	DT	SM	SM	SM
20	Dev Team Activities	Maintain TI Involvement	Ensure TI has visibility of backlog items requiring documentation	PO	PO	A	DT	PO	SM	PO

Figure 1 – Product Owner's activities heat-map in areas: Agile Activities, Product Strategy, Dev Team Activities

ID	Area	Activity	Description	A	B	C	D	E	F	G
21	Org wide TC Edicts	Understand TC requirement	Gain technical and operational understanding of Org-Wide TC work item	EM	PO	A	DT	A	EM	EM
22	Org wide TC Edicts	Identifying time constraints / dependencies	Establish external constraints and requirements of the TC work item (e.g. Day 1 support)	EM	PO	A	PO	A	EM	A
23	Org wide TC Edicts	Establishing business value for prioritization	Ensure correct business value understanding to support TC prioritization in backlog, feedback upon completion.	EM	EM	?	PO	A	?	A
24	Engineering Excellence	Establish expected value	Document the expected return on investment from the EE effort	EM	EM	A	?	EM	EM	EM
25	Engineering Excellence	Measure delivered value	Measure the return on investment as delivered and compare to expectation	EM	EM	A	EM	EM	EM	EM
26	Engineering Excellence	Defining the requirement	Document the target outcome, acceptance criteria and activity to be completed	EM	EM	A	EM	EM	EM	EM
27	Runway	Identify Runway Candidates	Extract unanswered runway (UX/Arch) questions from product roadmap and backlog, taking to relevant team	PO	A	A	?	A	A	A
28	Runway	Manage Architectural Runway	Ensure architectural runway enablers align with product roadmap, update stakeholders on progress	A	A	A	A	A	A	A
29	Runway	Manage UX Runway	Ensure UX runway enablers align with product roadmap, update stakeholders on progress	?	A	A	?	?	?	PM
30	Runway	Manage Customer Interviews	Ensure customers are being asked the questions which the backlog and roadmap need answering	PM	PM	PO	PO	PM	?	PM
31	Backlog Management	Prioritisation	Arrange backlog items into the order they are targeted to be addressed	PO	PO	PO	PO	PO	PO	PO
32	Backlog Management	Remove stale backlog items	Review, evaluate and remove backlog items which are not currently relevant	PO	PO	PO	PO	PO	PO	PO
33	Backlog Management	Feature Decomposition	Document stories which, combined, satisfy the requirements of their parent feature	PO	A	DT	PO	PO	PO	PO
34	Backlog Management	Story Refinement	Ensure completeness and shared understanding of story and acceptance criteria and size, and establish any dependencies	PO	PO	A	DT	PO	?	PO
35	Backlog Management	Feature Refinement	Enriching backlog features with high level UX, Architecture and intended outcomes to support deconstructing into User Stories	PO	PO	PO	PO	PO	?	PO
36	Backlog Management	Feature validation lifecycle	Ensuring there's a target validator and process lined up for pre-GA APAR, Review, Demo etc. Part of Feature DoR	PO	PM	PO	PO	PO	PO	PM
37	Backlog Management	Defect Management (Rally)	Prioritize and Track defects in Rally	PO	PO	SM	PO	EM	?	EM
38	Backlog Management	Customer Requirements Gathering	Understanding and analysis of customer / stakeholder problems to distil discrete requirements and Non-Functional Requirements (performance, security etc)	PM	PM	PM	PO	PM	?	PM
39	Backlog Management	Feature Definition	Defining features in the product backlog which represent validated customer needs, potentially progressing the product roadmap	PO	PO	PO	PO	PO	PO	PO
40	Backlog Management	Technical Debt Feature Definition	Defining features representing large reengineering efforts to resolve technical debt / design optimisation	EM	EM	A	EM	PO	?	PO
41	Backlog Management	Technical Debt Story Planning	Identifying discrete TD items that have value to complete, positioning with other feature work in adjacent code-spaces	PO	EM	DT	DT	PO	?	EM
42	Backlog Management	Validate UX readiness	Ensure UX inputs for backlog (e.g. mockups / designs) are available in time for the development team to use in planning and development.	PO	PM	A	?	?	?	?
43	Customer Communication	Product Presentations	Product Roadshows, Sales meetings, product updates & feedback	PM	PM	PM	PM	PM	PM	PM
44	Customer Communication	Case Management (Volken)	Track customer cases needing development team assistance to close. Manage customer interaction and communication	L1	PO	A	SM	EM	?	EM
45	Customer Communication	User Communities Management	Online user communities communication, support & mgmt	L1	PM	PO	PO	PO	PM	PO
46	Customer Communication	Ideas Communities Management	Process and respond to customer ideas	PO	PO	?	PO	PO	PO	PO
47	Customer Communication	Customer Validation	Prepare and perform customers validation of features to be released using a validation kit / centerpoint	PO	PO	PO	PO	PO	PM	A
48	Customer Communication	Proactive Notifications	Manage content and process of PNS for advisory, new releases etc.	PM	PO	PM	PO	PO	PO	PO
49	Customer Communication	Trade Shows/ Conferences	Represent MSD and product/solution space at conferences. Collect user and market insights.	PM	PM	PM	PM	PM	PM	PM
50	Customer Communication	Writing Blogs	Produce and publish blogs to educate, publicise and maintain MSD thought leadership	?	PM	PM	?	?	?	PM
51	Customer Communication	NPS Survey Preparation	Product specific question preparation	PM	PM	?	?	PM	PM	PM
52	Customer Communication	NPS Survey Followup	Customer followup following survey	PO	PM	?	?	PM	PM	PM
53	Release Process	PTF/Release Checklist/Postcard	Coordinate and complete post card items and seek release approval	PO	PO	?	PO	PO	?	PO
54	Release Process	Feature Videos Creation	Create and publish Feature Videos introducing customers to new functionality	PO	?	PM	?	PO	?	PM
55	Release Process	Internal Product Training & Demos	New features training and education to internal users and support teams	DT	EM	A	DT	PO	EM	PM
56	Release Process	Request Security Exceptions	Manage and escalate security policy exceptions/	EM	A	A	EM	A	EM	PO
57	Internal Communications	Internal Stakeholder Communication	Primary point of contact for internal stakeholder communication around a product	PO	PM	PO	PM	PM	PM	PO
58	Internal Communications	Resolving dependencies	Manage, communicate and help resolve cross functional/cross team/cross product dependencies	PO	PO	A	?	SM	?	PO
59	Internal Communications	Communicate Delivery Against Plan	Inform solution level and external stakeholders of deliverable status and potential deviation from plan	PO	PO	PO	PO	PO	?	PO
60	Internal Communications	Maintain Health Sheet	Update with team input and present at Sync Meetings	PO	PO	PO	PO	PO	PO	PO
61	Internal Communications	Exercising Stakeholder Feedback Loop	Ensuring stake holders have up to date understanding of progress, and that project is moving along lines agreed, that the goal is still desirable.	PO	PM	PO	PO	PO	PO	PM
62	Internal Communications	Quarterly Interlock	Participate on preparation for PI / Quarterly review prior to planning.	PO	PM	PM	PM	PO	PM	PM

Figure 2 - Product Owner's activities heat-map in areas: Org Wide TC Edicts, Engineering Excellence, Runway. Backlog Management, Customer Communication, Release Process, Internal Communications

5. Discussion

The results presented in this paper were obtained during three focus group gatherings and individual follow-up exercises. Presented data give the view on the activities of Product Owner in SAFe, directly from the perspective of the Product Owner in the local context. Thus, the objective (1) to provide an overview of the activities performed by the Product Owners in the selected organization so that their management better understands the scope of their activities, is met. As for the objective (2) comparison with existing findings, we provide the following reasoning; All the Product Owners implied that Trade Shows/Conferences, Product Presentations, and Product Roadmapping are the primarily the responsibility of the Product Manager. However, during the initial mind-map creation, the focus group members listed these as activities in which they are involved. Hence, this is not to state that Product Owners are not involved in external representation of their product. Rather, the Product Manager is considered the primarily responsible party for externally facing activities and product roadmapping. This seems to be aligned with Remta and Buchalcevova's (2021) findings, that the Product Owner has limited agency or ownership of product strategy in SAFe. Bass's findings that on a large scale, the scope of activities goes beyond the capacity of one person acting as a Product Owner (Bass & Haxby, 2019) were confirmed in the examined environment, where SAFe is practiced. The results show that boundaries for the activities are not clearly defined but rather emergent from the activities of the broader team. This is a common trait in modern knowledge worker roles (Kelloway & Barling, 2000). Berntzen's et al. (2019) analysis of Product Owner indicated that coordination with the team leader role varies depending on the context of each Product Owner (type of team, experience, preferences). From the results in this paper, it is not possible to distinguish who acts in the team leader role, neither provide additional insights to Product Owners management and leadership responsibilities (Unger-Windeler et al., 2019). However, we can see that the ownership of various activities differs among the Product Owners. It suggests that not only the coordination varies, but even the responsibilities and scope of the Product Owner activities are very context-specific. Factors which define the context within a software development product team incorporate the size of the team, the seniority of a teams composition and leadership, the historical investment within the product which is reflected in team staffing and developmental velocity, the underlying technology, codebase, and architectural complexity which also impacts developmental velocity. That management need to ask the Product Owners to qualify the scope of their activities supports the hypothesis that the role is highly adaptive and variable. The obtained results did not provide any evidence that implementing SAFe limits the ability to choose which features to implement and that Product Owners divide features between teams without involving the developers, as Gustavsson et al. (2022) described.

Presented preliminary empirical results suggest no complete alignment of the Product Owner's role in SAFe with the Product Owners role in other large-scale environments. In the examined environment, the Product Owner seems to be covering fewer or different activities, especially activities related to product promotion and roadmapping. The Product Manager role in SAFe mostly covers these. Although SAFe offers rigorous descriptions of processes and roles (Remta & Buchalcevova, 2021) it is still presented as a framework. Thus, not all processes and descriptions have to be strictly followed. Hence, the local configurations and factors will always impact the final set of Product Owner's activities. Aside from the confirmed fact that Product Owner activities are on a large scale beyond the capacity of one person, the obtained results don't provide enough data to fully understand the real day-to-day activities. Although the empirical findings presented in this paper are not sufficient to the existing gap in empirical research in Product Owners in SAFe, we believe it provides a valuable contribution to existing knowledge about SAFe Product Owners in practice that could be leveraged for further research.

Limitations. In this paper, we present only preliminary results from the focus group that requires additional analysis accompanied by follow-up clarifications and interviews to enrich the data source for in-depth qualitative research. All participating Product Owners were from a single Value Stream of a large multinational enterprise and, therefore, were influenced by the local context. However, the single case-study method can certainly contribute to the cumulative development of knowledge (Flyvbjerg, 2006). To allow for the generalization of any findings provided, more empirical research, including other organizations practicing SAgFe, is needed.

6. Acknowledgment

This work was supported by an internal grant funding scheme (F4/35/2022) administered by the Prague University of Economics and Business.

7. References

- Alqudah, M., & Razali, R. (2016). A Review of Scaling Agile Methods in Large Software Development. *International Journal on Advanced Science, Engineering and Information Technology*, 6(6), 828.
- Bass, J. M., & Haxby, A. (2019). Tailoring Product Ownership in Large-Scale Agile Projects: Managing Scale, Distance, and Governance. *IEEE Software*, 36(2), 58–63.
- Berntzen, M., Moe, N. B., & Stray, V. (2019). The Product Owner in Large-Scale Agile: An Empirical Study Through the Lens of Relational Coordination Theory. *XP*, 121–136.
- digital.ai. (2021). 15th State of Agile Report. <https://digital.ai/resource-center/analyst-reports/state-of-agile-report>
- Dikert, K., Paasivaara, M., & Lassenius, C. (2016). Challenges and success factors for large-scale agile transformations: A systematic literature review. *Journal of Systems and Software*, 119, 87–108. <https://doi.org/10.1016/j.jss.2016.06.013>
- Flyvbjerg, B. (2006). Five Misunderstandings About Case-Study Research. *Qualitative Inquiry*, 12(2), 219–245.
- Gustavsson, T., Berntzen, M., & Stray, V. (2022). Changes to team autonomy in large-scale software development: A multiple case study of Scaled Agile Framework (SAgFe) implementations. *International Journal of Information Systems and Project Management*, 10(1), 29–46.
- Kelloway, E. K., & Barling, J. (2000). Knowledge work as organizational behavior. *International Journal of Management Reviews*, 2(3), 287–304.
- Knaster, R., & Leffingwell, D. (2020). SAgFe 5.0 Distilled; Achieving Business Agility with the Scaled Agile Framework. Addison-Wesley.
- Putta, A., Paasivaara, M., & Lassenius, C. (2018). Adopting Scaled Agile Framework (SAgFe): A Multivocal Literature Review. *Proceedings of the 19th International Conference on Agile Software Development: Companion*, 39:1-39:4.
- Remta, D., & Buchalcevova, A. (2021). Product Owner's Journey to SAgFe®—Role Changes in Scaled Agile Framework®. *Information*, 12(3), 107.
- Richard, B., Sivo, S. A., Orlowski, M., Ford, R. C., Murphy, J., Boote, D. N., & Witta, E. L. (2021). Qualitative Research via Focus Groups: Will Going Online Affect the Diversity of Your Findings? *Cornell Hospitality Quarterly*, 62(1), 32–45.
- Runeson, P., & Höst, M. (2008). Guidelines for conducting and reporting case study research in software engineering. *Empirical Software Engineering*, 14(2), 131.
- SAgFe. (2020). Scaled agile framework. <http://www.scaledagileframework.com/>
- Schwaber, K., & Sutherland, J. (2020). The Definitive Guide to Scrum: The Rules of the Game. <https://www.scrumguides.org/docs/scrumguide/v2020/2020-Scrum-Guide-US.pdf>
- Sutherland, J. V., & Schwaber, K. (1995). The SCRUM methodology. *Proceedings of the tenth annual conference on Object-oriented programming systems, languages, and applications*, 170–175.

- Uludag, Ö., Philipp, P., Putta, A., Paasivaara, M., Lassenius, C., & Matthes, F. (2021). Revealing the State-of-the-Art of Large-Scale Agile Development Research: A Systematic Mapping Study. 47.
- Unger-Windeler, C., Klünder, J., & Schneider, K. (2019). A Mapping Study on Product Owners in Industry: Identifying Future Research Directions. IEEE, 135–144.
- Vaidya, A. (2014). Does DAD Know Best, Is it Better to do LeSS or Just be SAFe? Adapting Scaling Agile Practices into the Enterprise. Proceedings of the Thirty-Second Annual Pacific Northwest Software Quality Conference, 2014, 21–38.

STRESS MITIGATION IN AGILE SOFTWARE DEVELOPMENT

Sergei Shcherbinin, Alena Buchalcegová

Department of Information Technologies
Faculty of Informatics and Statistics
Prague University of Economics and Business
shcs00@vse.cz, alena.buchalcegová@vse.cz

DOI: 10-35011/IDIMT-2022-429

Keywords

Agile software development, stress in agile, agile challenges, agile impediments

Abstract

Agile, being one of the most used approaches for software development, is at the same time challenging. Stress among software developers, especially in the agile environment, is an important issue that can drastically decrease the productivity of an agile team if it is not addressed. The aim of this paper is to investigate the main sources of stress experienced by members of agile teams and propose solutions for coping with them.

1. Introduction

Agile software development has been already existing for more than twenty years (Larman & Basili, 2003). It aims to improve the development process, making it more flexible and adjustable to rapidly changing environments. Unlike the classical waterfall approach, agile does not have a detailed plan of work at the start. Instead, the entire development process is based on iterations delivering valuable software increments. Agile considers individuals as an important part of the software development lifecycle. The development team must quickly respond to the requirements changes and conflicts between the teammates may jeopardize the entire development lifecycle.

In software development, like in any other field, stress may occur. Since employees spend nearly one-third of their lives working, job stress impacts both their physical and mental health. In turn, poor health of staff directly affects the overall team productivity and performance (Crawford et al., 2014; Meier et al., 2018). Software developers appreciate the good organization of their workday and consider day good if it consists of certain expected activities (Meyer et al., 2019). Also, emotions and mood, which may be directly impacted by stress, deeply affect the performance and creativity of software developers (Graziotin et al., 2014). Stress among software developers, especially in the agile environment, is an important issue that can drastically decrease the productivity of an agile team if it is not addressed. Agile is intended to minimize the bureaucratic aspect and makes teams self-organized. Studies show that agile frameworks have more potential for stress mitigation compared to conventional project management (Pfeiffer et al., 2019). However, every agile practice that may reduce the stress level can also have downsides creating new stress sources. Delivering a valuable increments in short iterations may be challenging, but can lead to burnout (Evenstad, 2018). While agile highlights communication between team members, if it is

organized poorly, the entire team can be stressed (Sonnentag et al., 1994). Other potential reason for stress is work overload. Sometimes team commits to fulfill more than it is capable to do which could lead to stress and decrease the quality of work (Sonnentag et al., 1994). A lower focus on documentation also has both positive and negative impacts. On one hand, team members can focus more on creating a working product instead of documenting its features in detail. On the other hand, a lack of documentation may lead to mess and cause problems in the future. Agile is suitable for changing environments, however, a frequently changing environment can also cause more stress.

The aim of this paper is to investigate the main sources of stress experienced by members of agile teams and propose solutions for coping with them. This research has been made within the diploma thesis (Shcherbinin, 2022).

The rest of the paper is organized as follows. Following the Introduction, Section 2 describes the the research approach. The results of the Stress factors survey are presented in Section 3, while the Stress checklist is introduced in Section 4. Conclusion is presented in Section 5.

2. Research Method

In this section, the overview of the research approach is provided. First, review of relevant literature was conducted. To determine the main stress factors perceived by members of agile software development teams a research was conducted in a big software company with more than 1,300 people involved in development of software solutions in different areas from healthcare to finance. The company has been using agile methods for more than ten years.

Research conducted in this company had three steps. First, an open-question survey was designed that is described in Section 2.1. Then, several interviews were conducted to examine possible ways to mitigate found stress factors (see Section 2.2). Stress mitigation practices were presented in the form of a checklist that was then tested in several agile software development teams (see Section 2.3).

