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The composition diagram of a complex process: Enhancing understanding of hierarchical business processes

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ABSTRACT

The article presents the Composition Diagram of a Complex Process (CDCP), a new diagramming method for modelling business processes with complex vertical structures. This Method addresses the limitations of traditional modelling techniques such as BPMN, Activity Diagrams (AD), and Event-Driven Process Chains (EPC).

The experiment was carried out on 277 students from different study programs and grades to determine the effectiveness of the methods. The main objective was to evaluate the usability and effectiveness of CDCP compared to established methods, focusing on two primary tasks: interpretation and diagram creation. The participant's performance was evaluated based on the objective results of the tasks and the subjective feedback of the questionnaire. The results indicate that CDCP was the effective method for the reading and drawing tasks, outperforming BPMN and EPC in terms of understanding and ease of use. Statistical analysis of variance showed that while the year of the study did not significantly affect performance, the study program and Method used had a significant effect. These findings highlight the potential of CDCP as a more accessible and intuitive business process modelling tool, even for users with minimal prior experience.

1. Introduction

The understanding of business processes is extracted from graphical process models, which mainly focus on the temporal or logical relationships between business activities and business rules, which are the constraints and mandates that control the behaviour of the process and business activities [9]. A business process is "a workflow flowing from one person to another and, in the case of a large process, probably from one department to another" [21]. According to Davenport and Short, "a process is a series of logically linked tasks performed to deliver a defined business output" [6]. According to the Ministry of Interior of the Slovak Republic, "A process is a set of interrelated activities that started in response to a start-up event and whose implementation leads to a specific outcome for the customer and other stakeholders in the process" [17]. Aguilar-Savén defines a business process as "a combination of a set of activities within an enterprise with a structure describing their logical order and dependence whose objective is to produce a desired result" [2]. A business process is characterized by its repeatability. It represents a steady and repeatedly performed activity in a particular company, consisting of several steps designed to transform a certain set of inputs into a set of outputs and achieve a predetermined objective. A business process is, therefore, a generalization of a complicated business activity that represents a workflow. One particular process execution is then referred to as *a process instance*. As we mentioned earlier, every process can be executed repeatedly, and there can be many instances of the same process in the state of a simultaneous execution [14]. Business process modelling is closely related to creating and managing information systems. According to Alotaibi, one of the biggest challenges is to derive IT goals from business goals [4].

The historically older, functional approach to business management focused only on isolated monitoring and control of the execution of individual functions by organizational units (departments, divisions, sections, etc.) responsible for their execution. Thus, the functional approach ignored the interdependence among these functions and evaluated each organizational unit only by how much it performed its functions [12]. A functional approach to business management does not pay attention to what processes this or that organizational unit participates in and how effective these processes are. However, with a more modern, process-based approach to business management, the functions of the individual organizational units become parts of more complex

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activities – business processes. One, two, three or even more departments can participate in each business process. Processes consist of functions of the individual organizational units. A function of an organizational unit can be defined as an activity routinely performed by this unit. Thus, a function expresses what the department associated with executing this function is in charge of and its mission. The functions can be interdependent. This means that the outputs of one function can be inputs into another. In this notion, business processes can be considered chains of business functions, some of which can be performed sequentially and others concurrently, depending on the needs and specificities of the particular process.

A process may have its horizontal and its vertical structure. *A sequence of activities represents the horizontal structure of a process* in a specific order, leading to the desired goal of the process. Some of these activities may be performed parallelly to shorten the total process execution time if possible. All activities forming the horizontal structure of a process are on the same hierarchical level. On the other hand, *the vertical structure of a process* represents a hierarchical breakdown of the process activities into several levels of sub-processes until we gradually get to elementary steps that cannot be further broken down. A process that consists only of elementary steps that cannot be further broken down can be referred to as *an elementary process*. In other words, an elementary process is a process that can be described by its horizontal structure only (i. e., it has no vertical structure). On the contrary, a process with a vertical structure can be called *a complex process*. Thus, a complex process is a process that can be hierarchically broken down into several levels of sub-processes until we gradually get to elementary steps that cannot be further broken down. Splitting a process into sub-processes is advisable in the case when there are too many functions forming the process. With too many functions, a process becomes too complicated, and the overview of its exact course is lost. If this is the case, we can split such a process internally into a few sub-processes (i.e., child processes), making the parent process more transparent and comprehensive. A sub-process (i.e. a child process) is a business process that is a part of another business process, which we can refer to as its parent process. However, individual sub-processes may also be too complicated, and it may be useful to split them internally into smaller sub-processes to make them more transparent.

Each business process has certain characteristics. Typical characteristics of business processes include [22]:

- **Process goal** - Each process must have a clearly defined goal, which represents the purpose of carrying it out. If we do not know the exact goal of the process, then we cannot effectively manage it. In this respect, it is very important to express the goal of each process in a deterministic way (i.e., to formulate it unambiguously and comprehensibly), preferably using quantifiable indicators. It is impossible to optimize a process whose objective is unclear.
- **Process owner** –is a person who is responsible for achieving the goal of the process and for its long-term functioning. This person is responsible for monitoring each instance of the process and its performance, managing it, systematically improving the process and solving any problems that may arise during the course of each instance of the process. In addition to accountability, he must have sufficient competencies to act actively.
- **Process customer** – a key player in the process. This is the subject to whom the results of a certain process are intended. The customer of a process can be either internal or external, and their satisfaction is crucial for the success of the process.
- **Process inputs** – a process is a deterministic way of transforming a set of inputs into a set of outputs corresponding to the goals of the process. The individual inputs can come either from the company's internal environment (outputs of other processes fall into this category) or from its external environment (materials from suppliers or raw materials extracted directly in nature). Internal and external inputs can be divided into physical, financial and informational.
- **Process outputs** - a set of outputs intended for the process customer. These outputs can also be divided into three categories: physical outputs, financial outputs, and informational outputs.
- **Process efficiency** – a critical characteristic that determines the success of the process. It is the extent to which the actual outputs of the process instances match the required ones. The closer the match, the more efficient the process. This should be a key focus for all involved in the process.
- **Management regulators** are laws, directives, standards, decrees, orders, etc. Each process must be governed by certain rules, which can be divided into internal rules (internal directives and regulations) or external rules (national laws, decrees of ministries, municipalities' regulations, supranational directives, etc.
- **Process risk** - Each process may have some segments where the execution fails. It is important to identify these segments and pay special attention to them.
- **Resources** - Resources are means used (i.e. consumed or depleted) in transforming inputs into outputs. For example, human work, technology (wear of machinery and equipment), financial resources, energy, time, and information are considered resources.