2.1. Stress Factors Survey

An open-question qualitative survey was carried out to reveal the reasons that made members of agile teams feel stressed. For the survey, only software developers were selected. As all software development teams in the company have adopted Scrum, everyone who participated in the survey had at least one year experience with Scrum. Developers were asked to answer following question:

As a software developer working in an agile environment, what, in your opinion, are sources of stress you encounter at work?

The respondents had a set of free-text fields where they could put their responses and thus they had a chance to list an unlimited number of stress sources they had experienced. The option (None) could have been chosen by respondents who felt a lack of stress at work.

2.2. Stress Mitigation Interviews

As a follow-up to the survey, qualitative interviews were conducted. Participants were selected based on requirements: (1) having more than five years experience in agile software development, (2) being different from respondents of the Stress Factors survey, (3) performing various roles. Overall, five agile professionals who volunteered to contribute to research were interviewed: two Scrum masters, an Agile coach, a Product owner, and a Developer. The interviews were carried out in a face-to-face format and people were asked if they had an experience how to mitigate stress

factors that had been identified in the survey. These answers were analyzed and a Stress checklist that is presented in Section 4 has been developed.

2.3. Stress Checklist Evaluation

The Stress checklist was evaluated in three Scrum software development teams in the same company. Each team consisted of ten members: one Scrum master, one Product owner, and eight developers. First, teams were asked to make self assessment and answer Yes or No for each of the 22 checklist items. No team was able to score Yes for more than 12 checklist items out of 22. Then, the teams were asked to work during the following five iterations on the checklist items where the answers were “NO” and to follow action items that were provided (action items are not listed in the paper due to page limit). As the iteration length was two weeks, teams were adopting the practices throughout ten weeks. At the end of the evaluation period, teams were asked to fill out the checklist again. The results after the application of the Stress Checklist showed that all the teams managed to adopt most of the practices and demonstrated results close to 100%.

3. Stress Factors Survey Results

Stress factors survey, described in Section 2.1, was conducted at the beginning of 2022 year. Responses from 257 agile professionals were received. Each respondent mentioned at least one source of stress he has encountered, some respondents mentioned two or more stress sources. In the end, 449 sources of stress were recorded. After removing duplicates, 23 unique sources of stress were listed. Stress sources mentioned in less than 2% cases were combined into the Other group, and so twelve stress sources, that are depicted in Figure 1 and described in the next paragraph, were identified.

According to the survey the following stress sources in agile software development teams were mentioned:

SS1. Inadequate planning (estimation). Individuals feel stressed because in some cases the tasks are not estimated accurately. The real scope of these tasks is broader than it was originally assumed, and the developers feel pressured being unable to accomplish them on time.

SS2. Short sprints. Some developers feel frustrated having only two-week Sprints. They feel they are forced to deliver too small features that do not bring significant value.

SS3. Work-life imbalance. Several surveyed developers feel too involved in work, even though Scrum promotes different practices for work-life balancing.

SS4. Frequent changes. Some respondents find themselves lost in a frequently changing environment and cannot adapt to changes so quickly.

SS5. Meetings overload. Several individuals mentioned that they attend meetings almost half of all their work time although they do not actively participate in some of them.

SS6. Lack of control. Some developers reported their opinion is not heard. They do not have a feeling that they make decisions and have to obey the opinion of the majority even though they do not agree with it.

SS7. Too big tasks. Several respondents pointed out that the scope of tasks they work on is too broad. They feel frustrated not knowing what to start with and struggle to connect different parts of the tasks.

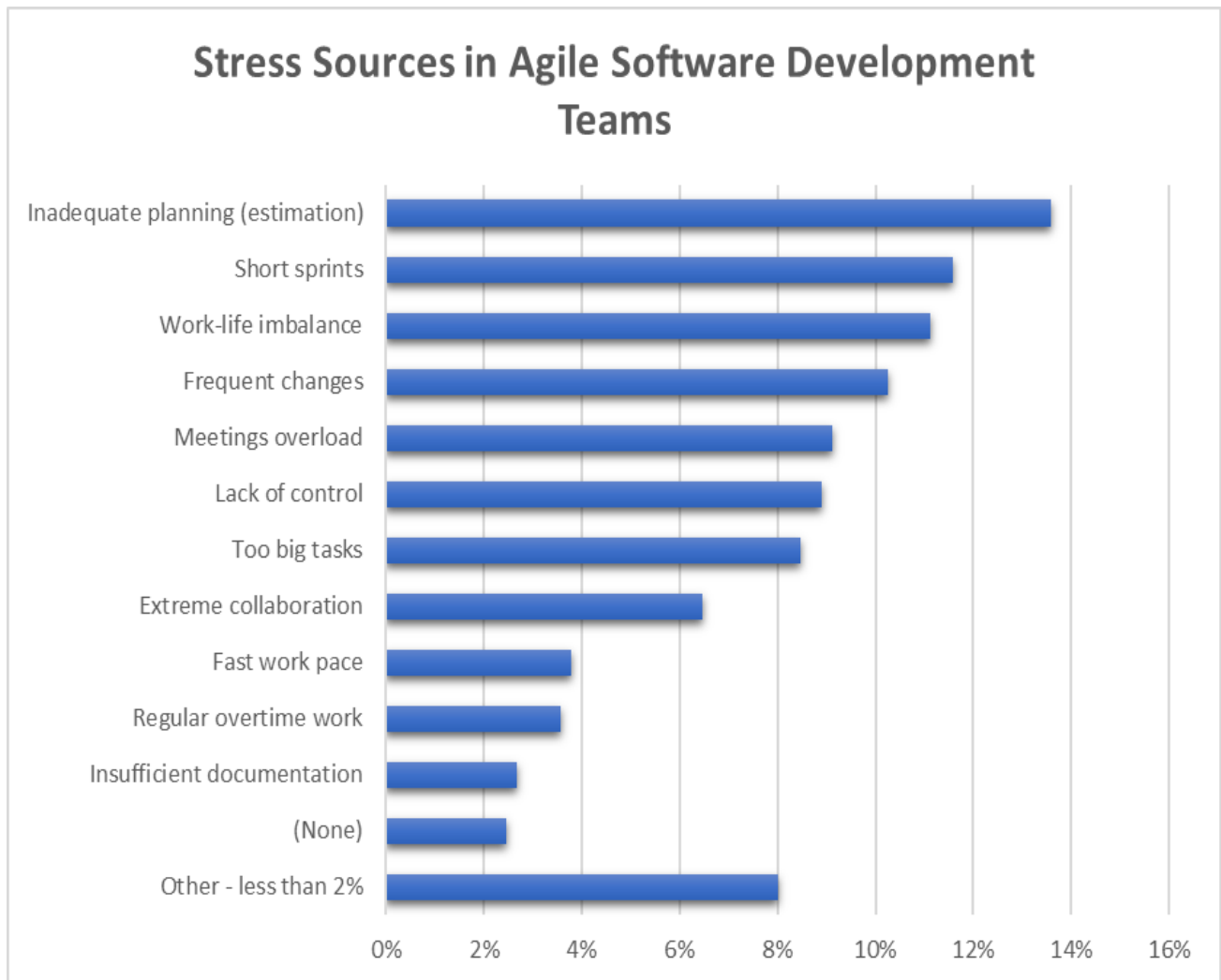


Figure 1 - Stress Sources in Agile Software Development Teams

SS8. **Extreme collaboration.** Some people mentioned that except for meetings they have too many interactions with other team members.

SS9. **Fast work pace.** A few software developers feel stressed because they have less time to deliver their work and it directly affects its quality.

SS10. **Regular overtime work.** Some individuals feel stressed because they have to work extra hours to accomplish their work. They mentioned that they voluntarily stay in the office outside of normal working hours to keep work on track.

SS11. **Insufficient documentation.** A few people stress out because they cannot find information on the source code they deal with due to poor documentation. Some of them also feel bad about having not enough time to create comprehensive documentation.

SS12. (None). 11 out of 257 (4.28%) respondents said that they feel absolutely no stress at work.

4. Stress Checklist Items

As a result of qualitative interviews described in Section 2.2 the Stress checklist has been proposed consisting of 22 items each representing a good practice for stress level reduction. For each checklist item, there were also one or two action items defined. By performing these action items

the respective practice is achieved. However, due to the page limit proposed action items are not presented in the paper. The checklist items and their mapping to identified stress sources are listed in Table 1.

Table 1: Checklist Items Mapped to Stress Sources

Checklist Item ID	Checklist Item Description	Mapping to Identified Stress Sources
SC1	All the tasks my teams work on are defined as user stories with descriptions in the following format: “As a <user type> I want <goal> so that <reason>”.	SS1
SC2	The team knows its velocity and regularly estimates the workload for every user story based on the team’s experience. The actual workload of user stories is verified upon completion.	SS1
SC3	Every user story has dependencies listed before the work on the user story is started.	SS1
SC4	Every user story is the smallest piece of work possible. It cannot be split into smaller user stories.	SS2
SC5	Iteration length always allows delivering a valuable increment of the product. It is always possible to group user stories with cumulative estimation fitting into the iteration length and have a valuable increment upon completion of all the user stories in the group.	SS2
SC6	Team capacity for every iteration considers actual working hours planned for all the team members.	SS3
SC7	None of the team members works overtime.	SS3, SS10
SC8	Every team member must have a workplace where they can fully concentrate on their work.	SS3
SC9	The team always clearly understands the problem and has enough knowledge to deliver a valuable increment of the product.	SS4
SC10	The team participates only in the meetings required by the adopted framework and other meetings where all the team members actively participate.	SS5
SC11	Meetings are planned in a way that every team member has at least three working hours a day without meetings.	SS5
SC12	All the team members agree with the collaborative decisions made by the team. If applicable, collaborative decisions are regularly reviewed.	SS6
SC13	None of the user stories, in progress and planned, can be split into smaller user stories.	SS7
SC14	None of the user stories, in progress and planned, are estimated for more story points than the number corresponding to ten man-days.	SS7
SC15	If a story is estimated for more than five man-days, it is done either by more than one person, or some milestones must be defined.	SS7
SC16	Collaboration protocol is established. The protocol defines specific hours for the team and every team member when they can collaborate. Every team member must have at least three working hours in a row outside of collaboration hours.	SS8
SC17	Rules for collaboration priority are established. The rules explicitly define how to classify needed collaboration acts. Specific collaboration hours in the collaboration protocol include the priorities. For example, collaboration hours are from 13:00 to 16:00 but from 15:00 to 16:00 only for high-priority cases.	SS8
SC18	Overhead and extra work is always considered during the iteration planning.	SS9
SC19	All the team members have regular short breaks at least once an hour.	SS9
SC20	All the team members often change the type of activity during a workday.	SS9
SC21	Documentation is easy to create and maintain, templates, examples are provided, automated solutions for documentation creation are used.	SS11
SC22	Documentation created by team members is a subject of review, it is sufficient. Quality and volume of documentation are included in teamwise common quality standards.	SS11

5. Conclusion

Overall, most of the stress checklist items are related to work organization, planning and estimation. Looking at the most common stress sources and proposed actions for their mitigation, most of the stress is connected with inappropriate planning. Team members could be affected by incorrect task estimation, which can put additional pressure on them. Inadequate planning makes maintaining a sustainable pace impossible. Moreover, because of a lot of events during the workday developers cannot concentrate on their work which can cause inappropriate working pace.

We can conclude that the stress level is a significant factor directly affecting performance of agile software development teams. Good piece of news is that most practices mitigating stress can be easily adopted without substantial investments. Suggested practices include improved planning, recommended estimation techniques, cooperation and collaboration practices, and work organization tips.

5.1. Limitations of the Study

The research was conducted primarily using data that are relevant for team members practising Scrum or a hybrid agile method based on Scrum, which are the mostly used agile methods (Digital.ai, 2021). However, most research outcomes could be applicable also to other agile methods.

The research was focused on the examination of the most common issues related to stress and impediments in agile software development and the investigation of the ways how to effectively address them. Professionals who worked on several agile projects and in more than one company were selected as respondents and participants. This approach made it possible to address most of the issues that could be encountered by the vast majority of teams and organizations. However, it could be considered incomplete for teams working on unique tasks where stress sources and impediments can be specific to their area.

6. Acknowledgment

This work was supported by an internal grant funding scheme (F4/35/2022) administered by the Prague University of Economics and Business.

7. References

- Crawford, B., Soto, R., de la Barra, C. L., Crawford, K., & Olguín, E. (2014). Agile Software Teams Can Use Conflict to Create a Better Products. *Communications in Computer and Information Science*. https://doi.org/10.1007/978-3-319-07857-1_5
- Digital.ai. (2021). 15th State of Agile Report. In Digital.ai. <https://stateofagile.com/#>
- Evenstad, S. (2018). The Virtuous Circle of Ephemeralization and the Vicious Circle of Stress. *Futures*, 103(October), 61–72.
- Graziotin, D., Wang, X., & Abrahamsson, P. (2014). Happy software developers solve problems better: psychological measurements in empirical software engineering. *PeerJ*, 2, e289. <https://doi.org/10.7717/peerj.289>
- Larman, C., & Basili, V. R. (2003). Iterative and incremental developments. a brief history. *Computer*, 36(6), 47–56. <http://ieeexplore.ieee.org/document/1204375/>
- Meier, A., Kropp, M., Anslow, C., & Biddle, R. (2018). Stress in Agile Software Development: Practices and Outcomes. *Agile Processes in Software Engineering and Extreme Programming*, 259–266.

- Meyer, A. N., Barr, E. T., Bird, C., & Zimmermann, T. (2019). Today Was a Good Day: The Daily Life of Software Developers. *IEEE Transactions on Software Engineering*, 47(5), 863–880. <https://doi.org/10.1109/TSE.2019.2904957>
- Pfeiffer, S., Sauer, S., & Ritter, T. (2019). Agile methods as stress management tools? An empirical study. *Work Organisation, Labour and Globalisation*, 13(1), 20–36. <https://doi.org/10.13169/workorglaboglob.13.2.0020>
- Shcherbinin, S. (2022). Role of Individuals in Agile Software Development Teams. University of Economics and Business, Prague.
- Sonnentag, S., Brodbeck, F. C., Heinbokel, T., & Stolte, W. (1994). Stressor-burnout relationship in software development teams. *Journal of Occupational and Organizational Psychology*, 67(4), 327–341.

MOTIVATIONAL DIFFERENCES AMONG SOFTWARE PROFESSIONALS

Marcel Valový

Faculty of Informatics and Statistics
Prague University of Economics and Business
marcel.valovy@vse.cz

DOI: 10-35011/IDIMT-2022-437

Keywords

Software Engineering; Motivation; Big Five Personality; Hierarchical Cluster Analysis.

Abstract

[Context] The motivation and well-being of software professionals are challenged. COVID-19 pandemic shifted the work landscape, making hybrid and remote workplace settings the standard and putting previously established motivation management tools at risk. Increasing autonomous motivation of software professionals and optimizing multitasking to remain within preferred IT roles might be one approach to overcoming the new obstacles.

[Method] Using a quantitative approach, the present study examined the proposed nomological network of software engineering roles, motivation, and personality traits. A conveniently sampled quantitative survey was employed in eight IT companies and two professional IT forums. It produced a considerable ($N = 243$) data corpus. Based on the state-of-the-art research, hypotheses were formulated, and their statistical counterparts tested by suitable statistical methods, such as the Kruskal-Wallis test. In addition, hierarchical cluster analysis was employed to meaningfully characterize personal differences among software professionals. Finally, correlation analysis was used to derive the strengths of the causal relationships.

[Result] Software professionals in this study were of four distinct personality types with varying motivational levels. The openness/intellect dimension was found to significantly nurture motivation in project manager, developer, and analytical roles. In contrast, neuroticism was detrimental to motivation in all roles. The results and future study recommendations were discussed.

1. Introduction

This article presents an empirical study of autonomous motivation in the IT context. Why is this important? Work is perhaps the most dominant domain in most adults' lives, yet workers have highly varied experiences. Some find work engaging and fulfilling; others see it as a time to be endured. A highly motivated workforce is key to every project's success in software engineering. The profession is infamous for its inherent multitasking nature, which can push the cognitive workload of its practitioners to the limits (Vasilescu et al., 2016). Autonomous motivation has become prolific to software professionals' performance and psychological and physical well-being in the current hybrid and remote workplace settings. Understanding the personality and motivation of software professionals will be necessary to orchestrate more effective teams.

Traditional motivational theories regarded motivation as a unitary concept, where the amount of motivation, or “energy for action,” predicts the quantity of work. Self-determination Theory (SDT; Ryan & Deci, 2000), on the other hand, measures motivation on a continuum from controlled to autonomous: (0) amotivation, (1) external, (2) introjected, (3) identified, (4) internalized, and (5) intrinsic. Different kinds of motivation (in equal quantities) will lead to different quality of work.

Perceived locus of causality (PLOC; de Charms, 1968) is a concept for describing whether we believe the source of our actions to be internal or external. Behaviors motivated by internal PLOC are, by definition, autonomous; they are experienced as being volitional and emanating from one’s self. In contrast, extrinsically motivated actions can vary in character from very heteronomous or controlled to very autonomous or self-determined — from external to an entirely internal PLOC.

When a person is autonomously motivated, their interests and values align with their actions, which are *biologically* distinct from controlled behaviors (Ryan, Kuhl, Deci, 1997). Consequently, autonomous motivation leads to higher creativity, better problem solving (*e.g.*, thinking outside the box), increased performance (particularly in heuristic activities, such as programming), positive emotions, and psychological and physical wellness (Ryan & Deci, 2017).

This paper proposes a nomological network to represent the constructs of interest in our study, their observable manifestations, and the interrelationships between them. The core constructs are software engineering roles (independent variable), motivation (dependent variable), and personality traits (moderating variable). The latter two variables must be modeled quantifiably to provide actionable insights. For modeling motivation, intrinsic motivation from the Self-determination framework will be used. Personality will be assessed using the Big Five model (Goldberg, 1993). Lastly, because all motivational theories and frameworks should take national culture into account (Latham & Pinder, 2005), the author will perform the research locally – in Czechia.

Research problem:

How to increase the autonomous motivation of software professionals.

Research questions:

RQ1: Are motivational levels dissimilar across software professionals?

RQ2: Does personality moderate autonomous motivation differentially in various roles?

2. Background

The following chapter provides the basic rationale for the author’s research. It delineates the theoretical framework used for the study, defines key concepts, reviews literature pertinent to the study, critically synthesizes empirical reports, analyzes historical literature reviews, and postulates operational assumptions and hypotheses for research purposes.

2.1. Personality

Recent scientific development in neuropsychology explains how motivation and personality share the same biological roots (Corr et al., 2013; DeYoung, 2015) and provides us with a *unified* theory where one mediates another (Dweck, 2017). Following this trend, our research incorporates personality variables as moderators of motivation. Moderators or boundary variables can amplify or attenuate the effect of the independent variable, such as the software engineering role, on the dependent variable, such as the software professional’s intrinsic motivation (Latham, 2012).

Psychologists use Big Five traits to describe the array of variables in which individuals differ and refer to an individual’s characteristic behavior patterns (DeYoung, 2015). Each of the five

dimensions of human personality can be considered the result of an evolutionary trade-off (Nettle, 2006). Because the traits have no unconditionally optimal value and are 60-80% inherited, genetic diversity with the formation of clusters in the population is expected (Riemann & Kandler, 2010).

In the context of IT, certain empirical studies described software engineers as having propensities for specific tasks and roles predetermined by their personality (e.g., Capretz et al., 2015). Other studies and systematic literature reviews (SLRs) indicated the inadequacy of state-of-the-art (e.g., Cruz et al., 2015). Although a rich body of studies exists, the central portion used the Myer-Briggs Type Indicator (MBTI) for personality assessments. While this method is still popular today, it has been widely discredited, and the better alternative lies in the domain of the Big Five model (cf. McCrae & Costa, 1989). This study will use the latter, five-factor approach consisting of OCEAN dimensions: openness/intellect, conscientiousness, extraversion, agreeableness, and neuroticism.

2.2. Motivation

Since a long time ago, we have known that software professionals differ in their personalities (Wynekoop & Walz, 2000) but also in motivation (Ferratt & Short, 1986).

For the theory of motivation, the author has chosen the Self-determination theory (Ryan & Deci, 2000) because of its capability to integrate motivational theories of needs, expectancy, goals, self-efficacy, and many more under one umbrella (Latham & Pinder, 2005).

The previous research on motivation in the IT context seems inadequate. Several SLRs (e.g., França et al., 2011) concluded that the understanding remains unclear about the software professionals' job, what motivates them, how they are motivated, or the outcome and benefits of doing so. Novel studies on managing the motivation of software professionals are appearing (Varona & Capretz, 2021; França, 2014) but use historical motivational theories.

Thoroughly scrutinizing studies of personality and motivation in the IT, we operationally assume:

- The personalities of software professionals are heterogeneous.
- Motivation toward software engineering roles is moderated by personality.

2.3. Hypotheses

Four hypotheses were postulated based on the synthesis of knowledge from multiple disciplines:

H1: Software professionals hold distinct personalities.

H2: Software professionals prefer different roles based on their Big Five personalities.

H3: The openness/intellect dimension correlates positively with intrinsic motivation in analytical, developer, and project manager roles.

H4: The neuroticism dimension negatively correlates with intrinsic motivation for all roles.

This empirical study is performed to test the hypotheses and variables in our nomological network.

3. Methods

The following chapter explains the selection of methods for our research, including the required criteria for their application. Afterward, it presents the inquiry framework and questionnaire design.

3.1. Context

In the context of the Czech Republic, a conveniently sampled quantitative survey was employed during February and March 2022. It was dispersed in eight IT companies (Prusa Research, Microsoft, Seznam, Alza, Tesena, RaiffeisenBank, MSD, Avast) and two professional IT forums, producing a significant quota-adhering data corpus. The response rate varied per company; in total it was around 20 %.

Our research hypotheses were based on a thorough examination of state-of-the-art research.

3.2. Inquiry framework

Recent studies (e.g., Graziotin et al., 2021; Feldt et al., 2010) advocated the use of instruments coming from psychology and related fields for systematic studies in the IT and emergent “behavioral software engineering” field (Lenberg et al., 2015). The core of our inquiry framework is formed by the Big Five Inventory (BFI) and Multidimensional Work Motivation Scale (MWMS).

Several versions of the BFI questionnaire exist. The author has chosen BFI-10 (Rammstedt & John, 2007), which consists of 10 Likert-scale questions and maintains the same or better statistical properties (reliability, consistency, validity, and less redundancy) than the other versions.

MWMS is a 17-question Likert-scale multidimensional device intended to measure the work motivation levels of participants (Gagné et al., 2015). The measured types of motivation are amotivation, extrinsic-material, extrinsic-social, introjected, internalized, and intrinsic motivation.

3.3. Questionnaire design

Several pilot phases were conducted before the final questionnaire design was formed. The final version used in our survey consisted of 39 questions and was dispersed using Office Forms link in eight major IT companies and two professional forums. It had the following structure:

- Informed consent (1 question) + optional email address for delivery of psychometric results
- Demographics (11 questions)
- Big Five Inventory (10 questions)
- Multidimensional Work Motivation Scale (17 questions)

3.4. Statistical methods

To make sense of the data, our research sample was subjected to hierarchical cluster analysis, and distinct personality groups with their centroids were identified. Then, Kruskal-Wallis and p -value tests were used to verify statistical hypotheses. Pearson’s correlation coefficient was used to derive the strengths of causal relationships.

The first research question (and second hypothesis) could be answered by testing for equality of motivational levels in different roles. Despite ANOVA being the most common method, two of its three necessary assumptions were violated. The Shapiro-Wilk and Kolmogorov-Smirnov tests proved that the normality assumption was violated ($p < 0.01$). Therefore, the Kruskal-Wallis test, a non-parametric alternative to one-way ANOVA, was used.

For the second research question (and the first hypothesis), a multivariate statistical procedure called hierarchical clustering analysis was used to determine if entities of our interest are similar enough to be grouped under clusters. The Dunn index metric (Bezdek & Pal, 1995) indicated using a hierarchical clustering algorithm with four clusters and a complete linkage method.

Pearson's correlation analysis and *p-value* test were used for testing hypotheses H3 and H4. All statistical tests and computations were performed using R v4.2.0 and its packages.

4. Results

4.1. Descriptive statistics

A convenient sample of ($N = 243$) professionals exhibiting representative characteristics was studied. 80.7 % of respondents were males, 17.3 % females, and 2 % others. 84 % of respondents were 15-34 years old. Thus, our conveniently sampled population adhered to the global population quotas (e.g., Eurostat, 2021 – 89 % men, 80 % aged 15-34). Of the career length, the majority (34.2 %) had 2-5 years, 29.6 % had < 2 years, 20.2 % had >10 years, and the remainder, 16 %, had between 5 and 10 years of experience.

Regarding the roles, 95 respondents were developers, 30 were quality assurance, 28 were project managers, 28 were analytics, and 22 were support staff. The remainder (40) was in a different role.

4.2. Personality clusters

The four centroids created by the cluster analysis are present in Figure 1 with their respective means. The first and the fourth cluster are characterized by high openness/intellect and low extraversion, but they differ heavily in conscientiousness (5.48 vs. 8.56, respectively) and neuroticism (7.42 vs. 5.16, respectively). The second cluster groups people who are extroverted and insensitive to negative emotions (low neuroticism). The third cluster exhibits no unique properties apart from a heightened sensitivity to negative emotions (high neuroticism).

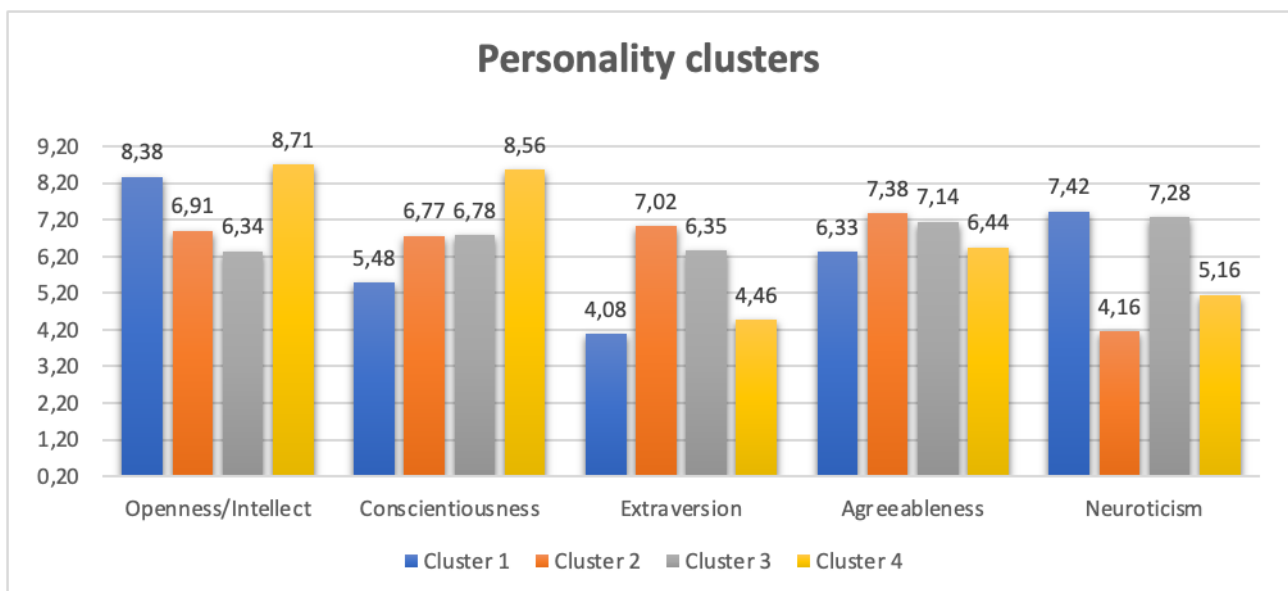


Figure 1 – Personality clusters (source: author)

4.3. Motivation across clusters and roles

The results of the MWMS questionnaire from ($N = 243$) professionals are present in Fig 4.2.

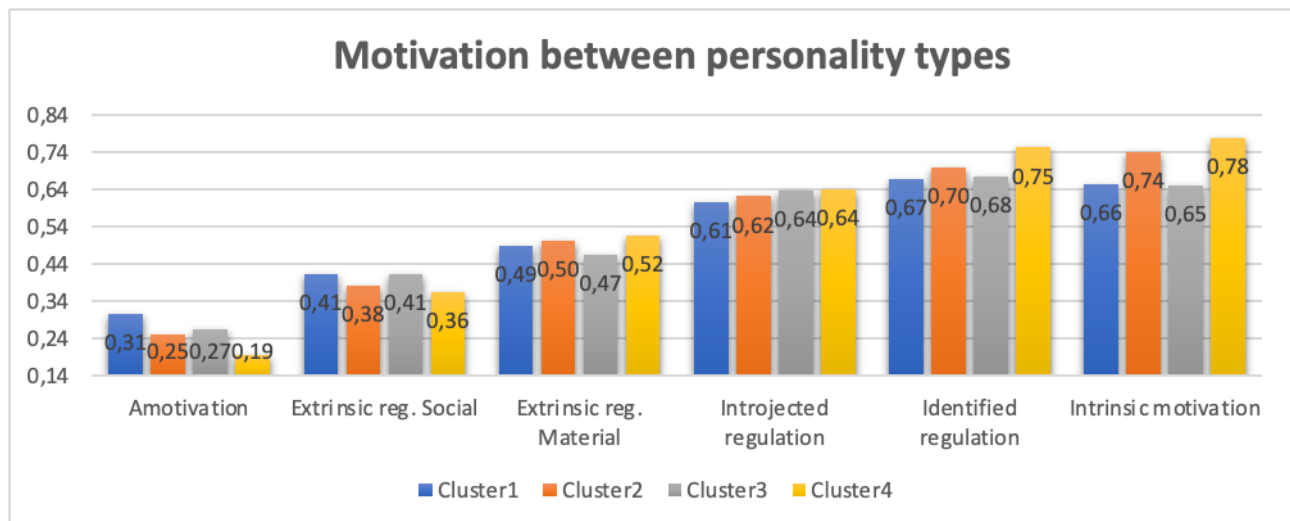


Figure 2 – Motivation between personality types (source: author)

As can be seen from the results, software professionals are motivated mostly autonomously, which is positive. Nevertheless, their motivational levels vary with their personalities. Figure 2 suggests that cluster 4 could represent a more autonomously motivated population of software professionals out of the four studied, scoring high on Identified regulation (0.75) and Intrinsic motivation (0.78).

4.4. Hypotheses testing

When investigating preferences for different roles (H2), the Kruskal-Wallis test was applied. This method tested whether there is a significant difference in motivation by role. The test result ($p = 0.0352^{**}$) was rejected on a 5 % significance level. Therefore, we reject the null hypothesis for H2 that motivation was equal for all roles and confirm the relationship that software professionals prefer different roles based on their Big Five personalities.

The first hypothesis that software professionals differ in personality was not statistically tested but was confirmed by four generated clusters, which are internally homogenous and externally heterogeneous, and were used in the subsequent tests.

Hypothesis H3 and H4 were confirmed by Pearson's correlation analysis and *p-value* test. Openness/intellect dimension holds a positive relationship with intrinsic motivation in analytical, developer, and project manager roles, $r = 0.246$, with *p-value* = 0.00236. Neuroticism, on the other hand, is detrimental for motivation in all roles, $r = -0.1724$, with *p-value* = 0.00705. The equality-testing null hypotheses for H3 and H4 were rejected on a 5% significance level ($p < \alpha = 0.05$).

5. Discussion

This is a pioneering study on the Big Five of Czech software professionals. It provides insight into their psychometrics and identifies the well-known (Couger & Zawacki, 1980) introvert personality type as well as three others, which might be specific to Czech IT culture. Future studies should validate the existence of these new three personality types.

The main aim of our study was to shed light on the nomological network linking software engineering roles to the Big Five personality traits and motivation. Prior research in the global context was extended by utilizing the novel approach of measuring autonomous motivation within the self-determination framework and measuring the effects separately for distinct roles.

Our findings show that individual differences among Czech software professionals are reflected in distinct motivational levels and role preferences. This study's instruments and analytical and interpretative methods can detect such connections. The results can be a starting point for future studies on promoting wellness and productivity in software teams in the Czech context. Future studies should also verify the common existence of the identified clusters.

6. Conclusion

This study scratched the surface of the relationships between personality and motivation in the IT context and revealed the Big Five profile of software professionals in the local context. It illuminated several statistically significant relationships in our nomological network, but we still lacked the explanatory power for fully reasoning about why they hold. To provide considerable scientific import, IT roles could be reduced to activities. The activities would form our new nomological variable, replacing roles and explaining how personality types and specific activities are interrelated concerning motivational levels and how this can be leveraged in project management. Such research, however, would be challenging to carry out. The main obstacle in its execution would be mapping the motivation of employees onto certain activities. A viable but costly approach might be an experimental study with participants of different personality types, measuring their motivation in various activities with tools developed specifically for experimental settings, such as SDT's Intrinsic Motivational Inventory.

7. Acknowledgment

This work was supported by an internal grant funding scheme (F4/34/2021) administered by the Prague University of Economics and Business with project number IG406011.

8. References

- Bezdek, J. C., & Pal, N. R. (1995, November). Cluster validation with generalized Dunn's indices. In *Proceedings 1995 second New Zealand international two-stream conference on artificial neural networks and expert systems* (pp. 190-190). IEEE Computer Society.
- Capretz, L. F., Varona, D., & Raza, A. (2015). Influence of personality types in software tasks choices. *Computers in Human behavior*, 52, 373-378.
- Corr, P. J., DeYoung, C. G., & McNaughton, N. (2013). Motivation and personality: A neuropsychological perspective. *Social and Personality Psychology Compass*, 7(3), 158-175.
- Couger, J. D., Zawacki, R. A. (1980). *Motivating and managing computer personnel*. Wiley.
- Cruz, S., da Silva, F. Q., & Capretz, L. F. (2015). Forty years of research on personality in software engineering: A mapping study. *Computers in Human Behavior*, 46, 94-113.
- de Charms, R. (1968). *Personal Causation: The internal affective determinants of behavior*. New York: Academic Press.
- DeYoung, C. G. (2015). Cybernetic big five theory. *Journal of research in personality*, 56, 33-58.
- Dweck, C. S. (2017). From needs to goals and representations: Foundations for a unified theory of motivation, personality, and development. *Psychological review*, 124(6), 689.
- Gagné, M., Forest, J., Vansteenkiste, M., Crevier-Braud, L., Van den Broeck, A., Aspel, A. K., ... & Westbye, C. (2015). The Multidimensional Work Motivation Scale: Validation evidence in seven languages and nine countries. *European Journal of Work and Organizational Psychology*, 24(2), 178-196.