Process models visually represent the flow of an organization's business activities. Decisions made based on process models tend to be better than those that are not. Therefore, process models can help to increase revenue, and the efficiency of managing and monitoring business processes is improved [9]. Antunes et al. [5] state that the main focus of BP (business process) modelling is still more concerned with technological constraints than human needs. Even when BP models are well designed, they may not be used in practice because of a lack of acceptance from end-users. Our effort concerns the visualization of business processes in a way that preserves a strong attachment to reality and does not alienate the end-users.

This paper focuses on complex processes and the options of their visual representation. We have set our goal to create a new graphical representation of business processes aimed at providing a managerial (i. e. global) overview of the structure of a complex process at the highest level of abstraction to improve the understandability of process models to help users understand them. As authors argue in [28], a lack of understanding of the business process can lead to many risks. For example, users may inadvertently violate required operating standards or make uninformed decisions.

Such a managerial overview of a complex process is important for the process owner who manages it and for the designers of an information system intended to support the proper running of the process and its individual sub-processes.

2. Current state of the art in the field of business processes visualization

A process's horizontal structure can be visualized using standard diagram techniques, such as flowcharts, BPMN (Business Process Model and Notation) diagrams, IDEF3 notations, EPC, and Activity diagrams.

A systematic review of the literature related to the visualization of business process models, published between 2009 and 2019, is given in [25]. As the authors state, exactly half of the studies aim at improving the understandability of process models explicitly, and half of the studies are concerned with improving the understandability of process models by proposing different ways of visualizing the process models or visualizing information about process models [25]. Figl [9] focused her literature review on understanding procedural visual business process models, which we consider their key features. She systematically categorised and summarised existing findings on the factors that influence comprehension of visual process models.

A brief comparison of a few business process modelling techniques was done by Aldin & de Cesare [3], Witsch & Vogel-Heuser [33], List & Korherr [16], Xinming & Haikun [36] or Korherr [15]. However, we have done a specific analysis from the perspective of the managerial overview of complex business processes, which is presented in this section. The traditional diagram techniques cannot capture a hierarchical breakdown of a complex process into several levels of sub-processes in a single diagram. Of course, these techniques can depict the vertical structure of a complex process in the form of a few interconnected diagrams. However, with many sub-processes, the global overview of the process structure can be lost using these techniques. Besides, each standard diagram technique has shortcomings related to complex processes with a complicated vertical structure.

Activity diagrams, part of the Unified Modeling Language (UML), model workflows and system behaviours. They display various activities or actions and their sequence, supporting parallelism and decision points. Activity diagrams are suitable for visualizing processes involving sequences of steps executed manually or automatically. Their strengths lie in their simplicity and intuitiveness, making them accessible to stakeholders with limited UML knowledge and their ability to effectively model parallel tasks and decision points. However, activity diagrams have limitations in depicting complex hierarchical relationships and detailed process ownership or timing information, making them less suitable for representing intricate multi-level structures. A comparison of activity diagrams and BPMN diagrams for business process modelling was done by Geambaşu [10].

ARIS EPC (Event-driven Process Chain) is another business process modelling method developed by IDS Scheer. EPC illustrates the flow of events and activities in a process, where events trigger tasks that lead to subsequent events. It is widely used in organizations for process analysis and optimization. Its strengths include the ability to model detailed process flows, integrate multiple views (such as organizational or data-related perspectives), and support process improvement efforts. Nevertheless, as with other traditional techniques, EPC diagrams can become difficult to read with increasing process complexity, and they struggle to represent hierarchical structures effectively in a single diagram. Additionally, EPC diagrams may lack clear integration of organizational or time-based details within the diagram. A semantic analysis of ARIS EPC models for business process management was done by Stein et al. [26].

BPMN defines a Business Process Diagram (BPD) based on a flowcharting technique tailored to create graphical business process operations models. A Business Process Model is a network of graphical objects, which are activities (i.e., work) and the flow controls that define their order of performance [34]. The notation inherits and combines elements from several previously proposed notations for business process modelling, including the XML Process Definition Language (XPDL) [35] and the Activity Diagrams component of the Unified Modeling Notation (UML) [18]. BPMN process models are composed of (i) activity nodes, denoting business events or items of work performed by humans or by software applications, and (ii) control nodes capturing the flow of control between activities. Activity and control nodes can be connected using a flow relation almost arbitrarily [7]. A comprehensive analysis of the different BPMN symbols was done by Genon, Heymans and Amyot [11].

The key feature of business process visual models is generally considered to be their comprehensibility, closely related to people's ability to process images. When displaying complex business process models through traditional methods (primarily BPMN), the models can be more difficult to read, and therefore, ways to simplify them are intensively sought. A vast body of research focuses on studying the factors that influence process model comprehension and methods to get new insights into process model comprehension [27]. Two main directions of research aimed at increasing the understanding of process models can be observed in the literature: methods to get new insights on process model comprehension, e.g. [32,37,38] and techniques that enrich process models to foster their comprehension e.g. [1,29] or techniques that simplified process models, focusing on various aspects of a process model e.g. [8,19,20,24,30].

Conceptual graphs (CG), as developed by John F. Sowa, are primarily used in knowledge representation, natural language processing, and complex data structure. However, their use in business practice, especially when modelling business processes, is limited, similar to the applicability of flowcharts and process thread diagrams in certain complex scenarios where these tools do not meet the requirements for detailed analysis or system integration.

We used other approaches to create a simple (easy to write and read) new method of process model visualization that can provide a managerial (i.e. global) overview of the structure of a complex process at the highest level of abstraction. This managerial overview of a complex process is important not only for the owner of the process in managing its flow and execution but also for the designers of an information system intended to support the proper running of the process and the individual sub-processes it consists of. It is also very important that the presented Method is easy to read, even for customers, most of whom are laymen. This new Method can be called the Composition diagram of a Complex Process (CDCP). The symbols of this approach and their basic meaning have already been presented in two conference papers [13,23]. Those were the initial versions presented to the professional public, and based on feedback and practical experience, a comprehensive new version is presented. The Method has been modified and improved. This paper presents exact rules for using the new CDCP method to display complex business processes.

3. Research methodology

Based on many years of teaching experience, we found it difficult for most students to see the dependencies across individual diagrams modelling the same business process. Without understanding these contexts, it is impossible to perceive a process's vertical and horizontal sides simultaneously, which results in a misinterpretation of the described process. Various techniques exist to facilitate communication between the designer and the customer, such as BPMN, UML, EPC diagrams, etc. However, even while using these techniques, it is often necessary to use several diagrams to capture the essence and know how to explain the solution to the customer properly. This no longer works with complex processes of a slightly more complicated nature. Customers do not understand the interconnections among the diagrams, and the solutions have to be explained verbally, which often leads to great inaccuracies and misinformation. These two reasons led us to create a new method and diagram technique that would be easy to understand for customers and pleasing even in teaching. They would include both vertical and horizontal planes.