- Graziotin, D., Lenberg, P., Feldt, R., & Wagner, S. (2021). Psychometrics in behavioral software engineering: A methodological introduction with guidelines. *ACM Transactions on Software Engineering and Methodology (TOSEM)*, 31(1), 1-36.
- Eurostat. (2021, September 16). More than 4 out of 5 ICT-educated workers are men. <https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20210916-1>
- Feldt, R., Angelis, L., Torkar, R., & Samuelsson, M. (2010). Links between the personalities, views and attitudes of software engineers. *Information and Software Technology*, 52(6), 611-624.
- França, A. C. C. (2014). A theory of motivation and satisfaction of software engineers.
- França, A. C. C., Gouveia, T. B., Santos, P. C., Santana, C. A., & da Silva, F. Q. (2011, April). Motivation in software engineering: A systematic review update. In *15th Annual Conference on Evaluation & Assessment in Software Engineering (EASE 2011)* (pp. 154-163). IET.
- Goldberg, L. R. (1993). The structure of phenotypic personality traits. *American psychologist*, 48(1), 26.
- McCrae, R. R., & Costa Jr, P. T. (1989). Reinterpreting the Myers-Briggs type indicator from the perspective of the five-factor model of personality. *Journal of personality*, 57(1), 17-40.
- Latham, G. P. (2012). *Work motivation: History, theory, research, and practice*. Sage.
- Latham, G. P., & Pinder, C. C. (2005). Work motivation theory and research at the dawn of the twenty-first century. *Annu. Rev. Psychol.*, 56, 485-516.
- Lenberg, P., Feldt, R., & Wallgren, L. G. (2015). Behavioral software engineering: A definition and systematic literature review. *Journal of Systems and software*, 107, 15-37.
- Nettle, D. (2006). The evolution of personality variation in humans and other animals. *American Psychologist*, 61(6), 622.
- Rammstedt, B., & John, O. P. (2007). Measuring personality in one minute or less: A 10-item short version of the Big Five Inventory in English and German. *Journal of research in Personality*, 41(1), 203-212.
- Riemann, R., & Kandler, C. (2010). Construct validation using multitrait-multimethod-twin data: The case of a general factor of personality. *European Journal of Personality*, 24(3), 258-277.
- Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist*, 55(1), 68.
- Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. Guilford Publications.
- Ryan, R. M., Kuhl, J., & Deci, E. L. (1997). Nature and autonomy: An organizational view of social and neurobiological aspects of self-regulation in behavior and development. *Development and psychopathology*, 9(4), 701-728.
- Varona, D., & Capretz, L. F. (2021). A study of McClelland's Motivations in Relation to software practitioners. In *Proceedings of the 32nd Workshop of the Psychology of Programming Interest Group (PPIG 2021)*. On-Line.
- Vasilescu, B., Blincoe, K., Xuan, Q., Casalnuovo, C., Damian, D., Devanbu, P., & Filkov, V. (2016, May). The sky is not the limit: multitasking across github projects. In *Proceedings of the 38th International Conference on Software Engineering* (pp. 994-1005).
- Wynekoop, J. L., & Walz, D. B. (2000). Investigating traits of top performing software developers. *Information Technology & People*.

VIRTUAL COLLABORATION & EXCHANGE - CHALLENGES AND EMERGING APPROACHES

OPTIMIZING FORMATIVE FEEDBACK GUIDELINES IN COLLABORATIVE ONLINE INTERNATIONAL LEARNING

Mattis Altmann

TU Dresden, Chair of Information Management

Mattis.Altmann@tu-dresden.de

DOI: 10-35011/IDIMT-2022-447

Keywords

Formative Feedback, E-tutor, COIL

Abstract

The effects of formative feedback in higher education are intensively discussed within the scientific community. Students' engagement with received feedback is considered as important as the delivery of feedback. Nevertheless, feedback in higher education is often criticized by students. But also, teachers are often caught between the quality and extent of feedback and their time resources. The number of students in a module and the social form, whether individual or group feedback, is also a decisive factor. Using feedback within the framework of Collaborative Online International Learning (COIL) poses additional challenges. It requires professional competencies and secure handling of the virtual working environment, but design recommendations in this domain are rare. Using the example of two Virtual Collaborative Learning (VCL) modules, each held in collaboration with a partner university, this paper examines the effects of providing formative feedback to students within COIL modules. The investigation is an iterative extension of a prototype of feedback guidelines, which was already published in 2021. The study is based on 126 students' reflection reports from the years 2019 to 2022 and a total of four modules. With the help of Qualitative Content Analysis, the existing findings in the categories frequency and time, style and tone, recipient and sender, as well as form and content should be expanded and supplemented to understand the engagement of students in COIL modules better and thus to be able to support them in a more targeted manner. In this context, the existing categories serve as a basis for the deductive, inductive mixed coding of the student reflections and thus for the enrichment of the existing categories and the creation of new ones. The beneficiaries are the students, who will be provided with better and more user-friendly feedback, and the teachers, who will have a guideline for providing feedback that will be better accepted by the students and thus lead to a better learning behavior.

1. Introduction

The design of feedback is a complex challenge in higher education, whereas feedback is considered a powerful intervention in the learning process of students (Hattie & Timperley, 2007; Panadero & Lipnevich, 2021). Even though there is intensive research on this topic, results often differ due to the context in which studies took place. In particular, the focus should be on the characteristics of formative feedback that lead to improved learning. (Goldin et al., 2017). Teaching in the context of

multi-institutional exchanges presents challenges for providing effective feedback. For example, balancing student demands for intensive, applicable, and personalized feedback with the justification of the grade in the module (Vattøy et al., 2021). Here, Winstone et al. (2017) refer to Whitey's (2013) feedback paradox, which describes how students recognize the importance of feedback and criticize it while adapting it only marginally. This paper examines students' perceptions of formative feedback and their tendency to implement it. The focus is on modules in the Virtual Collaborative Online International Learning (COIL) framework where students work in small interdisciplinary groups on a complex case study with weekly assignments. The formative feedback is given by E-tutors who have previously undergone a qualification in the form of a module but differ significantly in their experience and thus also in the quality of their support. To narrow down the scope of the study, it should be noted that the focus here will not be on the psychological design of feedback but social and technical factors, considering the virtual learning environment. This is made clear by a quote from Goldin et al. (2017): "Although the psychological mechanisms that people employ to respond to formative feedback will not likely change, the social organizations and technologies we create to provide and improve formative feedback will continue to advance rapidly" (p. 390).

This paper should be regarded as an iterative step within an action research design and draws on findings from Altmann et al. (2021) regarding the creation of formative feedback and student engagement with it. For this examination, the following research questions are posed:

1. Which effects can be identified regarding students' perception and implementation of formative feedback in COIL modules?
2. Which design recommendations for giving formative feedback in COIL modules can be derived?

In the context of the study, the theoretical background is presented first. This is followed by a description of the modules in which the data were collected and the qualitative content analysis method according to Mayring (2014). This is followed by the presentation of the study's results and a discussion with derived design recommendations and culminates in a conclusion in which the findings are presented with the most intensive code-co-occurrences in a network.

2. Theoretical Background

Formative feedback is traditionally given in the higher education context by people who are in the role of supervisor or peer. The agents can also be the learner themselves, or they can act on the learner from the outside. In addition, modern Information and Communications Technology (ICT) environments offer further possibilities for giving feedback, such as public posting in a learner team with options for reaction and interaction, as well as the collection of digital traces which are not present in an analog format. At the same time, it also opens new dimensions that require feedback, such as feedback for the use of virtual collaboration tools (Goldin et al., 2017). Shute (2007) offers a widely used definition: "Formative feedback represents information communicated to the learner that is intended to modify the learner's thinking or behavior for the purpose of improving learning" (p. 1). Vattøy et al. (2021) highlight the importance of seeing feedback not as a one-way road but rather focusing on the interaction between recipient and sender. Thus, feedback should be given (e.g., in written form) in a way that allows further discussion of the agents and therefore interaction with the feedback (Vattøy et al., 2021; Winstone et al., 2017). Students have the critical decision of when to ask for feedback and whether to interact with it (Winstone et al. 2017). Various influencing factors should be considered, such as applicability, the opportunity for dialogue and reflection, and the timing and quality of the feedback given, to positively influence the students' decision to interact with the feedback. Conversely, feedback must be used by students to make an impact. In

this process, the instructors or external feedback agents also have the task of carefully and precisely creating the feedback and integrating it into the module's design. Simply giving feedback without specified integration can become problematic in practice and thus influence students' decisions regarding how to deal with the feedback they receive (Vattøy et al., 2021). In doing so, teachers should also step into the role of the teacher as a designer, especially in the context of technology-enhanced teaching and integrate and actively use available tools within their module (Rolf, 2021).

3. Modules

The data of this study is collected within a master's and a bachelor's module, both held in a bilateral collaboration between Technische Universität Dresden and a partner university. The modules are designed within the Virtual Collaborative Learning (VCL) framework, offering entirely online project-based working experience (Balasz, 2005; Clauss et al., 2021). The VCL framework consists of four design dimensions described in the following. The realistic task design consists of a case study design based on real-world incidents and situations (Clauss et al., 2021). The task design complements the approach of problem-based learning, according to Kopp et al. (2014). Finally, it includes formal and informal learning objectives such as collaboration on digital learning platforms in an interdisciplinary team. The second design dimension concerns using a digital learning platform on which the module takes place. The third dimension involves learning analytics. Here, E-tutors will be supported by information visualization of learning activities. Finally, the fourth dimension involves the professional support of learners by qualified E-tutors, who are also responsible for giving formative feedback (Clauss et al., 2021; Schoop et al., 2021).

Furthermore, it is essential to note that the modules were held within the Collaborative Online International Learning (COIL) framework, which describes the connection of students from different countries or universities using ICT to help them acquire global competencies (Stevens Initiative, 2020). "Virtual exchange is closely associated, or used interchangeably with, several other terms, including COIL" (Stevens Initiative, 2020, p. 5). This is primarily about co-creating environments where learning can take place, creating shared content, and integrating the results into the respective curriculum at the students' home institution. A COIL module does not necessarily have to be international but can also be inter-institutional (Sunny COIL, 2022).

Case-based learning in the virtual Classroom

The bachelor's module takes place in local cooperation between Technische Universität Dresden and Hochschule für Technik und Wirtschaft Dresden. Every summer semester, around 70 participants enroll for this module. The students work in a fictitious joint venture between the city of Dresden, a local energy supplier, and a local car manufacturer. In the process, they will develop concepts for a platform business model to promote electromobility in the greater Dresden area (Schoop et al., 2021).

Collaboration in the Virtual Classroom

The master's module is an established cooperation between TU Dresden and Shiraz University since 2019. The students work within heterogeneous small groups of four to six members. As fictitious employees of the so-called GASOILINA Holding and the sub-company Innovation Blu, the interdisciplinary and international groups generate their ideas on a virtual learning platform. Within these groups, the students need to solve complex tasks on a weekly basis to develop a project proposal for the green energy transformation of a fictive company located in the MENA region (Altmann et al., 2021).

Formative feedback procedure

Formative feedback is given by E-tutors. In all of the modules examined here, the feedback was given according to the scaffolding principle: There is obligatory feedback in the first two weeks of each module, after which it is only provided on request. Furthermore, a get-to-know meeting with the E-tutor is integrated into the assignment, which should take place in the first week on the digital learning platform. The E-tutors also have the opportunity to discuss with the module supervisor at any time to clarify questions and problems.

4. Research Design

This study was conducted in the higher education context at a German university. At the end of each module, a written reflection report with questions concerning the experienced feedback situations and their engagement during the module has to be written by the participants. The students were instructed to write their reflections with the help of Gibbs's reflective cycle (1988), incorporating the stages of description, feelings, evaluation, analysis, conclusion, and action plan. This standard tool for reflection is widely used in higher education research to provide students with a simple and adaptable cyclic model to capture their experiences. It also fosters students' analysis competencies regarding their learning processes (Issa et al. 2021).

The sample consists of 126 written reflections of students participating in either a bachelor's or a master's modules within 2019 - 2022. Both modules are held within the VCL framework and support of E-tutors as described in Chapter 3. The response rate is 100% as the written reflection has been implemented as an obligatory task after the completion of the module and thus covers the complete experience of the feedback given during the module. In detail, 32 bachelor Students from winter semester 2019 – 2020, 15 master's students from summer semester 2020, 31 master's students from summer semester 2021 and 48 bachelor students from winter semester 2021 – 2022 participated. A qualitative content analysis approach by Mayring (2014) has been chosen to analyze student reflective reports. To examine students' experiences and feedback situations during the module, an inductively and deductively mixed scenario was used to compromise results from earlier research within this domain (see Altmann, Langeesee & Misterek 2021). In detail, this procedure is called Theme Analysis, which uses themes from an already conducted study and uses them as an initial basis for deductive coding (Mayring, 2014). Through this method the established categories from earlier research can be enhanced, or reduced without losing the connection to the previous research.

The themes Frequency & Time, Style & Tone, Recipient & Sender, Form of delivery and content are taken as an initial point for the development of the code structure (Altmann, Langeesee & Misterek 2021). However, these codes serve as an initial point of the study. They may change during the coding process with the present material and the second step of this approach, the inductive category formation, to generate new insights.

After the development of the research question, the category system was established as described before. In a third step, the coding rules and anchor examples for the existing categories have been defined. Afterward, the first analysis sequence for the material took place. In this case, the Atlas.ti software was used for the coding. After 20 percent of the material had been analyzed, a revision of the existing codes and categories was implemented whereas none of the existing categories were removed as they were already represented in the codes, but a renaming of categories and establishment of new subcategories was done with the help of a peer colleague, and constant documentation of the adjustments to meet the quality criteria standards. Afterward, the material has been worked through completely, and the first 20 percent has been analyzed again according to the

changed code system. In the final step, the established category system has been analyzed and interpreted (Mayring, 2014). The findings are described in the following chapters.

5. Results

The coding process revealed 787 codes for the topic-relevant themes (see figure below) and another 639 codes for the evaluation themes *Evaluation: handling & perception* (479) and *Evaluation: effects* (145). In total, 1411 codes were set during this paper's research process. The distribution of codes topic relevant themes can be found in the following figure.

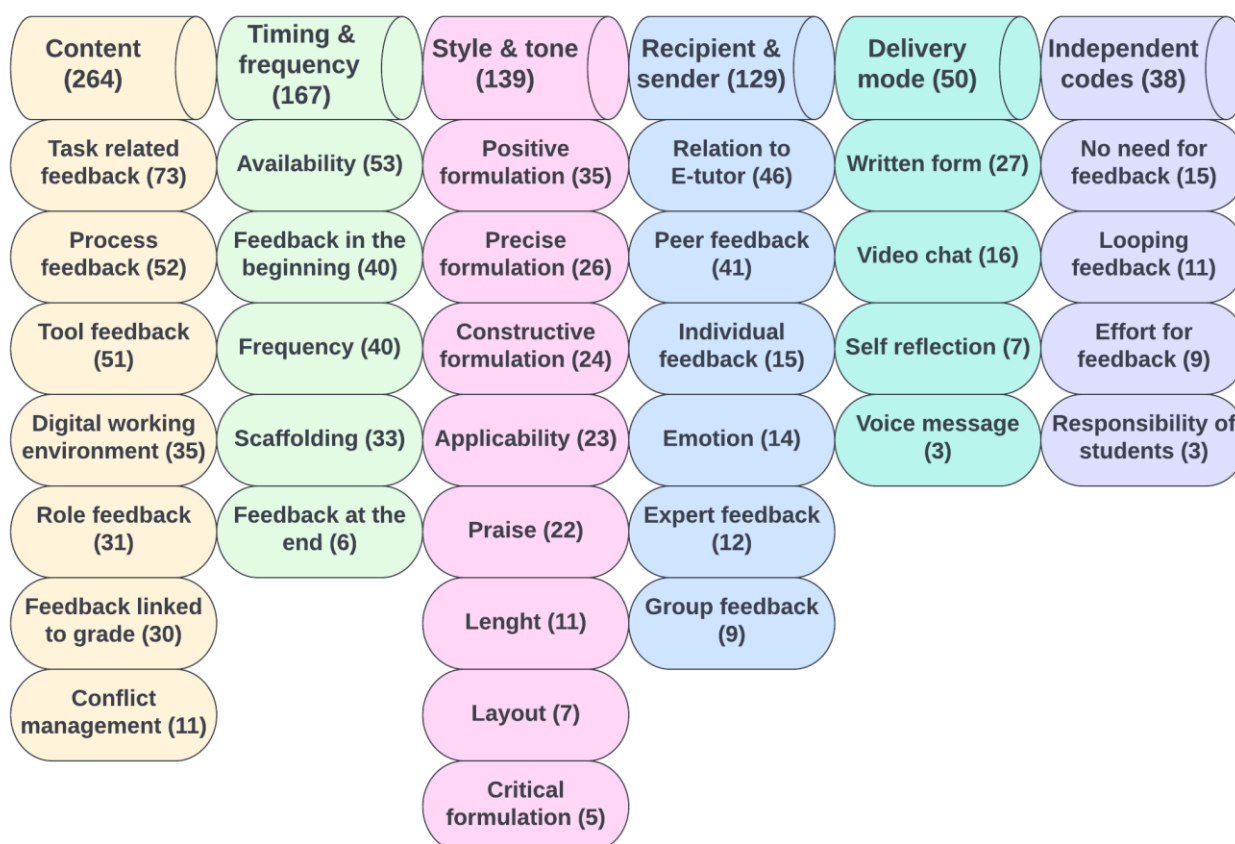


Figure 1: Coding frequency of topic-relevant themes (own representation)

The topic-relevant codes displayed in figure 1 are used to thematically classify the different dimensions involved in students' perception of formative feedback. They are described and analyzed individually in the following section, and the analysis results are presented. For a detailed code-co-occurrence analysis and the representation of relationships between the codes, the two evaluation themes, *Evaluation: Effects* and *Evaluation: Handling & perception*, were also introduced. This allows drawing conclusions about barriers and potentials regarding the implementation of formative feedback in COIL scenarios as well as the improvement of design recommendations. Particularly conspicuous effects are additionally supported with an anchor example. Here the source is specified in the following format: (D12:3, p.4) where the D and the number stand for the assigned document number, the number after the colon for the numbering of the code in the respective document, followed by the page number. The codes and themes are written in *italic* to allow a good reading experience. In the following, all created themes will be described briefly, and the two most frequent codes will be explained in detail.