To design this Method, we analysed the current techniques for business process visualization and identified their advantages and shortcomings. The results of this analysis are summarised in Chapter 2.

To verify the expected properties of the proposed Method, we conducted an experiment, which is described in Chapter 6 and Chapter 7.

4. The new method for displaying complex processes

4.1. Description of the new method

This chapter describes a new method for displaying complex business processes, called **the composition diagram of a complex process**. Before that, however, we will focus on a precise explanation of the concept of a complex process. We understand a complex business process as a continuous chain of sub-processes. Again, these sub-processes can be formed by a continuous chain of sub-processes. This creates a hierarchical structure of processes and their sub-processes, consisting of several hierarchical levels. The complex business process itself forms the highest hierarchical level in this structure. The highest hierarchical level can be marked as the zero level. Processes at the first hierarchical level are sub-processes of the process at the zero hierarchical level. If needed, sub-processes form them at the second hierarchical level to further break the sub-processes at the first level. Thus, processes at the second hierarchical level are sub-processes to processes at the first hierarchical level. They can be further broken down to sub-processes at the third hierarchical level if this breakdown is needed, etc. The total number of processes and their sub-processes are not limited in any way, and it depends on the needs and specifics of the particular complex process that we are modelling. Thus, a complex process can be hierarchically decomposed into hierarchical levels of processes. In Fig. 1, we can see an illustration of a complex process vertical structure. However, this is not the composition diagram of a complex process. More about the vertical structure of the business process is written in the book Business Process Management: Concepts, Languages, Architectures [31].

The simple schematic representation of a complex process displayed in Fig. 1, which resembles a process map, does not contain a lot of important information, such as information about the expected duration of the individual processes, the owners of individual processes, their trigger events, inputs and outputs, possible cycles or branches. etc. Therefore, we have created a special new diagram technique that allows all this information to be included in a comprehensible way, which makes it a suitable tool for representing a global view of a complex process vertical structure.

As outlined, we understand a complex business process as a continuous chain of sub-processes on a lower hierarchical level. A continuous chain of sub-processes can again form each sub-process on a lower hierarchical level. The hierarchical structure of a compound process is thus actually a hierarchical arrangement of such chains of sub-processes. *In the composition diagram of a complex process,* ***each chain of sub-processes must follow these rules:***

- A chain can start with **a trigger event** (a complex process as a whole must have a trigger event defined, but chains at lower hierarchical levels don't have to have a trigger event, only if necessary, based on the specifics of a particular chain). A trigger event is an event that starts the execution of the first sub-process in the chain. If the trigger event does not occur, execution of the chain cannot begin, and this event must be waited for. The trigger event is drawn as an empty arrow. If it is necessary to supply any inputs to the chain, these inputs are written inside this arrow. In general, the inputs can be material, financial or informational. An example of a trigger event may be receiving an order from a customer. This order itself is also understood as an input, and the act of receiving it is the trigger event. In this case, the event of receiving the order starts the chain of interrelated sub-processes ensuring the processing of the order.
- *Each chain comprises* ***a sequence*** *of sub-processes, but it can also contain* ***branches*** *or* ***loops*** *if necessary.*
- *The execution of individual sub-processes in a chain may be conditioned by the fact that* ***a transition event*** *must occur.* For example, it may be necessary to receive a specific document, signal, material, or another specific stimulus at first because, without this stimulus (i.e., without the fulfilment of the transition event), the chain of sub-processes cannot be started.
- *If no transition event is needed, then the output of the ending sub-process is the input to the next sub-process, so no special trigger is required to start the next sub-process.*
- *Each subprocess in a chain can be an individual chain of subprocesses at a lower hierarchical level.*
- *An output symbol can terminate a chain if it is supposed to give a specific material, financial or information output as a result (the complex process as a whole must always be terminated by an output symbol).*
- *The individual chains of sub-processes are connected* ***by arrows,*** *depending on the order in which they are to be executed.* If an arrow does not connect two chains, their execution shall start simultaneously (i. e., these chains shall be executed **in a parallel manner**).
- *If it is necessary to redirect the flow of the process from a certain place in the diagram to another remote place, we do not want to connect these two places with an arrow because it could affect the comprehensibility of the diagram negatively* (i. e., we don't want to have too many arrows in the diagram or we don't want the crossing of arrows to occur), *we can use a pair of the so-called* ***redirection symbols.*** This pair of symbols represents a kind of teleport that connects two distant places and progresses the process from one place to a different place in the diagram.
- ***For a complex process as a whole and each sub-process at any hierarchical level, the following rules shall be applied:***
- Each process or sub-process is drawn using a frame that contains three basic pieces of information: the name of the process or sub-process, its expected duration, and the specification of the owner of the process or sub-process.
- If the particular process or sub-process consists of one or more other sub-processes, we draw each sub-processes using a separate frame inside the frame for their parental process on the principle of a matryoshka doll. Each frame must again contain three basic pieces of information, namely, the name of the sub-process, its expected duration and the specification of the owner of the sub-process.
- For each process or sub-process, it is necessary to specify its expected execution time based on the expected execution times of its sub-processes. For example, if the process consists of a sequence of three interrelated sub-processes, each of which has its own expected execution time, then the total execution time for the parental process is the sum of these sub-times. Properly determining the aggregate

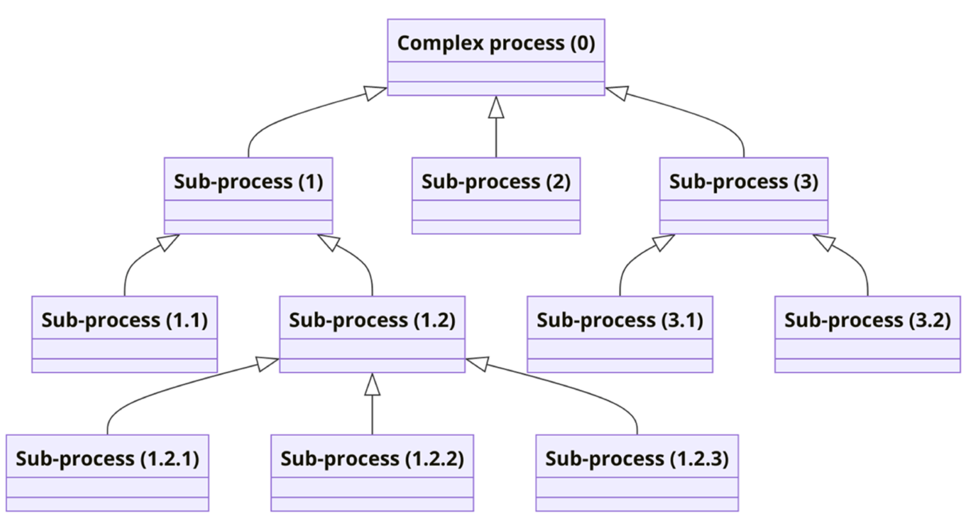

Fig. 1. An example of a complex process structure.

expected time for the parental process is complicated because some sub-processes may be planned to be executed parallelly. For example, suppose the parental process consists of two sub-processes that shall be executed parallelly. Each of these sub-processes has a different expected execution time. In that case, the total execution time for the parental process is equal to the higher of these two partial times.
- It is necessary to specify the owner of each process or subprocess, who is responsible for the successful execution and operation of that particular process or subprocess.

The following rules shall be applied specifically to the complex process as a whole:

- For the complex process as a whole, **a trigger event must be specified**, which is also a trigger event for the chain of sub-process at the first hierarchical level. Each time this trigger event occurs, a new instance of the complex process starts. Several instances of the same process can run simultaneously and in an unfinished state. If the trigger event does not occur, a new process instance cannot start.
- For each complex process, we must specify **its inputs and outputs**. The inputs and outputs can be material, financial or informational. A complex process can produce some outputs not only at the end of its execution but also during its course (i.e., while it is running, it can produce some intermediate outputs besides the final outputs).
- Each complex process must be terminated by the **symbol of an end of its execution**. However, there may be several qualitatively different ways in which the same process can end. In other words, there may be multiple qualitatively different end states that can be reached at the end of the process execution (of course, every instance of the process may end only in one of these end states, but there may be multiple possibilities how the individual instances may end). If this is the case, the process contains a plurality of branches terminated by the symbol of an end where each end represents a different end state.
- Each end symbol indicates **an immediate termination** of the execution of the current process instance, regardless of whether its course was successful. Thus, if a complex process contains multiple branches ending with an end symbol, the execution of the current process instance must be terminated immediately when one of these end symbols is reached.

4.2. Description of symbols used in the new method

Every process or sub-process should be displayed using the following frame portrayed in Fig. 2.

The sub-processes that form a parent process together are drawn inside this parent process under the principle of a matryoshka doll, as displayed in Fig. 3. If the execution order of the individual sub-processes matters, then we must connect them with arrows. If their execution order is not important, we omit the arrows. Thus, the sub-processes remain unconnected. We distinguish three types of flow from one sub-process to another. These flow types are depicted in Fig. 4.

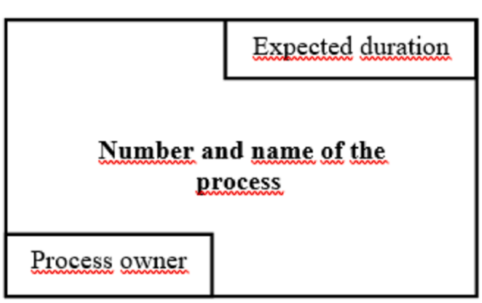

Fig. 2. Frame representing a process.

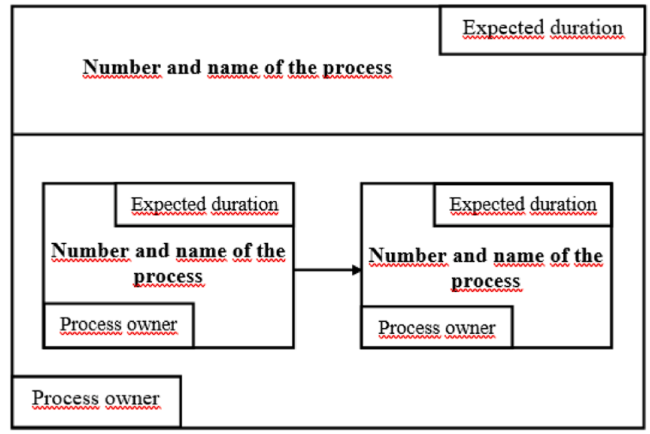

Fig. 3. A process and its sub-processes.

A **trigger event** is an event that must occur to start a new instance of the complex process. However, it can also be used to start a chain of sub-processes. A trigger event is drawn by a symbol of an empty arrow, as pictured in Fig. 5. It can be an internal or an external event. An example of an internal trigger event is a drop in the amount of material in stock below a critical threshold value, which is a signal to trigger a new instance of a material purchasing process. An example of an external trigger event is the arrival of an order sent by a customer, which triggers a new instance of a customer order processing process. The symbol of an empty arrow may also symbolize a process input.

A full arrow symbol draws the output of a whole complex process or its sub-processes, as shown in Fig. 5. As we said earlier, there may be situations where the complex process has to provide some output (for example, a document). Still, this output does not mean the termination of the execution of the process instance. Thus, in these situations, the execution of the process instance has to continue after the output is provided. Because of this, we use a separate symbol for a process output, which is different from the symbol for the end of a process instance execution.

Sometimes, it is necessary to wait for a special event to occur in order to continue with the execution of a process. Such an event can be marked as a **transition event.** For example, receiving a special document, signal, material, or instruction is necessary to start the next sub-process. A transition event is drawn by an oval symbol portrayed in Fig. 5.

The **end of a process instance** execution (i.e. the place where the execution of the process instance has to be terminated) is drawn by a symbol of a circle with the letter "E" inside, as pictured in Fig. 5. A symbol for the start of a process instance is not needed because it is represented by the symbol of the trigger event, which was introduced already. When the trigger event occurs, the execution of a new process instance starts.

As we said earlier, there may be situations in which the fulfilment or non-fulfilment of a certain condition conditions the flow of the process instance (if-else branching). The branching of the process flow can be depicted by a square symbol, in which the formulation of the condition is written. The condition must be formulated as a question. If the question is formulated to be answered only by a "yes" or "no", then two branches lead from this square. However, instead of a "yes" or "no" there can also be other values. The notation for this situation is depicted in Fig. 5.

If the question is formulated so that it can be answered by multiple answers (more than two) we need to use an *n*-way branching. In that case, each branch must be marked with a specific value representing one of the possible answers to the question. This is not a problem since we may add as many branches as we need. The notation for this situation is depicted in Fig. 5.

Flow type	Symbol	Meaning
Physical flow	Name of the physical object	The output of a sub-process is a physical object transferred as an input to the following sub-process. Along with the transferred physical object, the necessary information is also transferred.
Information flow	Name of the information or document	The output of a subprocess is information that is transferred as an input to the following subprocess. Typical examples are requirements, orders, signals, documents, reports, statistics, etc.
Sequence flow		It represents the sequentiality of sub-processes. No special output should be transferred from one sub-process to another. However, this symbol also represents a basic connector.

Fig. 4. Different types of flows between sub-processes.

In some situations, if-else branching can be conditional on waiting for a certain event to occur. If two or more events can occur and the further course of the process instance depends on which events occur first, we can use the **waiting-for-first-event** (XOR) symbol. As shown in Fig. 5, a join mechanism can be used to join the branches into a single branch later, if needed.