Evaluation: Handling & perception

This theme refers to the perception (positive or negative) and Implementation (implemented or not implemented) of formative feedback discovered in the material. These codes were not set standalone but always connected with a topic-relevant quotation from the reflections so that they can be assigned to the respective topic afterward

In total, 306 codes (69,87% measured against *negative perception*) have been identified where formative feedback has been *perceived positively*, and 132 codes (30,13% measured against *positive perception*) were *perceived negatively*. Further, 109 codes (68,13% measured against *not implemented*) have been identified where formative feedback has been *implemented*, and 51 codes (31,87% measured against *implemented*) where it was *not implemented*. A comparison of the code-co-occurrences shows that in the formative feedback *implemented*, 84 out of 109 (77,06%) of these feedbacks were also *perceived as positive*, and the remaining 25 codes were neither positive nor negative connotated. In contrast, for the *not-implemented* formative feedback, 36 out of 51 (70,59%) were also *perceived as negative* while 9 codes were neutral. However, it is noticeable that 6 out of 51 (11,76%) feedbacks *perceived as negative* have been implemented. Looking more closely at these 6 codes, it is apparent that the students here felt that not accepting the feedback would harm their grade and therefore implemented it.

Evaluation: Effects

This evaluation theme describes formative feedback's effects on students when they receive it. As in the other evaluation theme, the codes here are set together with a topic-relevant code to relate the identified effects to the respective categories. The codes of *guidance* (25), *group discussion* (30), *learning behavior* (44), and *motivation* (54) were determined under this theme. According to Shute (2007), formative feedback intends to change the learner's behavior to improve the learning itself. But also, *motivation* is seen as a facilitating factor of student engagement and performance if the formative feedback is delivered correctly.

Within the code *motivation*, 34 (62,92%) codes are also marked as *perceived positively*, whereas only 13 (24,07%) of the 54 codes are also coded as *implemented*. As an explanation, the feedback also considers elements that are already going well, and thus there is no need for implementation.

“In my opinion, the received feedback was very helpful. It was detailed, constructive and all points were understandable. The feedback started in a positive way by highlighting the good collaboration so far. This had a motivational effect.” (D86:1; p.5)

Regarding the code *learning behavior* within this research, it is noticeable that 33 (75,00%) codes were *perceived as positive*, and 31 (70,45%) were *implemented*, whereas only 2 (4,54%) codes were *perceived as negative*, and 3 (6,81%) codes *not implemented*. Thereby 24 (54,54%) codes were *perceived as positive* and *implemented*.

“Another suggestion for improvement was to create a more detailed weekly report. In the following weeks, we reflected more on our work and on our own learning behavior. This was very helpful to have a more accurate overview in retrospect and to work more productively in the future.” (D5:9; p.9)

In the following section the results of the topic-relevant themes will be shown.

Content

73 codes have been set for *task-related feedback*, and 29 (39,72%) of these were *perceived as positive*, 29 (39,72%) as *negative*, and 15 (20,27%) as neither positive nor negative. Thereby, a particularly strong code co-occurrence with the code *Frequency* (6) from the theme *timing & frequency* is shown, which clearly indicates that some students would like to receive more feedback

on the task, which is even amplified by the code co-occurrence with *task-related feedback* and *guidance* (5).

“After each submission, brief feedback could be given to the extent to which the created results correspond to the target and if there were any discrepancies in what they consisted of.” (D89:3; p. 5)

The perception of *task-related feedback* correlates with the percentage distribution of the *Feedback linked to grade* code, in which 10 (33,33%) *negative* and 12 (36,36%) *positive* perceptions were coded, and 8 were neither positive nor negative. However, it is noticeable that 20 times it was coded that the *feedback linked to grade* was *implemented* and only 1 time that it was *not implemented*. An explanation can be found in the following anchor example:

“To avoid possible conflicts with the E-tutor in this context, some points were simply accepted without talking about them again. In my opinion, a possible conflict was avoided mainly because our E-tutor is jointly responsible for the evaluation of the project and therefore one has a certain inhibition threshold to openly address problems.” (D56:2; p.3)

In relation to the other codes in this theme, these are the most negative perceptions. In comparison, 32 *positive* and only 2 *negative* perceptions were coded for *tool-related feedback* (51), and 31 *positive* and 8 *negative* perceptions for *process feedback* (52) which also had the most substantial connection to learning behavior with 15 common codes.

Timing & Frequency

The *availability* (53) of the E-tutor is the most frequent code within this theme and is perceived as positive in 33 (62,26%) codes and as negative in 10 (18,86%) codes, whereas implemented (3) and not implemented (3) codes are rare. The strongest code-co-occurrence can be found in *Relation to E-tutor* (11). It should be noted that *availability* plays a significant role in the relationship with the E-tutor. If the availability is evaluated negatively, i.e., the E-tutor is too late or not in contact with the group at all, this also has a negative influence on the relationship of the group to the E-tutor, whereas a constantly available E-tutor has better chances to build up a positive relationship with the group.

“In our case the E-tutor communication was very satisfying. Our E-tutor assisted us when we needed help and tried within her limits to help us solve our issues. She responded always quickly to our messages and gave us the feeling of being heard.” (D126:1; p. 3)

The second strongest code-co-occurrence of *availability* is connected to *Tool feedback*(6), whereas the quick answer to a tool-related question can have the potential of further positive side effects

„I was very inexperienced and unsure and didn't know what the possibilities were for working on a project in teams. But luckily I was not the only one in my group. Thanks to the quick and concrete feedback from our tutor, we were able to explore the platform quickly and immediately tried to put her comments and advice into practice. A short time later we already knew our way around teams and from week to week we tried to use all the tools for our collaboration. This worked very well.“ (D54:4; p. 4)

The code *Frequency* (40) has been perceived negatively in 24 (60,00%) cases and positively in 16 (40,00%) cases. In terms of code-co-occurrence, the most substantial reference is to the theme *content* (11) and the code *task-related feedback* (6), with 4 of 6 having been coded negatively. In contrast, the code *Feedback at the beginning* (40) has been *perceived positively* in 32 (80,00%) codes and *negatively* in 7 (17,5%) codes and has the strongest code-co-occurrence with the theme *content* (14). Compared to the code *frequency*, the code *Feedback at the beginning* has 4 code-co-occurrences with *process feedback* and *tool-feedback* and only 2 with *task-related feedback*.

Style & Tone

This theme has 139 codes and has been coded 75 (55,97%) times *positively* and 34 (24,46%) times *negatively*. Further 28 (20,15%) codes are connected to *implemented*, and 23 (16,55%) codes to *not implemented* feedback. The strongest *negative* perception is connected to the code *applicability* (10). Even 12 codes were made for *not implemented* regarding the *applicability*.

“Her feedback that each team member should spend at least 15 minutes a day commenting, and liking was very excessive. As I was also in exchange with members from other teams, I knew that their E-tutor did not require such a thing. There should be a consistent approach between the E-tutors so that some teams do not feel pressured to communicate on the platform especially when there is nothing to communicate at the moment.” (D125:4; p. 3)

The strongest *positive perceptions* can be found in the codes of *constructive formulation* 22 (15,83%), *positive formulation* 21 (15,11%), and *praise* 14 (10,07%). The codes *positive formulation* (14) and *praise* (10) correlate weakly with *motivation*, while *constructive formulation* (6) has a significantly smaller code-co-occurrence with *motivation* but is coded the most for *positive perception* (22). Furthermore, it is remarkable that the code *praise* appears several times together with the code *peer feedback* (4) as well as the code *precise formulation* together with the code *digital working environment* (4).

Recipient & Sender

With 129 codings in this theme, 66 (51,16%) *positive perceptions*, 30 (23,26%) *negative perceptions*, and 33 (23,58%) neutral perceptions were recorded. Thereby 17 (13,18%) common codes were set with *implemented* and 15 (11,63%) with *not implemented*. However, there were hardly any commonalities regarding the theme effects such as the codes *motivation* or *learning behavior*. Besides the strong connection to *availability* (explained in more detail in the section timing & frequency), the code Relation to E-tutor is most strongly represented with 30 (23,26%) *positive* and 15 (11,63%) *negative perceptions*. Particularly interesting is the strong *positive perception* (22, 17,05%) of the code *peer feedback*, which in contrast, was coded only 2 (1,55%) times together with *negative perception*.

“I found the group work very harmonious and the respectful way we treated each other made me feel positive. I think that the feedback from the other group members was always at the right time and adapted to the needs of the feedback recipient. This enabled us to grow together into a team and a unit within the module.” (D124:16; p. 4)

Delivery Mode

With 50 codings in this theme, 23 (46,00%) codes co-occurred with *positive perception* and 11 (22%) co-occurred with *negative perception*. The effects on the implementation are only marginal in this study. The strongest code is *written form* (27, 54,00%) with 15 (30,00%) *positive* and 4 (8,00%) *negative* shared codes, whereas 50% of the *negative* codes correlate with the theme of *style and tone*.

“We received feedback from our E-tutor in writing and publicly via Team for the entire group. It was very detailed and could significantly contribute to improving structures in the team, including, for example, reactions by emotion to read messages, better linking of documents and better structuring of the platform.” (D123:5, p. 4)

In contrast, the ratio for *video chat* (16, 32,00%) is balanced with 6 (12,00%) *positive* and 6 (12,00%) *negative perceptions* whereas *voice message* (6, 12,00%) was exclusively *negative* (2, 4,00%) perceived.

“Another feedback we did not implement was the already mentioned voice message on a Sunday night from our E-tutor, which was an unprofessional format and did not make sense in term of its contents since she only mentioned aspects we had already explained and posted about on the platform.” (D108:5; p. 5)

Independent Codes

In this theme, further conspicuities from the material were captured, but there is little relationship to *positive* or *negative perception*, and the theme *effects* also show marginal relationships. With a total of 38 codes, 15 (39,47%) were grouped under the *no need for feedback* category.

“In addition, there were no conflicts or learning problems in our group or any problems at all within the group, which is why we did not request any more feedback or needed any support.” (D57:1; p. 3)

Furthermore, there were 11 (29,95%) codings for *looping feedback*, where the main issue is the reference of the new feedback to the previous one.

“What I particularly liked was that the E-tutors related the second feedback to the first one to see if and how well the last feedback was implemented.” (D92:1, p.5)

In the following chapter, the findings from the study are discussed, and recommendations for a further extension of the feedback guidelines from the previous design of Altmann et al. (2021) are given.

6. Discussion & Recommendations

Content

In future modules, the connection between feedback linked to grade and the implementation of such needs to be explicitly explained. The consequences of accepting or not accepting feedback need to be transparent for the students. Further, the task-related feedback needs to be improved in terms of frequency which also affects a more positive perception of guidance and thus leads to a higher implementation rate. Nevertheless, it is important to keep the balance between feedback on the task and working together on the solution. Process feedback was the most frequent code influencing the learning behavior and should therefore be considered in every feedback. Also, well-performing groups can benefit from a motivation boost, as described in the previous chapter.

Timing & frequency

The availability of E-tutors is crucial to ensure a good relationship to them and can be seen as a focal point in the decision of how feedback is perceived and if it is implemented. Therefore, the E-tutors should be sensitized for constant availability during the module. In particular, tool-related feedback should be considered, since a quick response can have other positive side effects, such as motivation. The frequency of feedback should be adjusted so that even after two obligatory feedbacks at the beginning, there are one or two additional ones, but with a greater time gap. The decision on the number of further obligatory feedbacks should be based on the length of the module. Finally, the feedback, in the beginning, should concentrate more on the tool-, and process-related feedback, while the feedback in the middle and end of the module should focus more on the task.

Style & tone

In this theme, increased attention should be paid to an understandable and applicable formulation because students who do not understand the feedback, or do not understand why they should adjust their behavior, tend not to implement the feedback. A quick check of the applicability should be

carried out before sending the feedback. Furthermore, it is advisable that inexperienced E-tutors have the feedback reviewed by an experienced E-tutor or the module supervisor. In contrast, positive formulation, constructive formulation, and praise influence the positive perception of the feedback and should therefore be applied when formulating the feedback. In particular, positive formulation and praise have an additional, and if implemented correctly, positive influence on the motivation of students and should therefore and also due to the ease of implementation, always be part of the feedback.

Recipient & sender

A key factor here is the relationship with the E-tutor, which can positively and negatively impact the acceptance and implementation of the feedback. In this study, availability was identified as the most critical factor for the relationship with the E-tutor, but role, task, and the applicability of the feedback, also play a minor role. For a good relationship, E-tutors should, therefore clearly communicate their availability from the beginning and adhere to it or organize a substitute in advance. Furthermore, peer feedback is almost entirely perceived positively, so it is advisable to integrate it regularly into the assignments and think about inter-group feedback in addition to intra-group feedback.

Delivery Mode

Written feedback is accepted chiefly and considered positive and should therefore be kept as the primary delivery mode. As half of the negative perceptions of written form correlate with the theme style and tone, the mistake should not be seen in the delivery mode but more in an adequate formulation. Some students prefer a face-to-face meeting or video chat for feedback. To meet this wish, this should be offered as an option in addition to an obligatory appointment at the beginning of the module to get to know each other. However, the strain on the E-tutor's time resources should not be disregarded. Finally, feedback via voice message should be avoided, as students perceive it as unprofessional and thus has little chance of being implemented.

7. Conclusion, Limitation & Outlook

The research has shown that students are more likely to need tool and process feedback at the beginning of the module, while the need for task-related feedback is more likely to be at the middle and end of the module. The positive formulation of the feedback as well as praise has a clear influence on the motivation of the students. Motivated students in this study usually perceive the feedback positively, so it can also be said that the feedback is accepted through the correlation of the code positive perception to the code implementation. Peer feedback also significantly affects positive perception and should therefore be implemented into the assignment at regular intervals. The availability of the E-tutors significantly affects the group's relationship with the E-tutor. A good or bad relationship is often accompanied by a positive or negative perception of the feedback, so regular availability of the E-tutors is also recommended regarding the acceptance and implementation of feedback. Critical to consider is the attention to applicability in the formulation of feedback. If this is not applicable, it is often accompanied by negative perception or non-implementation. Finally, it should be noted that feedback from the student's point of view or due to the writing style shows a connection to the student's grade is implemented regardless of positive or negative perception. In this case, special attention should be paid to a transparent presentation of the consequences of acceptance or non-acceptance. An Interpretation of these relations can be found in the following figure:

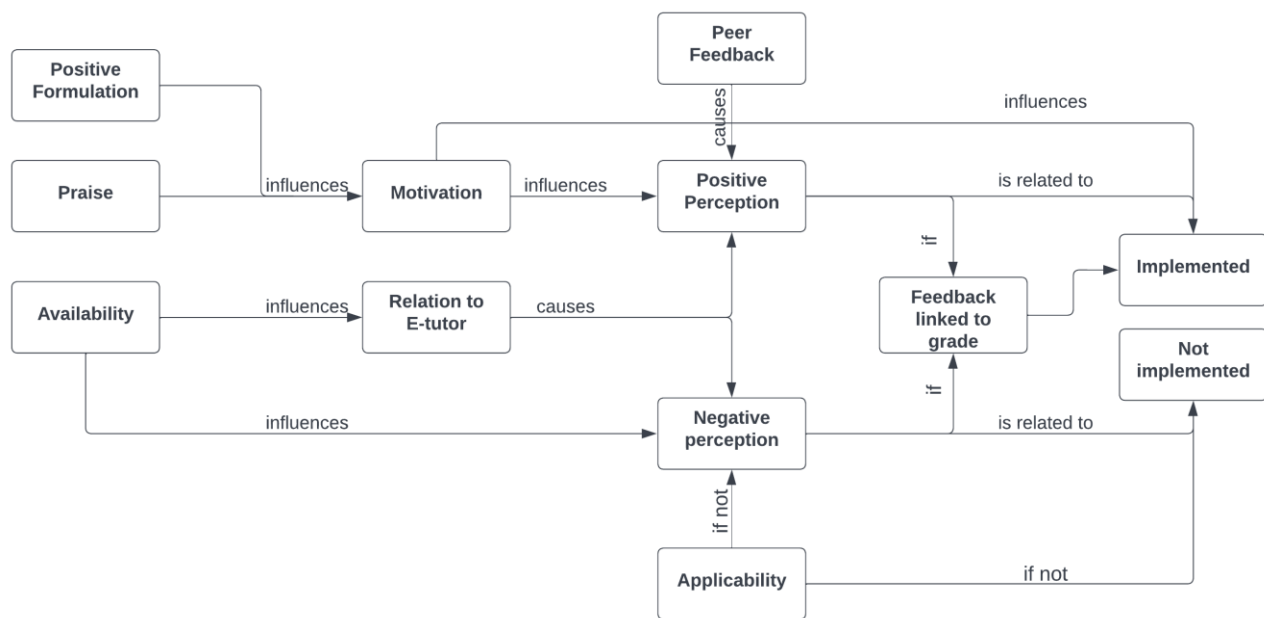


Figure 2: Network of formative feedback effects (own representation)

The connections in the network shown here are the result of this qualitative investigation and do not claim to be generally valid, for this, a further test of the relationships in the network is required. Thus, in a next interactive step in the Action Research Framework, the investigation could be extended to other COIL modules with group work to achieve a more valid picture. This could be realized by examining the perspectives of students, tutors, and teachers in a further qualitative study using several Instruments like a reflective journal for teachers, and focus group Interviews for students. In terms of limitation, it should be noted that the survey began shortly before the Covid-19 pandemic and took place during the pandemic semesters. Students were confronted with exclusively virtual events for the first time. In addition, the uneven distribution between bachelor's and master's students should be recognized, so more discriminatory power should be considered here in future research. In conclusion, it can be stated that formative feedback is subject to several influencing factors which, in their totality, influence perception and implementation and can be affected by following the findings in this study but cannot be forced.