In other situations, we need to wait for several events to occur, and the process can continue when the last occurs. If all of these events have not yet occurred, the process is temporarily suspended and only continues when all events have occurred. We can represent such situations with the **waiting-for-all-events** (AND) symbol. As shown in Fig. 5, a join mechanism can be used to join the branches into a single branch later, if needed.

When parallel execution of the sub-processes is needed, a simple fork-and-join mechanism can be used, as shown in Fig. 5. We can divide a single branch into multiple parallel branches and join multiple parallel branches into a single branch. This means that all parallel branches start simultaneously but can have different durations and be completed at different times. After completing the last parallel branch, all parallel branches are merged into a single branch.

There is also another type of parallelism, where two or more branches have to be executed simultaneously, and they have to be ended at the same time. In other words, these branches may not start at the same time, but they must end at the same time. This special parallelism can be seen at the bottom of Fig. 5. It is one of the specialities of our Method, which is not present in flowcharts, BPMN or other techniques for business process modelling.

Fig. 5 shows various symbols that can be used when drawing business processes using the CDCP method. Since the sequential flow is the basic connector, sequential flows are used in all symbols for simplicity, but physical or informational flows can also be used as needed.

A very important rule for the composition diagram of a complex process is that every line between two symbols must be directed. However, in large diagrams, there may be a need to move from one point to another without drawing a direct line between these two points because the line would be too long and could cross with other lines in the diagram. Crossing lines is undesirable because it makes the diagram less transparent. In such situations, we can use a pair of special **redirection symbols**. This pair of symbols represents a kind of teleport, further progressing the process to a different place in the diagram. Since there may be multiple pairs of redirection symbols in a single diagram, it is necessary to distinguish them by numbers so that those symbols that form a pair have the same number. Two redirection symbols forming a pair can be drawn, as depicted in Fig. 5.

5. Example of a complex process drawn using the new method

In this chapter, we would like to demonstrate a compositional diagram of a complex process using the example of the tomato puree production process.

First, let's look at the process of making tomato puree. It is a complex process consisting of two hierarchical levels of sub-processes. This Method can be shown in Fig. 6.

If there are not enough tomatoes, the production of tomato paste must be postponed, and the current instance of the process ends shortly after starting. If there are enough tomatoes, the process can continue. The Puree production department owns the entire process, and the estimated implementation time is 470 min.

At the first hierarchical level, there are three subprocesses:

- 1 Cooking puree
- 2 Puree canning
- 3 Packing in paper boxes

The pureeing process consists of a chain of the following sub-processes at the second hierarchical level:

- 1.1 Filling the boiler
- 1.2 First cooking of tomatoes
- 1.3 Filtration
- 1.4 Thickening the puree

The puree canning process consists of a chain of the following sub-processes at the second hierarchical level:

- 2.1 Filling the can filler
- 2.2 Disinfection of cans
- 2.3 Filling cans
- 2.4 Pasteurization of preserves

Fig. 6 shows each subprocess's owner and expected execution time, as well as the matryoshka principle.

For comparison, we present the same process drawn using the BPMN method (Figs. 7, 8). Due to the article's limited scope, we could not present a more complex process where the advantages of the CDCP diagram technique stand out.

6. Testing the usability of methods

Testing the usability of methods compared our proposed Method

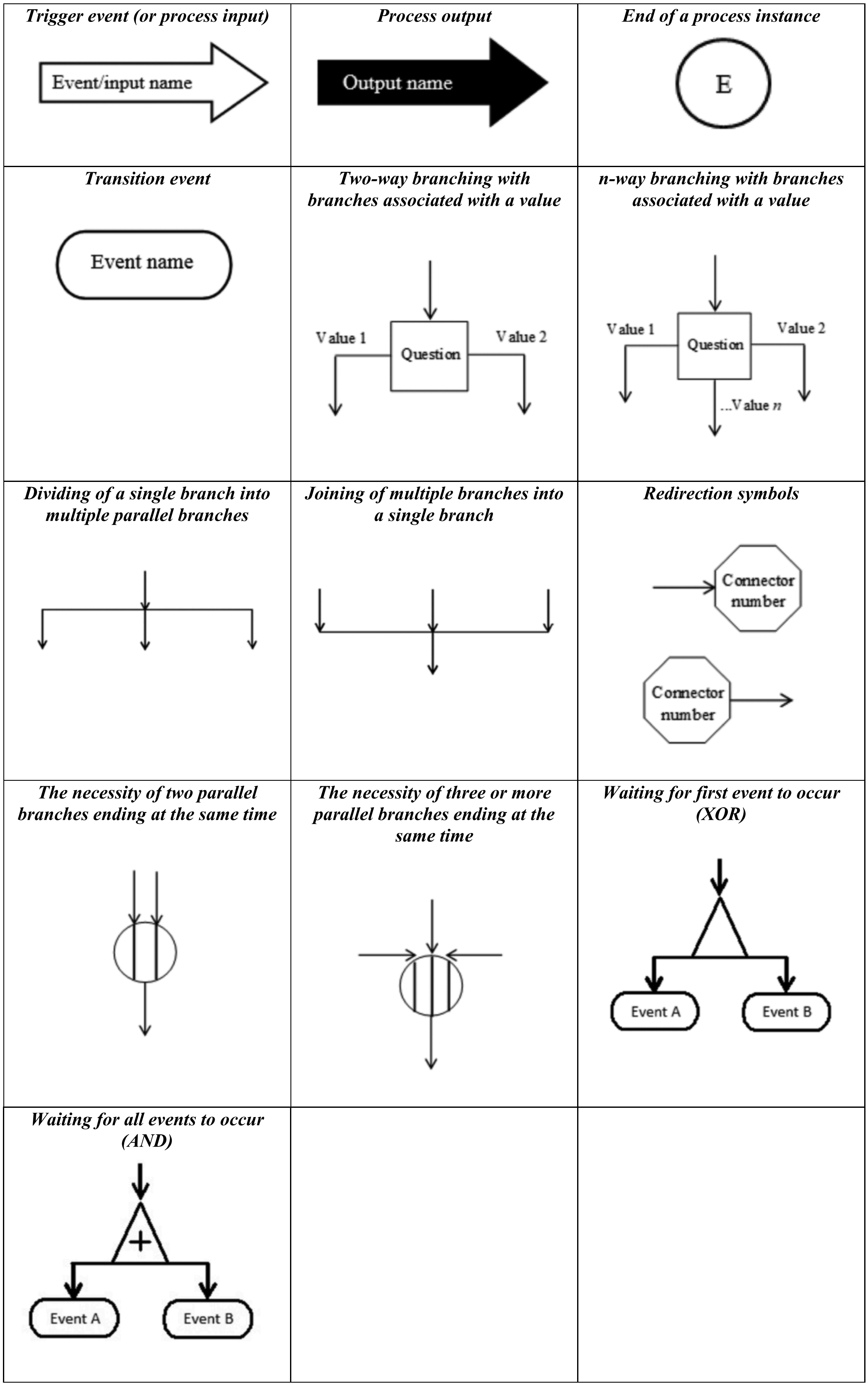

Fig. 5. Other symbols of the new method.

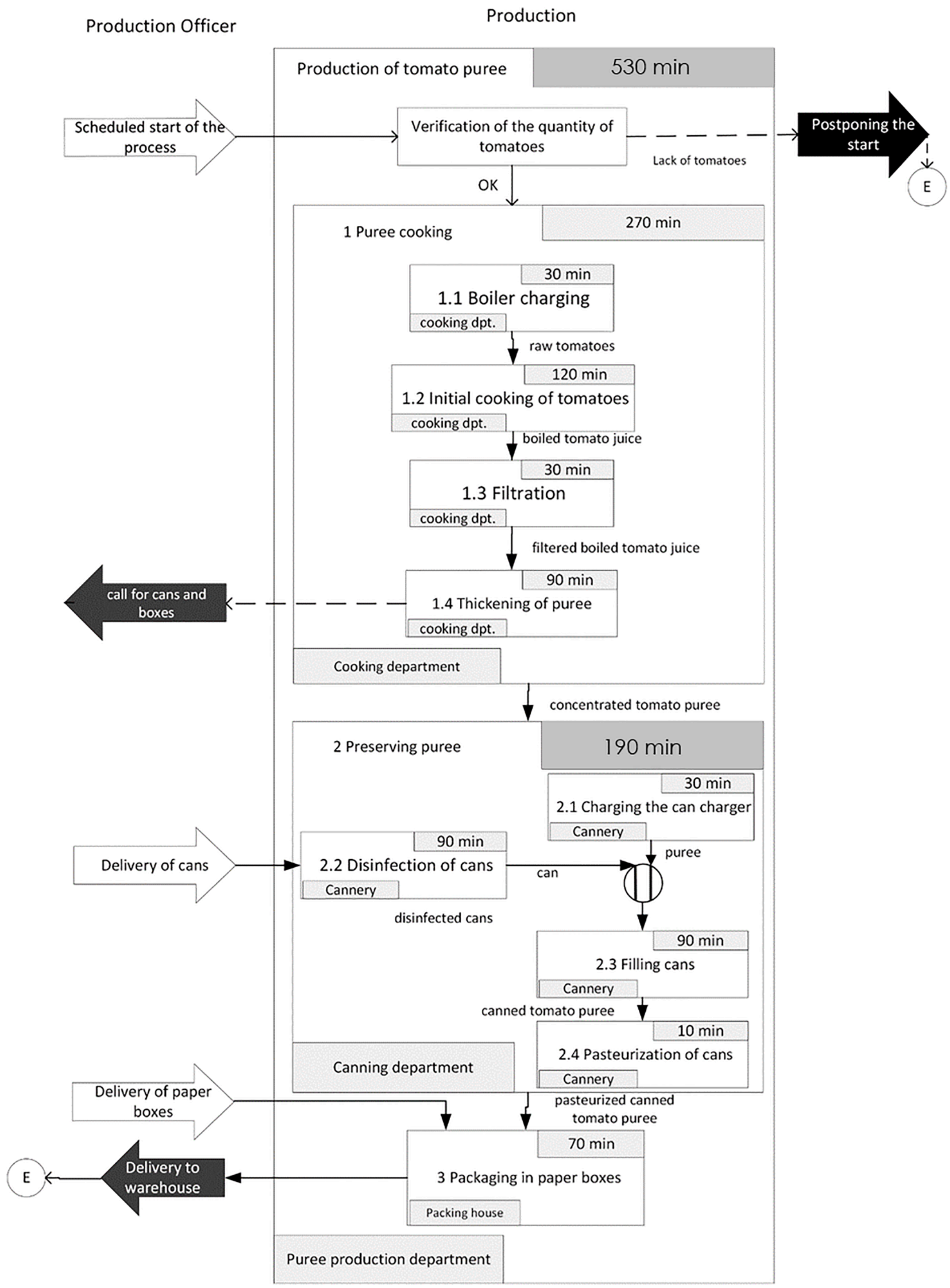

Fig. 6. An example of a tomato puree production process in CDCP.

with the three most used methods [25] for creating diagrams needed for business process modelling in practice. From this, it follows that the experiment compared the results of solving the same task using four different methods. In the experiment, we tested both skills required when working with diagramming techniques for business process modelling. The first skill is correctly interpreting a drawn diagram representing a business process (hereafter called "reading tasks"). The second skill is creating a diagram that correctly and fully represents a selected business process (hereafter referred to as "drawing tasks"). To verify both skills, we selected two tasks for each.

6.1. Test design

The reading tasks were labelled as Task A and Task B, while the drawing tasks were labelled as Task C and Task D. In Task A, participants were given a diagram depicting the process of tomato paste production (see Figs. 6 and 8). In Task B, they were given a diagram illustrating ordering and delivering pizza by phone. For Task C, participants received a recipe for baking a cake, which they had to represent through a diagram. In Task D, they were described the process for handling a business trip request, which they also had to represent through a diagram. The content of the tasks was selected to assess not only the participants' understanding of a linear sequence of activities but also more complex, event-driven process branches.

In the experiment, we designated the CDCP method as Method 1, the BPMN method as Method 2, the UML activity diagram as Method 3, and the EPC method of ARIS as Method 4. This created a total of 16 tasks labelled A1 to D4. Each participant was randomly assigned one reading task (A1–B4) and one drawing task (C1–D4). The assignments were distributed via the Moodle platform, ensuring the random allocation of tasks to each participant. The supervising teacher did not influence the task assignment and was not informed which participant completed