8. References

- Altmann, M., Langesee, L. M., & Misterek, J. (2021). Designing formative feedback guidelines in virtual group work from a student's perspective, *Edulearn21 Proceedings*, 8698–8706.
- Balázs, I. E. (2005). *Konzeption von Virtual Collaborative Learning Projekten* [Technische Universität Dresden]. <https://nbn-resolving.org/urn:nbn:de:swb:14-1111134624957-21292>
- Clauss, A., Altmann, M., & Lenk, F. (2021). Successful Virtual Collaborative Learning: A Shift in Perspective. In H. C. Lane, S. Zvacek, & J. Uhomiohi (Eds.), *Computer Supported Education* (S. 245–262). Springer International Publishing.
- Gibbs, G. (1988). *Learning by doing: A guide to teaching and learning methods*. Oxford: Oxford Further Education Unit.
- Goldin, I., Narciss, S., Foltz, P., & Bauer, M. (2017). New Directions in Formative Feedback in Interactive Learning Environments. *International Journal of Artificial Intelligence in Education*, 27(3), 385–392. <https://doi.org/10.1007/s40593-016-0135-7>
- Hattie, J., & Timperley, H. (2007). The Power of Feedback. *Review of Educational Research*, 77(1), 81–112. <https://doi.org/10.3102/003465430298487>

- Issa, T., Issa, T., Balapumi, R., Maketo, L., & Imtinan, U. (2021). The role of reflection in learning at higher education. *Research in Ethical Issues in Organizations*, 24, 99–115.
- Kopp, B., Hasenbein, M., & Mandl, H. (2014). Case-based learning in virtual groups – collaborative problem solving activities and learning outcomes in a virtual professional training course. *Interactive Learning Environments*, 22(3), 351–372. <https://doi.org/10.1080/10494820.2012.680964>
- Mayring, P. (2014). *Qualitative Content Analysis: Theoretical foundation, basic procedures and software solution*. SSOAR.
- Panadero, E., & Lipnevich, A. (2021). A review of feedback typologies and models: Towards an integrative model of feedback elements. *Educational Research Review*, 100416. <https://doi.org/10.1016/j.edurev.2021.100416>
- Rolf, E. (2021). *Teachers as designers : Analyses of pedagogical patterns and their use* (PhD dissertation, Department of Computer and Systems Sciences, Stockholm University). <http://urn.kb.se/resolve?urn=urn:nbn:se:su:diva-197748>
- Schoop, E., Sonntag, R., Altmann, M. & Sattler, W. (2021). Imagine it's "Corona" – and no one has noticed. Lessons Learned: Spin Offs of Digital Teaching Experiences Vol. 1, No.1&2. In print: <https://journals.qucosa.de/ll/index>
- Shute, V. J. (2007). Focus on Formative Feedback. *ETS Research Report Series*, 2007(1), i–47. <https://doi.org/10.1002/j.2333-8504.2007.tb02053.x>
- Stevens Initiative. (2020). *Virtual Exchange Typology*. Aspen Institute. https://www.stevensinitiative.org/wp-content/uploads/2021/09/Stevens-Initiative-Virtual-Exchange-Typology_090121_singlepages.pdf
- The State University of New York (Suny). (2022). *Suny Coil: CONNECT. ENGAGE. COLLABORATE*. New York. <https://coil.suny.edu/>
- Vattøy, K.-D., Gamlem, S. M., & Rogne, W. M. (2021). Examining students' feedback engagement and assessment experiences: A mixed study. *Studies in Higher Education*, 46(11), 2325–2337.
- Winstone, N. E., Nash, R. A., Rowntree, J., & Parker, M. (2017). 'It'd be useful, but I wouldn't use it': Barriers to university students' feedback seeking and recipience. *Studies in Higher Education*, 42(11), 2026–2041.

ATTITUDES AND PERCEPTIONS OF EMPLOYEES AND EMPLOYERS TOWARD REMOTE WORKING

Galina Ostapenko, Martin Šikýř, Vincent Montenero

Masaryk Institute of Advanced Studies

Czech Technical University in Prague

galina.ostapenko@cvut.cz, martin.sikyr@cvut.cz, vincent.montenero@cvut.cz

DOI: 10-35011/IDIMT-2022-459

Keywords

Covid-19, remote working, employee–employer attitudes and perceptions

Abstract

The aim of the article is to identify the attitudes and perceptions of remote working (RW) for employees, present the related employers' attitudes and RW management experience following the Covid-19 crisis, and discuss the useful measures to meet the future challenges of RW. Primary research with two types of questionnaires for employees and employers was conducted from October to December 2021 among 247 employees and 49 employers from different countries and industries. The benefits and drawbacks of RW were revealed. People's attitudes toward the organization of RW, work productivity, communication, and trust, as well as people's changing expectations of the future of work, were analysed. The findings showed that despite the fact that 57% of employees surveyed had never experienced RW, they easily adapted to the emergency use of working remotely without compromising their work productivity, feeling supported and trusted by their managers. The discrepancies were found between employee-employer perceptions toward the expected changes in the post-covid future of work related to the hybrid office implementation.

1. Introduction

For many years, several experts have imagined a new form of business operation, more precisely the idea that a significant part of the work would take place off-site (Tietzte, 2002; Bloom, et al., 2009; Messenger, 2019). Remote working (RW) also called distance working, teleworking, working from home has long been recognized as alternative work arrangements for many organizations, and used to be a popular benefit mostly for high performers. Generally, remote working allows employees to work part-time (mostly one or two days per week) or full-time (five days per week) from a location other than the employer's workplace, usually from their homes (Spurk & Straub, 2020).

The worldwide outbreak of the Covid-19 pandemic has changed the traditional view of the use of remote working (Toscano & Zappala, 2021). Due to the Covid -19 pandemic restrictions, remote working has become a standard work arrangement, and many employees around the world have experience the pros and cons of the full-time remote working. Several research focused mostly on the experience of remote working during the first year of Covid -19 pandemic from the perspectives of employees. It was discovered, that: the challenges of RW facing employees include necessary technical equipment and support, clear goals and deadlines, regular communication and feedback,

satisfactory work-life balance and social interaction (Wang, Liu, Qian, & Parker, 2021); ordered remote working may increase perceived stress and reduce work satisfaction (Sandoval-Reyes, et al., 2021); particularly full-time RW(five days per week) reduced productivity (Shimura, et al., 2021); workers who worked remotely before the pandemic restrictions handled the transfer to remote working much better (Donati, et al., 2021); remote working lacking regular social interaction may naturally deepen the feeling of social isolation (Van Zoonen & Sivunen, 2021; Shimura,et al., 2021).

Many questions arise to the post –covid future of work and remote work management. The analysis of research literature in the field of remote management showed the following. The future of more extended use of remote working within many organizations is mostly limited by the known fact that it is not appropriate for all jobs and all employees (Gallacher & Hossain, 2020). Among the main questions for employers are to decide: how much to work remotely from home office, how many days to work at the office and, when and how it should be organized?

The hybrid model of work (hybrid office) alternating work from home along with work from place of employment, work at place of employment. It allows employees to enjoy the benefits of both remote working and in-office work, giving more freedom over when and where work is completed, providing an optimal work-life balance, more productive work and people engagement with reduced stress and less commuting. According to McKinsey (2021) the post pandemic working will be hybrid. According our last research many managers consider that there would be no return backwards, and that it would be easy to set up a hybrid system after the COVID-19 crisis (Montenero & Cazorzi, 2022).

To help employees to cope successfully with remote working, employers should give clear expectations, good communication and support (Carnevale & Hatak, 2020). In order to meet new employee expectations and provide tools for employees to work effectively, the transition to hybrid workplace model rewire the company's processes. The employee engagement into successful implementation of changes "gives birth to a new shared culture of work" (Alexander, et al., 2021).

While the extent of the phenomenon of RW is clearly established, almost two years of Covid-19 crisis may rise new challengers both for employees and employers, changing their perceptions and attitudes on current situation and the vision of future of RW. Meanwhile, we found relatively little written material on the employees' attitudes and perceptions on complex problems (benefits and difficulties people experienced working remotely, their perceptions of RW organization and work control, communication, trust, the influence on RW productivity), as well as the perception of future comparing with the related vision and attitudes of employers.

We believe that a good understanding of the similarities and possible differences between the two groups should help decision-makers to know the points to be explored when they want to create a new type of operation combining the work in business premises and fully remoted.

The first objective of the research is to examine, after almost two years of working under the Covid-19, the extension of the use of the home office and to check whether the attitudes and perceptions of remote working have been identical between their managers and their employees.

The second objective is to understand how they imagine the hybrid mode of working in the future and to identify the differences.

2. Objective, methodology and data collection

By designing the research framework and constructing the International Survey which is mainly based on the questionnaire method of data collection, two sets of research questions were taken into

consideration. The first set of research questions aimed at identifying people's attitudes towards remote work during COVID-19. The research questions were the following: 1). What are the main challenges and opportunities employees and employers experienced? 2). How the emergent RW as a new mode of working is organized and managed, affecting the employees - employers' communication, people motivation and work productivity? By defining this set of research questions, we have hypothesized that the Covid-19 crisis had served as a learning and even de-dramatization of remote work, and that there is an identity of view between management and employees. Developing our first hypothesis (H1), we assumed that the majority (60%) of the interlocutors concerned – managers or employees, even those who had no regular experience of remote work– have adapted to the home office, and they appreciate this form of management. H1: *Despite no regular experience of working remotely prior pandemic, a majority of respondents (up to 60 %) quickly adapted to RW (working from home mostly)) without compromising the work productivity.*

The second set of research questions aims to better understand the respondents' perceptions of the future of remote working in the “new normal” after the pandemic, as well as the attitudes towards remote management. The research questions further seek to know: 3). Are flexible working arrangements and the hybrid office a beneficial way of working in a new normal? 4). How do you see the good proportion between working at the office and working full remotely; 5). What changes are needed to implement a flexible working policy and hybrid office? Formulating our second hypothesis (H2), we assumed that there is a consensus between employees and employers on the establishment of a hybrid system of work. H2: *There is a consensus between employee –employer attitudes in the creation of a “new remote work” and hybrid office implementation.*

Two types of questionnaires, one intended for managers and the other for their employees were constructed in the same way, but the questionnaire intended for employers was more direct on aspects related to managerial functioning or productivity. The fact of having interviewed managers and employees could allow us to: a) answer the research questions, identifying the similarities/differences of views, that exists around the evolution of remote working; b) prove/rejects our research hypotheses, regarding the attitudes and perceptions of two groups of respondents on present and future of RW; c) make recommendations for RW management development; c) identify areas for further research. In order to better reach our target audience with the questionnaires' clarity and brevity, we communicated in advance with the addressed managers from companies of different countries (Czechia, Russia, Italy, France, Israel, and Colombia). The primary research was conducted from 25 October to 9 December 2021. Almost 15 closed ended and multiple choice questions in each questionnaires (for employees and employers) were prepared in Google Forms. Almost 247 answers from employees and 49 responses from employers of related organizations were received. At the time of data collection the majority of all the participants were full - time remote working due to the third wave of Covid-19 restrictions. Respondents were employed in the following industries: banking, financial and insurance industries (26%); administrative, support and other service activities (23,5%); information technology (16,4%); wholesale and retail industry (13,5%); energy (9,3%); social media(8,0%); others (3,%).

The results from the primary research are presented below.

3. Results

Attitudes to remote working during Covid-19. General overview. Survey responses of 296 respondents showed that 43% of them had some experience with work from home /remotely, before the pandemic. They noted that remote work has been used in their organization in individual cases according the initiatives of the organization/managers/ employees, or that depends on jobs/projects.

Despite 57% of all respondents have never experienced RW, they quickly adapted to the emergency of its introduction during pandemic restrictions: 39% of interviewed answered they were “very satisfied with introducing RW model, and feel comfortable; almost 29 % are somewhat satisfied.

Attitudes towards RW benefits & challengers: employee – employer perspectives. The most common benefits all respondents choose were: high mobility and time flexibility (62, 5%); travel-time and cost savings (44%); finding the right work-personal life balance (38.4%), Table1.

Table 1: Advantages and disadvantages of RW (the percentage of employees’ and employers’ answers)

Advantages of remote working	Empl yees	Empl o y e r s	Aver age	Disadvantages of remote working	Empl yees	Empl o y e r s	Aver age
High mobility; time flexibility	64	61	62,5	Social isolation	40,4	51	45,7
Travel-time and cost savings	55	33	44,0	Difficulties communicating with team members/ managers	23,0	39,0	30,5
Balancing work and personal life	29,4	37,2	38,4	Lack of needed tools or information	25	31,2	28,2
Self-discipline and self-organization skills	25,8	29	27,4	Technical problems	35	11,8	23,4
Increased in productivity	25,2	21,7	23,9	Decline in productivity	23,5	21	22,3

The main challengers both groups have experienced were: social isolation (45,7%); communication (30,5%), organizational problems (28,2%), and technical problems (23,4%).

Attitudes towards RW organization, communication, trust, and work productivity.

The positive trend was found between employee –employer perceptions towards complex problems of RW organization and communication. The most preferable methods of communications for both groups are: online meetings (48%); over the phone (37%), and emails (31%). As shown in Figure 1 below, the relative agreement and clarity were reached between two groups in attitudes toward working time and regular employee availability, what makes the level of control more acceptable by all. This fact in turn increases the employees’ motivation and work productivity.

As shown in Figure 2 below, almost 26 % of employees answered they are more productive working remotely, than work in the office, and 29% of managers answered their employees are more productive; more than 40% of all respondents perceive that „remote vs. office “is equally productive than off-site mode of work (Figure 2).

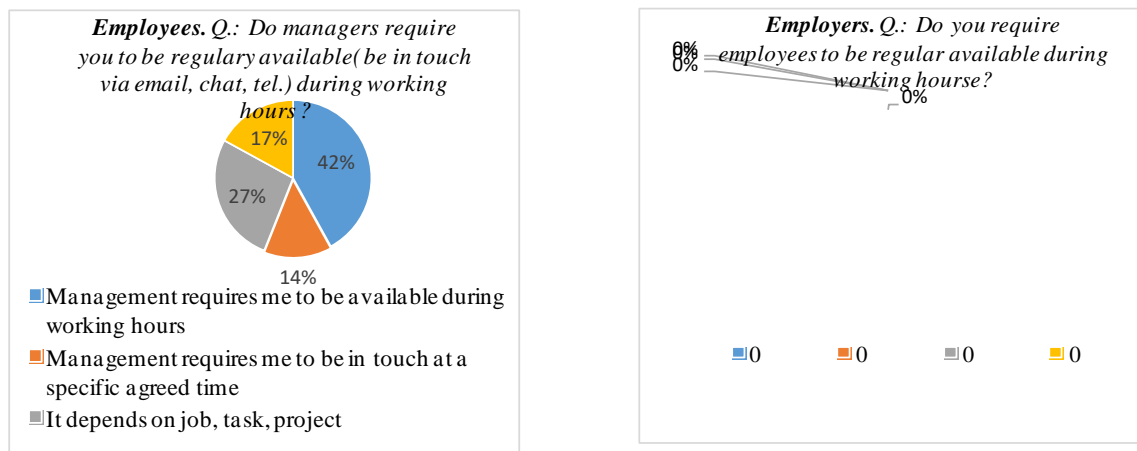


Figure 1 (a,b). Employees’ (a) and employers’ (b) attitudes to working time and availability

Almost 47% of employees answered also, that they feel trusted, supported by the managers and informed about any organizational changes.

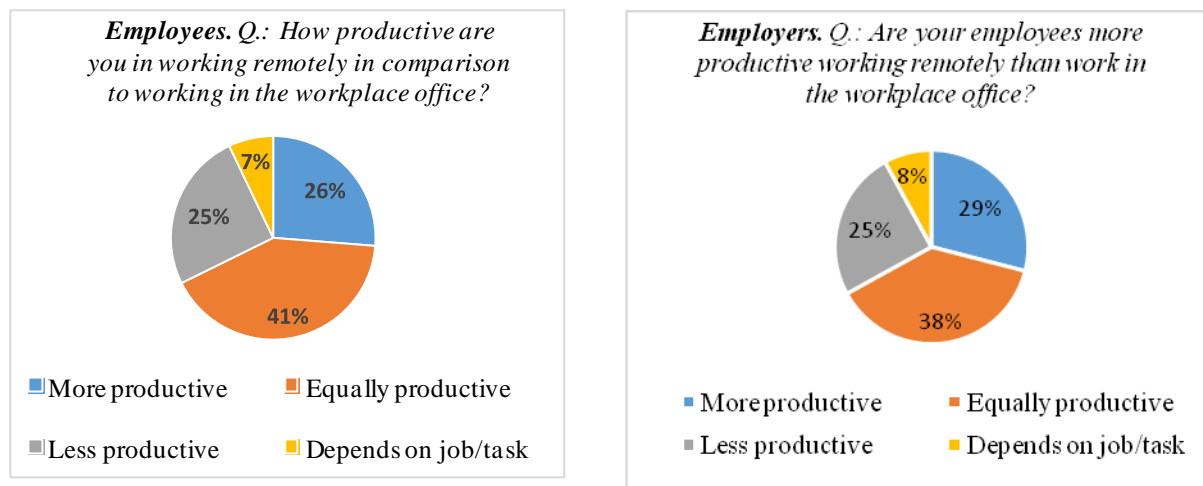


Figure 2 (a,b). Employees' (a) and employers' (b) perceptions towards work productivity

With the third wave of Covid-19 restrictions many organizations were experienced enough to measure the work performance. As follows from the Survey results, 39 % of employers measure it weekly according to a task map with clear deadlines and expected results; 37 % answered they use Key Performance Indicators to measure the efficiency of employees working remotely. Surprisingly, almost half of employers answered that they believe their remote workers intend to achieve the agreed results, and they even do not monitor regularly their working hours.

Many managers increased their focus on work done, instead on hours of work, what allowed us to conclude that remote work improve the performance management.

Attitudes and perceptions toward future of remote work. Attitudes to change.

Dealing with testing our second hypothesis, and research questions, aimed to clarify the respondents' perceptions of the post-covid RW future, first we asked the vision of respondents about a hybrid office implementation in their organizations; then we compared the employee - employer preferences towards the proportion they choose between working remotely and work in the office in a normal post-pandemic future at least we asked the changes employees and employers expect with hybrid office implementation. The most of the survey respondents (82%) ready to embrace an approach that future of work will be hybrid. As seen from Figure 3 below, more than 36% of all respondents prefer being mostly remote with 1-2 days working in the office; 34 % prefer being less remote with 3-4 days working in the office; almost 12% prefer full time RW; 17 % of everyone (13% of employees and 21% of employers) prefer to work only in the office.