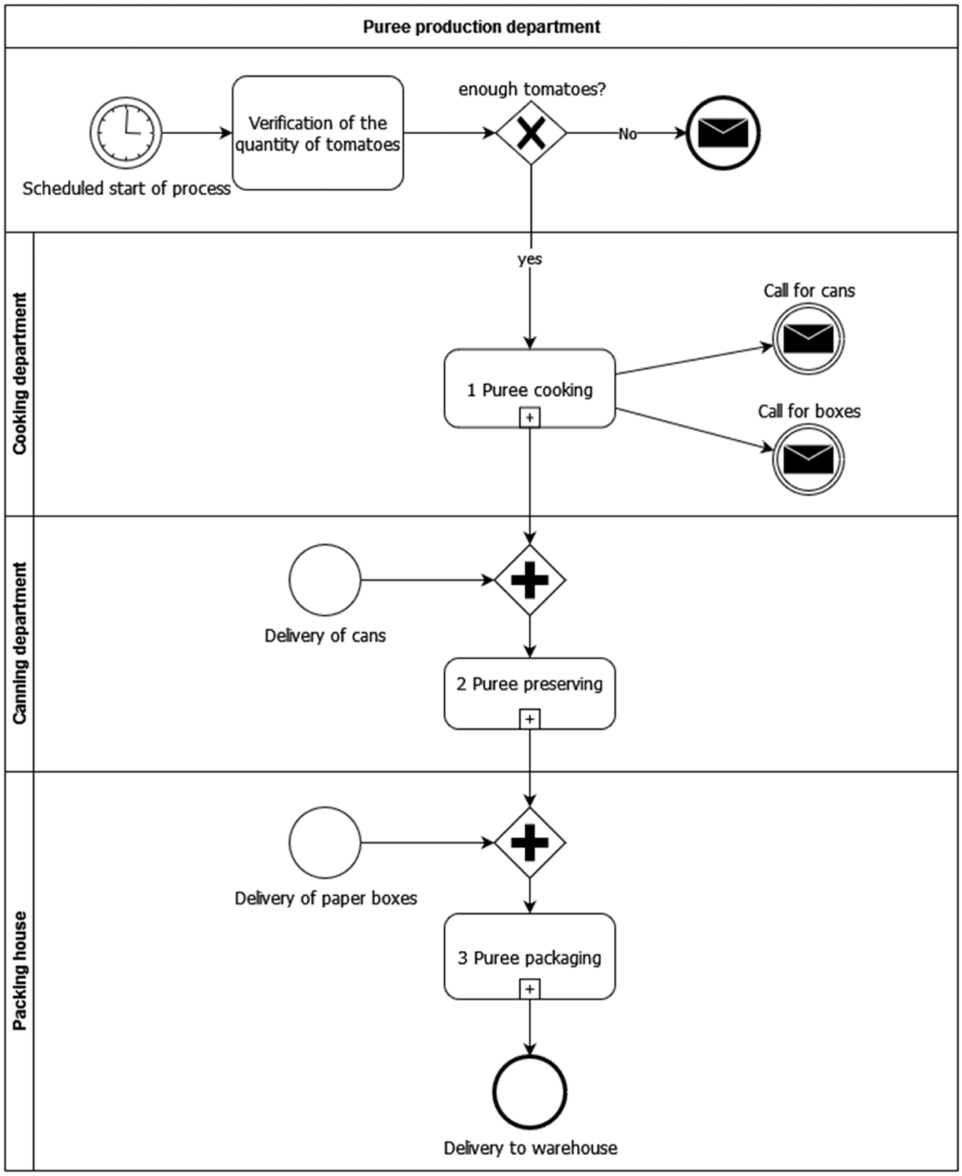

Fig. 7. An example of a tomato puree production process in BPMN.

which task. Participants completed the tasks on paper, recording only their year of study, their study program, and the task label in addition to their solutions. This ensured the anonymity of the results concerning the participants.

Each task assignment was accompanied by a manual for the corresponding Method, mainly containing the graphical symbols needed to create the diagrams. The manuals were provided because most participants had not yet encountered these methods in their studies and thus would not have been able to draw the required diagram without them. Since the experiment's goal was primarily to assess the ability of novice users to read and create diagrams for business process modelling, we selected students who were expected to have limited knowledge of the examined field.

After completing the tasks, participants were allowed to answer ten questions in an anonymous survey. We included an anonymous questionnaire in the experiment in order to obtain, in addition to the objective results of solving the tasks, a subjective evaluation of the user-friendliness of the use of individual methods. In the survey, students indicated their previous experience with business process modelling diagrams, which task they completed, how difficult they found it, what challenges they encountered during the task, and what year of study and study program they were enrolled in.

Experiment allowed us to collect data that objectively assessed the difficulty of using each Method based on the task results while also by questionnaire gathering the participants' subjective perceptions of the difficulty of each Method.

The experiment was conducted on a sample of 277 students from various study years and different academic programs, which ensured a diverse range of experience and skill levels in working with diagramming techniques. This diversity was also confirmed through an anonymous survey, which the students completed after finishing the experiment's tasks. All respondents were given 60 min to solve the tasks, while the anonymous survey was completed outside of this time limit. A total of 231 respondents filled out the survey. Despite this, the sample size was sufficient to compare the objectively achieved task results with the subjective perception of task difficulty.

After collecting the answer sheets, the supervising teacher handed them to a designated evaluator. The teacher responsible for evaluating the responses was not part of the experiment supervision team and was unaware of the experiment's objectives. Only one designated teacher