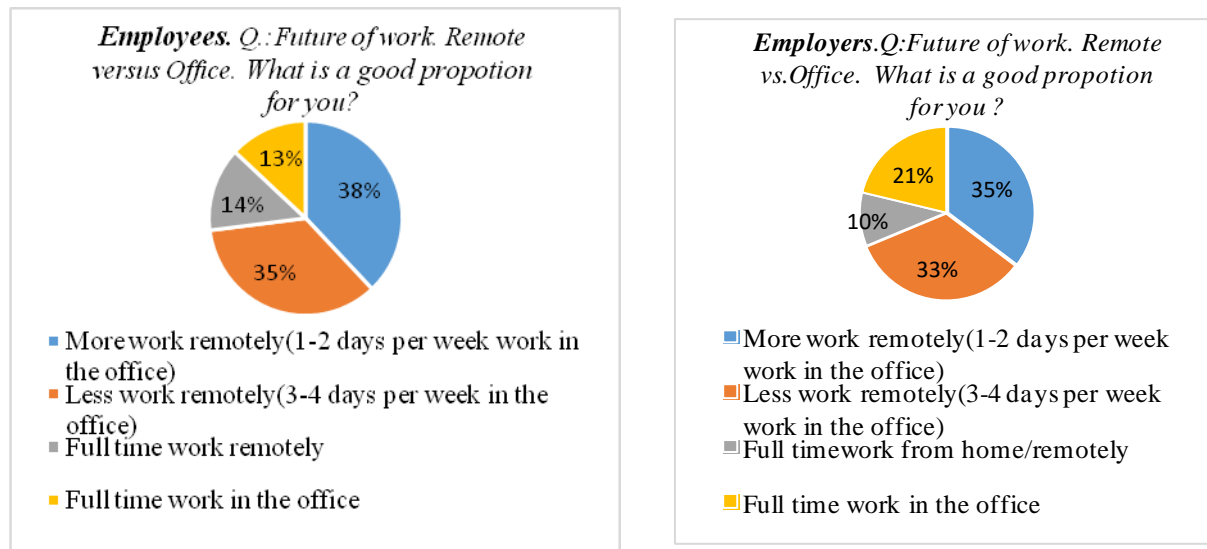


Figure 3 (a,b). Getting hybrid work right. Employees' (a) and employers' (b) preferences of RW

Regarding employees' involvement in change and implementing the hybrid office, only 11 % of employees answered that they are fully and directly involved in designing flexible work arrangements/hybrid office. However, almost 40% of employees answered that are not involved, and 31% of employees answered that their organizations have not hybrid policy (see Figure 4).

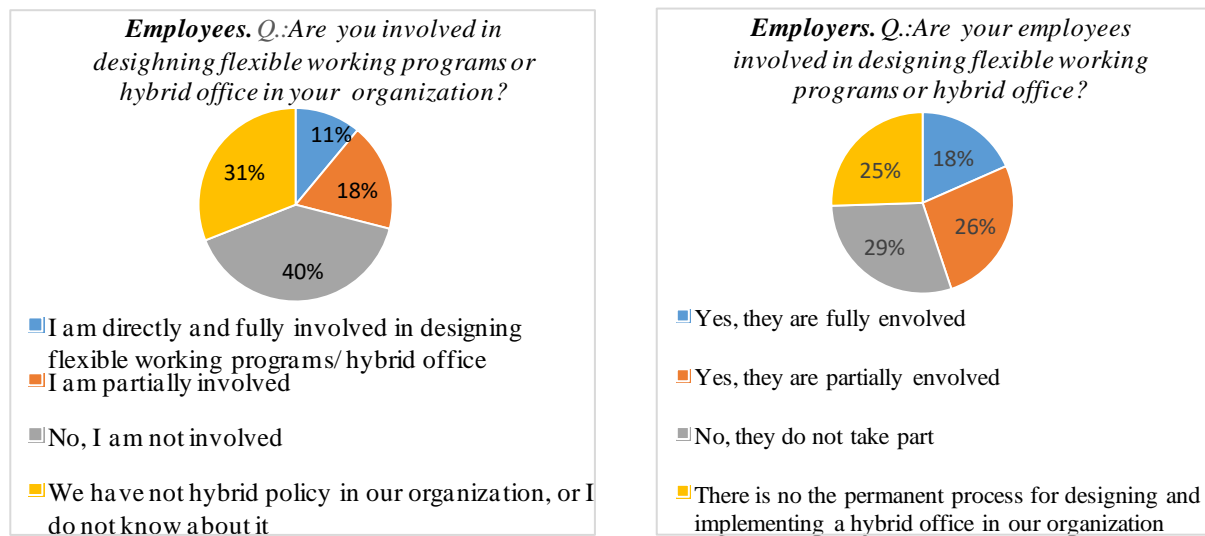


Figure 4 (a, b). Employees' involvement in designing the flexible working policy, a) employees; b) employers

The differences in viewpoints between the two groups surveyed were found also in their replies to the question: "What changes are need to implement flexible working policy/hybrid office in your organization? The employers responded that they would need "to provide clear recommendations and expected results for all employees" (38%), while employees top responses were: "to provide employees with technical and other support"(46%) and "ensure effective communication between all employees" (34%). Almost one-fifth of employees do not expect any changes in their workplace and mode of operations in post-pandemic future.

The findings confirmed that "remote work – works", and many challengers of the emergency RW are successfully overcoming by employees and employers during the second year of pandemic crisis (third wave of Covid-19). New elements of time management, attendance management and measurement performance management to RW have been introduced or successfully adapted. The

majority of respondents (68%) have positive attitudes toward emergency remote working during the coronavirus crisis. The employees easily adapted to the emergency use of working remotely without compromising their work productivity, feeling supported and trusted by their managers, which thereby confirms our first hypothesis (H1): *"The majority of respondents (up to 60 %) quickly adapted to RW (working from home mostly) without compromising the work productivity.* There is no consensus between managers and their employees on more flexible post-pandemic remote work and hybrid office implementation, moreover, we discovered many differences on vision of post-pandemic future of work. The second hypothesis (H2): *"There is a consensus between employee –employer attitudes in the creation of a "new remote work" and hybrid office implementation"* was therefore rejected.

4. Conclusion and Discussion

The research clearly demonstrate that employees and managers have a very close vision and attitudes on remote working, following their experience during the third wave of Covid-19 crisis. Both groups perceive the work mobility and time flexibility as the main advantages. The consensus was found between employees' and employers' attitudes toward organization and communication methods; working time - attendant management; performance measurement management; attitudes to trust. Despite 57% of employees having never experienced this working mode before the pandemic began, a large majority of them (68%) declared that they appreciated it, feeling comfortable, supported, and trusted by their managers. Above all, the two groups considered that the emergency RW did not affect the level of production or even increase work productivity. The results empathized the fact of employees' adaptability and resilience to remote working during the second wave of Covid-19 pandemic, as well as the responsible and effective remote management.

The survey analysis highlights the differences of views in the time that would ideally be assigned to different remote working models and hybrid office implementation. While the most of respondents (81%) are ready to embrace "hybrid" approach in different modes, it was discovered that employees do not have a global vision of the evolution of a new way of working in the company: almost 40 % of employees do not see the hybrid office as the system of policy implementation in their organization; too few of them have been involved in designing hybrid office, having shared detailed guidelines and flexible work arrangements.

The disagreement on the future of remote working shows the importance of creating extensive exchanges on this theme between the various levels of the companies concerned. In an announcement of general intent to embrace and implement more flexible remote and/or hybrid office, the employees should have shared detailed guidelines, approaches, and hybrid working policies, prepared on a consistent, legal basis. Therefore, it is the responsibility of the employers to unlock the potential of their workers by providing tools for them to work effectively, whether their employees work remotely, on premises, or in a blended manner, making people engaged in change, and implementing a living plan/policy for a hybrid workplace.

Study limitations. Data generalization and cross-group comparison design of the Survey allows us to trace the perceptions and associations between two investigated groups, but does not allow determining casual relationships between the variables. The quality of RW experience and the vision of post pandemic future of work definitely increase with different levels of problem design as, for example within cross-country and cross-industry analysis, including job-related attitudes and characteristics, what will be a subject of our further research.

5. References

- Amico, L. (2021). The realities of Remote Work. *Harvard Business Review*, December, 2021.
- Alexander, A., De Smet, A., Langstaff, M., Mysore, M. & Ravid, D. (2021). People and organization performance. What employees are saying about the future of work? Retrieved from <https://www.mckinsey.com/business-functions/people-and-organizational-performance/our-insight> (22.03.2022).
- Bloom, N., Kretschmer, T., & Van Reenen, J. (2009). *Work-life Balance, Management Practices and Productivity. International Differences in the Business Practice and Productivity of Firms*. Chicago: University of Chicago Press, 2009. DOI: 10.7208/9780226261959.
- Carnevale, J.B., & Hatak, I. (2020). Employee adjustment and well-being in the era of COVID-19: Implications for human resource management. *Journal of Business Research*, 116, 183-187.
- Donati, S., Viola, G., Toscano, F., & Zappala, S. (2021). Not all remote workers are similar: Technology acceptance, remote work beliefs, and wellbeing of remote workers during the second wave of the COVID-19 pandemic. *International Journal of Environmental Research and Public Health*, 18(22).
- Gallacher, G. & Hossain, I. (2020). Remote work and employment dynamics under COVID-19: Evidence from Canada. *Canadian Public Policy*, 46 (Suppl.1), S44-S54.
- McKinsey (2021). What executives are saying about the future of hybrid working model. Retrieved from <https://www.mckinsey.com/business-functions/organization/our-insights> (11.03.2022).
- Messenger, J. C. (2019). *Telework in the 21st Century, An Evolutionary Perspective*, ILO Future of Work series. Cheltenham, UK and Geneva: Edward Elgar and ILO. ISBN: 9781789903744.
- Sandoval-Reyes, J. Idrovo-Carlier, S., & Duque-Oliva, E.J. (2021). Remote work, work stress, and work-life during pandemic times: A Latin America situation. *International Journal of Environmental Research and Public Health*, 18(13). Retrieved from <https://www.mdpi.com/1660-4601/18/13/7069> (22.01.2022).
- Montenero, V., Cazorzi, C. (2022). Virtual Management during the Covid-19 Era: Leadership Management Changes. *International Entrepreneurship Review*, 8(1) June 2022.
- Shimura, A., Yokoi, K., Ishibashi, Y., Akatsuka, Y., & Inoue, T. (2021). Remote work decreases psychological and physical stress responses, but full-remote work increases presenteeism. *Frontiers in Psychology*, 12.
- Spurk, D., Straub, C. (2020). Flexible employment relationships and careers in times of the COVID-19 pandemic. *Journal of Vocational Behavior*, 119. Retrieved from <https://www.sciencedirect.com/science/article/pii/S0001879120300609?via%3Dihub> (20.01.2022).
- Tiete, S. (2002). When "Work" Comes "Home": Coping Strategies of Teleworkers and their Families. *Journal of Business Ethics* 41(4) pp.385-396. DOI: 10.1023/A: 1021236426657 .
- Van Zoonen, W., & Sivunen, A.E. (2021). The impact of remote work and mediated communication frequency on isolation and psychological distress. *European Journal of Work and Organizational Psychology*. Retrieved from <https://www.tandfonline.com/doi/full/10.1080/1359432X.2021.2002299> (21.01.2022).

DYNAMIC EMERGENCE OF FEATURES IN COMPLEX SYSTEMS

Gerhard Chroust

Inst. of Telecooperation
Johannes Kepler University Linz, Austria
gerhard.chroust@jku.at

DOI: 10-35011/IDIMT-2022-467

Keywords

Emergence, emergent property, system, feature, purpose, interaction

Abstract

An epidemic involves numerous persons and institutions in handling and mitigating the situation which is characterized by medical urgency, time pressure, political pressure and aggravated by the need to act in partially unknown territory. Many fields of knowledge have to be brought together to fight the challenges. The individual organizations, their actors and the general public have to interact with one another and this often results in unexpected situations, behavior and results, we speak of emergent effects.

Emergent effects sometimes are a welcomed support for actions taken, enhancing the desirable effects, but often they turn out to be counter-productive, reducing or even destroying the intended results. Emergent behavior of systems are a theoretically and practically challenging area of research. There is a rich knowledge about emergence in technical, medical and philosophical domains, for emergence in human behavior and societal issues there seems to be little knowledge available.

Our contribution stresses the difference with respect to a system system between general properties on one side and features on the other side (the relevant and characterizing properties of a complex system) and associate the phenomenon of emergence based on the feature set of a system.

1. Motivation: The elusive concept of Emergence

A pandemic is a situation during which many people, as well as technical and social systems have to interact. Decisions consider limited resources, based on often unreliable data, decisions must be made usually with short notice and under psychological stress. A pandemic challenges the interplay between human, governmental, and administrative systems etc. taking the health systems to their limits. A critical factor is the time pressure, preventing long-term deliberations concerning measures to be taken. The involved systems usually consists of numerous interacting subsystems ('components'), often in large numbers(!). Each subsystem contributes one or more of the needed functionality to the total system. Novel components and creative combinations are often needed to succeed.

In the technical/physical world, emergence has been identified and analyzed for a long time. Around 1890 Henri Poincaré introduced the 3-body conjecture into the scientific world's thinking as an example of emergence (see Francois, 2004, entry 0070). Even simple composite systems exhibit - under certain situations- unexpected and even undesirable behavior. A well-known example is the resonance of a car's suspension system at certain speeds.

This behavior has been labelled 'emergent'. It has undergone intensive investigations and discussions in System Theory (Klir, 2001; Jackson, 2003; Gibb et al., 2021). It turns out (as will be shown in the sequel) that the concept of a 'feature of a system' is one of the keys in understanding emergence.

Despite the large difference between nature, technical systems and society, an emergence can be recognized - *mutandis mutatis* - in all those domains.

Lessons learnt from the theoretical investigation of technical systems can be of use to understand the situation arising in societal systems, and the positive and negative effects of various measures, including emergent situations.

This paper discusses the basic concepts of interaction of components in systems and will give an explanation of emergence by considering "features" as relevant and characterizing properties of a system.

The discussion of figure versus ground will lead us to human psychology which allows us to filter the incoming information to reduce the computational load to be taken care of (Maier, 2015). It is also linked to cultural differences between different nations (Chroust, 2020). Some examples will support our opinion.

2. Approach and Method

2.1. The notion of System

Following (Thome, 1993) and (Open Systems Group, 1981) a system is defined as an assembly of components and their relationships such that

1. The components are connected in an organized way. The way they are connected has usually a key influence on the behavior of a system.
2. A component's behavior is affected by being in the system (and are changed by leaving it).
3. The system has properties other than those resulting from the sum of the properties of the components.
4. The assembly is active, it has a purpose.
5. The assembly has been identified by a person as being of special interest.

A key to the concept of 'system' is the phrase 'in an organized way'. Components and/or the system will show different properties and behavior, depending on the internal structure of the systems (Chroust, 2002), i.e. depending on the way the components are connected (Example: Connecting 3 lamps in series or in parallel makes a drastic difference in the light they produce and the energy they consume).

2.2. Purpose of a System

When talking about systems we have to distinguish, amongst other concepts, between properties, functions and features of a system.

A property of a system is any distinguishable attribute characterizing it. The human mind can find (and notice) or ignore numerous different properties.

Functionalism is the main characteristic of any theory aiming at explaining a system's behavior in terms of usefulness, purpose or practicality. R.M. Snow states: "Functionalists view any system in terms of the 'job' it was created to do: its purpose or function " (see Francois, 2004, entry 1362). Thus systems are built with a "purpose" in mind.

We define the Purpose of a System as an abstract notion explaining in some (often general) terms what the system is supposed to do. A purpose is 'realized' ('implemented') by one or more 'features' of a system (see Francois, 2004, entry 693)

J. van Gigch offers a context view of purpose: "Inanimate systems are devoid of visible purpose. They acquire a specific purpose or function when they enter into relationship with other subsystems in the context of a larger system" (van Gigch, 1993). In contrast "the purpose or objective of a living system (or artefact) is defined by its internal programs and controls, including those programs acquired by learning". We expect systems to provide some useful service (i.e. one or more 'functions' or 'features', their purpose). The interconnection between the components of a system (the internal 'structure') is an important property of a system.

A feature is a relevant set of specific properties intended to perform an identified purpose of a system. As a consequence the Feature Set of a system describes the totality of all the features of a system at a specific point in time. The view of the features of a system will change dynamically. A system's features depend on the structure of the system and on the properties of some (all?) of its components.

Their choice depends on the purpose or use we attribute to a system. The feature set change with the purpose we attach to the system.

2.3. What is a feature?

The concept of a 'feature' needs to be specified (Fiadeiro, 1996; Philippow et al., 2003).

Features are system properties but not all properties are features.

In Wikipedia around 25 different meanings of 'feature' are listed (e.g. a piece of journalistic writing). In our context: A feature is also seen as "an intentional distinguishing characteristic of a system (in behavior, performance, portability, or - especially - functionality)" or as "A feature ... as a logical unit of behavior specified by a set of functional and non-functional requirements" (Hoyer, 2007, p.5).

Systems are usually constructed with a certain purpose in mind, implemented via "features", namely to fulfil one or more purposes. To implement the various required features one or several components are combined in order to satisfy the required features either alone or in cooperation with other components.

Note that a system will have many properties - some of them are usually not even taken notice of by the observer. A feature of a system is attributed to the system by an external observer who considers a combination of properties to be of use in some way. Many different features of a system can be identified and named without any change in the structure or behavior of the system..

For our purpose we can define: "a feature of a product can be described as a prominent or distinctive user-visible aspect, quality, or characteristic of the system."

2.4. Properties, Purpose, Figures and Features

Basically we are interested in the features of a systems - the actual composition of a system is not of central importance. Replacing a component by a different one providing the same feature is often a welcome technical option with respect to cost, performance, etc. In this vein F. Bonsack emphasizes the necessity to clearly distinguish "property" from "function". A property is associated with a given system, but many systems can have the same properties AND a system (or part thereof) can be replaced by another system providing the same function (see 'property and function' (Francois, 2004, entry 2680)).

What is sometimes forgotten, is that each component may - or rather will - have additional properties beyond the "interesting features".

Some of the features are relevant and essential with respect to the system's intention and/or purposes, some of them are noticed by the observer but not relevant, others are not even noticed. In psychological terms we can interpret this as a need to filter the information around us (Example: As a saying goes: "The optimist sees the cheese, the pessimist sees the holes in it").

In more scientific terms the psychological interpretation is that we always distinguish between 'figure' and 'ground'. The Figure-Ground perception describes one of the most fundamental ways in which we simplify a visual image. Figure-ground perception refers to the tendency of the visual system to simplify a scene into the main objects that we are looking at and interested in (the "figures") and everything else that forms the background (the "ground").

Therefore: "A feature is in the eye of the beholder".

For different persons, the distinction of figure and ground is often completely different. This is the result of upbringing, education, current interest, intentions or need. (Wikipedia-english, 2013, keyword: 'Figure- ground (perception)').

2.5. Possible Interaction of Features

When combining the components of a system the features of the individual components may interact with one another in different ways. The Feature Interaction can be of following types:

neutrality The features of each component contribute to the total feature set without interference.

cooperation The features of each component 'reinforce' one another. The resulting feature is based on some aggregation of properties (Chroust, 2002) like summation, weighted summation, sums of squares and even more complex aggregation function.

reduction The individual features of each component weaken the effect of one another to some extent, a situation well known in medicine where adding further medicine may reduce the effectiveness of the present ones. (Example: A classical example is a medicine blocking the intended effect of another one)

contradiction The features of two (or more) components contradict one another. (Example: feature collision: a classical example is an automatic safety door lock permitting only the owner to open the door, but an emergency door-opening procedure exists in case of a fire. Faking a fire alarm would open the door to a hacker...)

2.6. What is Emergence?

Intuitively speaking 'emergence' of a system is linked to 'surprise' (Pessa, 1998). Emergence describes the experience that the whole is greater than the sum of the parts: interactions among the components of a system lead to distinctive novel properties. Emergence has been used to describe

the flocking of birds, the phases of matter and human consciousness, along with many other phenomena. Since the nineteenth century, the notion of emergence has been widely applied in philosophy, particularly in contemporary philosophy of mind, philosophy of science and metaphysics. It has more recently become central to scientists' understanding of phenomena throughout physics, chemistry, complexity and systems theory, biology, and the social sciences (Gibb et al., 2021; Artime and De Domenico, 2022).

We have to note that essentially these 'emergent' properties were often latent in the system, but irrelevant or even unnoticed, they belonged to the 'ground', see section 2.4. Using the system under changed conditions causes some properties to become significant or even essential: they become a useful, desirable or destructive and undesirable feature (a 'figure'). These features require our attention and analysis. A typical feature is the oscillation of an electronic circuit for tuning into a given radio station.

2.7. Types of Emergence

Maier distinguishes four different hierarchical levels (Maier, 2015):

Simple Emergence : A 'simple emergent' property can readily be predicted (not just explained) by modeling the individual system's components and their interconnection. If overlooked, the system designer explains it by: "the emergent property was simply overlooked" (Example: Ignoring the potential of an overweight of a complex system) .

Weak Emergence : A 'weak emergent' property can be readily and consistently reproduced by simulating the complete complex system, but not by simulating the individual components in isolation. It cannot be consistently predicted in advance. If overlooked, the system designer explains it by: "we forgot to consider the feedback from one component to another. (Example: Feedback of microphone and loudspeaker in a room.)

Strong Emergence : A 'strong emergent' property cannot be described and modelled within the set of the considered features of a system. This property becomes a new feature of the system, welcomed, not welcomed or even disastrous. But it lends itself to being modelled. If overlooked, the system designer explains it by: "we never realized that this property would show this behavior" (Example: In order to understand and control it, the intra-car vertical movement must be introduced as a feature).

Spooky Emergence : An 'spooky emergent' is not only a strong emergent property, but its behavior cannot be modelled in its totality by our means, mostly (always?) due to the multitude of often subtle outside influences and/or a huge dimensionality of the model. If overlooked, the system designer explains it by: "We could not foresee this behavior, and it is not even repeatable"! (Example: The 3-body conjecture introduced by Henri Poincaré (see (Francois, 2004, entry 0070)) is of this type.)

Quantum mechanics surprises the scientist with the interdependence of elements without an noticeable or explainable communication means (Choi, 2022).

We should note that the classical examples for emergence, even if they have sometime unexpected and even dangerous effects like the resonance of the car or the oscillation of an electronic circuit can readily (and have been for a long time) easily be modelled and - if desirable - avoided in a design. Obviously this effect is not 'spooky' at all. When we model a system (mentally or mathematically), in order to simplify modelling we usually ignore certain 'irrelevant influences', e.g. in software systems the influence of temperature, the curvature of the earth when travelling short distances, the influence of the observer, etc. Sometimes, however, these ignored influences

may cause 'emergent properties'. The literature is full of such examples. The only remedy is to enlarge and often modify the model,

3. Consequences: Feature Interaction and Emergence

3.1. Emergent Features

The interaction of features is a mixed blessing in engineering. It enables useful function, e.g. radio reception by utilizing resonance. On the other hand it can also have disastrous and destructive effects like the break-down of a bridge due to undesirable resonance. In technical disciplines emergence is one of the key issues (Chroust, 2002; Gibb et al., 2021), and in most cases an undesirable side effect.

A key to understanding emergence is the 3rd statement in the definition of a system: "The system has properties different from the sum of the properties of the components". This implies the appearance of new properties which emerge in the course of composition. These properties cannot be detected or modelled based on the components alone (Pessa, 1998). This situation gave rise to a complex theory of emergence, which is still highly controversial (Baas and Emmeche, 1997; Brunner, 2002; Huemer, 2001).

We define: An emergent feature of a system is a consequence of the interaction of the totality of features of a system. It cannot be determined by considering the features of the individual components in isolation. At least at its first recognition it comes as a surprise. Thus it is necessary to investigate the interaction of components which is largely determined by the system's structure (i.e. by the way the parts are connected to form the system, (Thome, 1993)).

It is obvious that emergent properties complicate the prediction of system properties since their value can only be determined by considering (beyond the participating components) the system structure (Chroust,

2002). As long as we allow any thinkable composition of the system there is little chance of making any reasonable statements about emergent system properties. A restrictive set of admissible composition will allow some statements to be made about the behavior of emergent properties under composition.

The above discussion leads to a new view of the phenomenon 'emergence'. It also removes some of the almost mystical notions of emergence. The notion of 'emergence' is based on the notion of features of a system (and not all properties of that system). Features are considered to be the user-recognized and relevant' necessary properties of a complex.

3.2. Emergence in Social Systems

In social systems we can also identify numerous emergent features. Due to the variability and volatility of human behavior they are more difficult to investigate than in technical systems. In management and business they are of considerable importance. Investigating them with the tools of systems science and emergence could prove quite interesting.

Examples are:

Spontaneous leadership Spontaneous leadership is a result of need, environment and personality. (ILD., 2000), in contrast to organizational leadership, as discussed in the GLOBE-study (House et al., 2004)),

Team Excellence, Creative Teams Team performance is a complex emergent property of excellent teams (Katzenbach and Smith, 1993),

Feeling of Flow This is the elating feeling of a well-running activity (Chen, 2007),

Sudden outbreaks of hooliganism as it is observed in sport games,

Mass psychosis or panic in large crowds,

More thoughts on this fascinating aspect can be found in (Artime and De Domenico, 2022).

4. Discussion

The paper has discussed a new idea: The differentiation between 'properties' and 'features' of a systems: in contrast to the potentially unlimited number of properties of a system there is only a limited number of 'features' which are the focus for modeling and use of a system.

The concept of 'figure' versus 'ground' allows a natural way of introducing new features, in the case of emergence when the original set of features is not sufficient. This also introduces a logical and natural way when speaking about emergence, including the hitherto somewhat mystical notion of certain forms of emergence. We realize that for social systems the concepts presented in this paper are also useful.

The consideration of feature interaction provides a sound basis for the influence on the behavior of systems based on the features of the individual components. It also allows a quite clear description of feature collision and emergence.

This paper shows the strong mutual influence of features and emergence. This discussion can be a basis for consolidation of terminology in this domain. I hope that it will be a source for fruitful discussion and additional clarification.

5. References

- Artime, O. and De Domenico, M. (2022). From the origin of life to pandemics: emergent phenomena in complex systems. *Phil. Trans Roy. Soc. A*, vol. 380, issue 2227, page 17.
- Baas, N. and Emmeche, C. (1997). On emergence and explanation. <http://www.nbi.dk/~emmeche/coPubl/97d.NABCE/ExplEmer.html> [2001-11-22].
- Brunner, K. (2002). What's emergent in emergent computing? In Trappl, R.: EMCSR 2002, Proc. European Meeting on Cybernetics and Systems Research, Vienna, April 2002, pages 189–192.
- Chen, J. (2007). Flow in games (and everything else) *Comm. ACM* vol. 50 (2007), no. 4, pages 31–34.
- Choi, Ch. Q. (2022) Spooky Holography at a Distance, *IEEE Spectrum*, April 2022, pages 7-8.,
- Chroust, G. (2002). Emergent properties in information systems. In Hofer, C. and Chroust, G. (eds.): IDIMT-2002, 10th Interdisciplinary Information Management Talks, Sept, 2002, Zádov, pages 277–289. Verlag Trauner Linz, 2002.
- Chroust, G. (2020). Human and cultural impacts on projects. In Doucek, P., Chroust, G., and Oskrdal, V., editors, IDIMT-2020 - Digitalized Economy, Society and Information Management, 28th Interdisciplinary Information Management Talks, pages 469–479. Trauner Verlag Linz, Sept. 2020
- Fiadeiro, J. (1996). On the emergence of properties in component-based systems. In Proc. AMAST96. Springer Verlag 1996, pages 421–443.
- Francois, C. (2004). *International Encyclopedia of Systems and Cybernetics*. 2nd edition, 2 volumes, K.G.Saur, München 2004.
- Gibb, S., Hendry, R. F., and Lancaster, T. e., editors (2021). *The Routledge Handbook of Emergence*. Routledge, March 2021.

- House, R., Hanges, P., Javidan, M., P.W., D., and Gupta, V. (2004). *Culture, Leadership, and Organizations: The GLOBE Study of 62 Societies*. Sage Publ. Calif., 2004.
- Hoyer, C. (2007). *ProLiSA - An approach to the Specification of Product Line Software Architectures*. PhD thesis, PhD-Thesis, J. Kepler University Linz, 2007.
- Huemer, M. (2001). The philosophical complaint against emergence. <http://www.rci.rutgers.edu/~owl/emergence.html>.
- ILD (ed. (2000). Common traits of leaders. <http://www.leadership-dynamics.com/leader2/sld009.htm>, Nov. 13, 2000.
- Jackson, D. (2003). *Systems Thinking: Creative Holism for Managers*. Wiley, Chichester, UK 2003. Katzenbach, J. and Smith, D. (1993). *The Wisdom of Teams*. Harvard Business School Press, Boston.
- Klir, G. J. (2001). *Facets of Systems Science*. 2nd ed., IFSR Internat. Series on Systems Science and Engineering, vol 15, Kluwer Academic/Plenum Publ, New York, Boston, Dordrecht, London, Moscow, 2001.
- Maier, M. (2015). The role of modeling and simulation in system of systems development. In Rainey, L. and Tolk, A., editors, *Modeling and Simulation Support for System of Systems Engineering Application*, pages 11–41. Wiley 2015.
- Open Systems Group, editor (1981). *Systems Behaviour* 3rd edition. Paul Chapman Publ. 1981.
- Pessa, E. (1998). Emergence, self-organisation, and quantum theory. In Minati, G.: *First Italian Conference on Systemics, APOGEO scientifica*, 1998, pages 59–79.
- Philippow, I., Pashov, I., and Riebisch, M. (2003). Application of feature modeling for architecture recovery. *Softwaretechnik - Trends* vol. 23 (2003) no. 2, pages 19–20.
- Thome, B., editor (1993). *Systems Engineering - Principles and Practice of Computer-based Systems Engineering*. Wiley Chichester-New York 1993.
- van Gigch, J. (1993). *Paradigms*. Delgado R.R., Banathy B.H.: *International Systems Science Handbook* Systemic Publications Spain,, pages 39–56.
- Wikipedia-english (2013). Wikipedia, the free encyclopedia. <http://en.wikipedia.org/wiki/>.

ANNEX

Statement of the Publication Ethics and Publication Malpractice

IDIMT's Publication Ethics and Publication Malpractice Statement is based, in large part, on the guidelines and standards developed by the Committee on Publication Ethics (COPE).

We expect all parties commit to these publication ethics. We do not tolerate plagiarism or other unethical behaviour and will remove any manuscript that does not meet these standards.

The relevant duties and expectations of authors, reviewers, and editors are set out below:

1. Author Responsibilities

Authors must certify that their manuscripts are their original work.

Authors must certify that the manuscript has not previously been published elsewhere.

Authors must certify that the manuscript is not currently being considered for publication elsewhere.

Authors must notify us of any conflicts of interest.

Authors must identify all sources used in the creation of their manuscript.

Authors must report any errors they discover in their manuscript.

2. Reviewer Responsibilities

Reviewers must notify us of any conflicts of interest.

Reviewers must keep information pertaining to the manuscript confidential.

Reviewers must bring to the attention of the Editor-in-Chief any information that may be reason to reject publication of a manuscript.

Reviewers must at any time evaluate manuscripts only for their intellectual content without regard to race, gender, sexual orientation, religious belief, ethnic origin, citizenship, or political philosophy of the authors.

Reviewer who feels unqualified to review the research reported in a manuscript or knows that its prompt review will be impossible should notify us and excuse himself from the review process.

3. Editorial Board Responsibilities

The Editorial Board must keep information pertaining to submitted manuscripts confidential.

The Editorial Board must disclose any conflicts of interest.

The Editorial Board must evaluate manuscripts only for their intellectual content.

The Editorial Board is responsible for making publication decisions for submitted manuscripts.

List of Authors

Affara, Muna	137	Kostiuk, Yaroslava	251	Romanovská, Františka	277
Altmann, Mattis	447	Kovářová, Marie	201	Rozehnal, Petr	93
Antlová, Klára	51	Kramreither, Nicole	127	Ruschak, Michal	251
Aumayr, Georg	127	Kutalek, Ruth	127	Rydvalová, Petra	51, 339
Basl, Josef	67	Lampert, Jasmin	145	Samartinho, João	93
Bauer, Friedrich	161	Leidwein, Alois	127, 137, 161	Saretzky, Janika	127
Bazsová, Blanka	109	Liakhovets, Daria	153	Sedláček, Jiří	269
Blažun Vošner, Helena	137	Lindinger, Sarah	161	Shaaban, Abdelkader Magdy	389
Böhmová, Lucie	381	Ljuhar, Davul	161	Shcherbinin, Sergei	429
Buchalceková, Alena	401, 429	Loesch, Christian W.	19	Schildorfer, Hermann	161
Bürger, Bernhard	127, 137	Lokaj, Aleš	93	Schimak, Gerald	137
Chroust, Gerhard	467	Lukáš, Martin	59	Schmittner, Christoph	389
Cornak, Anton	211	Malá, Ivana	117	Schmoll, Nikolaus	161
Čegan, Lukáš	313	Mansfeld, Michael D.	161	Schoitsch, Erwin	357
Čermáková, Ivana	367, 375	Marek, Luboš	117	Schütz, Mina	153
Čížková, Tereza	59	Markovič, Peter	235	Sieber, Jakub	227
Danel, Roman	367, 375	Maryška, Miloš	201, 285	Sigmund, Tomáš	185, 381
Delina, Radoslav	211	McLaughlin, Matthew	419	Simon, Rainer	145, 153
Demeter, Gabriel	211	Middelhoff, Michael	137	Singewald, Christoph	145
Doležal, Josef	401	Míková, Ladislava	339	Sonntag, Michael	259
Doucek, Petr	35	Ministr, Jan	77, 109	Svatá, Vlasta	305
Duro, Refiz	145	Mohelská, Hana	413	Syrovátková, Jana	193
Duscher, Georg G.	161	Mokrišová, Martina	345	Šikýř, Martin	459
Espinoza, Felix	285	Montenero, Vincent	459	Štěpánek, Lubomír	117
Gehre, Florian	137	Moravcová, Markéta	313	Tkáč, Michal	219, 227
Graser, Anita	153	Nedomová, Lea	35	Tkáč, Michal	219
Gutschi, Clemens	153	Neubauer, Georg	127, 137, 153	Ulman, Miloš	59
Habarta, Filip	117	Novák, Richard Antonín	381	Valový, Marcel	437
Hašek, František	413	Ostapenko, Galina	459	Vaněk, Ladislav	101
Hellemann, Karl M.	161	Pařová, Dana	243	Vašenkova, Tereza	375
Hlaváček, Karel	93	Pavlíček, Antonín	173	Vejačka, Martin	243
Hlaváčková, Eva	313	Peham, Johannes	137	Világi, Róbert	235
Hoffmann, Markus	127	Pechtor, Václav	67	Vlčková, Miroslava	331
Holá, Jana	313	Petera, Petr	295	Volková, Ladislava	323
Hološka, Jiří	35	Petruška, Igor	345	Vorraber, Wolfgang	153
Horváthová, Jarmila	345	Pitner, Tomáš	77, 277	Vössner, Siegfried	153
Ignjatović, Dražen	127, 137, 145, 153	Pollák, František	235	Widera, Adam	137
Jäger, Philippe	161	Pucihar, Andreja	43	Winkelmayer, Lisa	161
Jung, Oliver	389	Radváková, Věra	85	Završnik, Jernej	137
Jus, Aleksander	137	Rainer, Karin	127, 137	Zelenka, Martin	51
Kljajić Borštnar, Mirjana	43	Rathammer, Krista	161		
Kokol, Peter	137	Remta, Daniel	419		
Konečný, Michal	251	Requat, Theres	161		
Korčák, Jiří	185	Resch, Bernd	153		