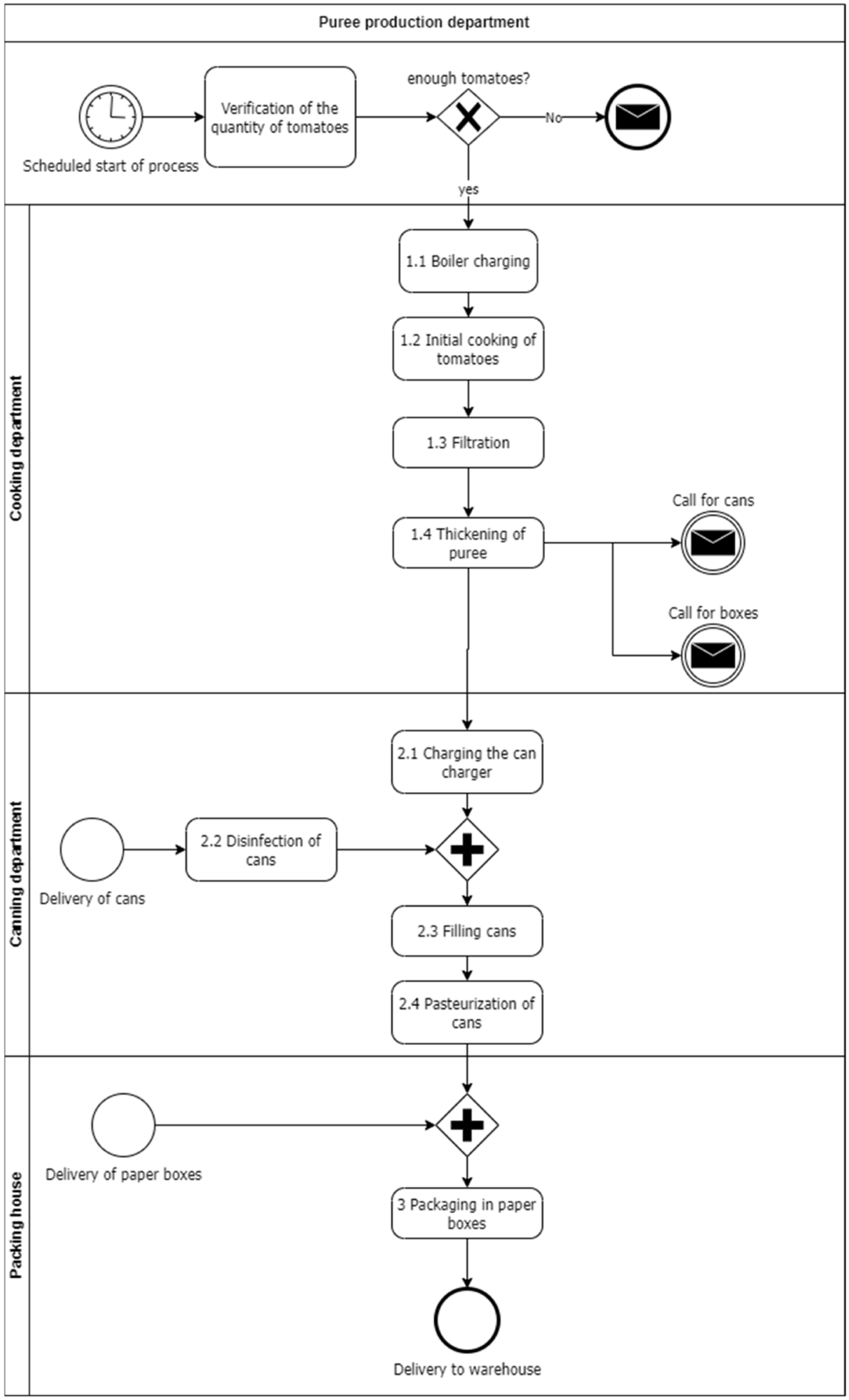

Fig. 8. An example of a detailed tomato puree production process in BPMN.

participated in the evaluation, ensuring uniform grading for all participants. The evaluation criteria were prepared in advance by the experiment's supervisory team and were provided to the evaluator. This teacher then assessed all participants' task solutions and submitted the evaluation results to the supervisory team upon completion.

Participants could earn up to 5 points for each task. The responses in the anonymous survey, related to self-assessment of the respondents' experience and expertise in business process modelling methods and their subjective perception of task difficulty, were measured using a 5-point Likert scale. This approach ensured that the objectively obtained results from task performance could be directly compared with the subjective perceptions of task difficulty.

The results for reading and drawing tasks were analysed separately using each Method. The criterion used to characterize the difficulty of a given method was the average number of points achieved for the tasks within the respective category.

We subjected the data obtained from the experiment and the questionnaire to statistical analysis. We used a multivariate analysis of variance method ANOVA for mean values.

7. Results and discussion

7.1. Experiment data

Table 1 shows the averages for individual tasks, types of tasks and overall methods calculated from the point evaluation of individual tasks.

Table 2 provides an overview of the key factors used in the analysis. Factors include study year, program, and Method, all treated as fixed variables. The factor Study year has five levels ranging from 1st to 5th grade, represented by values 1 to 5. The study program includes four different programs: DSE (Data Science), HI (Economic Informatics), IM (Information Management), and SM (Social Management). The Method factor also has four levels that correspond to the following diagramming methods: AD (Activity Diagram), BPMN (Business Process Model and Notation), CDCP (Custom Process Control Diagrams), and EPC (Event Driven Process Chain).

Table 2
Factor information.

Factor	Type	Levels	Values
Study_year	Fixed	5	1, 2, 3, 4, 5
Study_program	Fixed	4	DSE, HI, IM, SM
Method	Fixed	4	AD, BPMN, CDCP, EPC

7.2. Analysis of variance of data of the experiment

Table 3 presents the p-values obtained from the statistical analysis of the various factors affecting performance in the reading and drawing tasks and all tasks combined. Factors analysed include year of study, study program, and Method, along with their potential interactions (year * study program, study program * method, and year * method). For the reading tasks, Study Year ($p = 0.283$) was not statistically significant, while Study Program ($p = 0.002$) and Method ($p < 0.001$) had a significant effect. For the drawing tasks, all main factors showed statistically significant effects ($p < 0.001$). When analysing all tasks together, significant effects were observed for the year of study ($p = 0.003$), study program ($p = 0.013$) and Method ($p < 0.001$). The effect of the combination of factors study_year and Method in all tasks was not statistically significant.

Fig. 9 shows the average points from the reading tasks, considering three factors: Study Year, Study Program, and Method. Each point on the graph represents the average score of respondents for a given factor (Table 1). Study Year: Average scores increase slightly between Year 1 and Year 4, with Year 4 students achieving the highest average. However, 5th-grade students experienced a slight decrease. Study Program: Students in the SM program achieved the lowest average scores, while HI and IM students achieved similarly higher results. Method: CDCP achieved the highest average score, while BPMN recorded the lowest average points. AD and EPC methods had similar means but were lower than CDCP.

The Table 3 shows that method and study program factors significantly affect reading scores, while the year of study shows an insignificant effect.

The graphs in Fig. 10 show the average scores from the drawing tasks, analysed based on three factors: Study Year, Study Program, and Method*Study Year: Average scores increase significantly from Year 1 to Year 4, with Year 4 students achieving the highest scores. On the contrary, 5th-grade students show a sharp decline. Study Program: Like the previous chart, IM students had the highest mean scores, while SM students had the lowest scores. Method: CDCP again recorded the highest average score, while BPMN reported the lowest score among the methods. AD and EPC achieved similar means but were lower than CDCP. The graph clearly shows that the factors of the study year and study program significantly influenced the results in drawing diagrams, while the CDCP method was the most effective for drawing.

The graphs in Fig. 11 show the mean scores across all tasks. The curves are similar to Fig. 10, but the mean values are slightly shifted on the scale. The graphs highlight significant differences between years of study, study programs and methods in respondents' performances in all tasks.

Statistical variance analysis showed that the respondents' year of study did not significantly affect the results for the reading tasks (see Table 3). In contrast, the study program and the Method used had a statistically significant impact on the outcomes. This result was expected, as students from various study programs participated in the experiment, with only the informatics-related IM and HI programs. Students from other programs likely had only sporadic prior experience, as their curricula do not include subjects related to process modelling. The unexpected result for the 2nd-year DSE students was due to the relatively small number of respondents (4) from the DSE program, all of whom had taken an elective course that provided prior knowledge of modelling methods. This is also evident when comparing the 2nd and 5th-year DSE students (see Fig. 12). The most surprising result came from the 5th-year IM students, who were expected to perform the best. The highest scores were achieved by the 4th-year IM students. The reasons for this phenomenon will be the subject of further investigation.

The drawing tasks proved more challenging for the respondents, with an average difficulty exceeding 1.5 points out of 5 (most difficult=1 easiest =5), as shown in Table 1. The results of the diagram drawing tasks were statistically significantly influenced by all factors: the year of study, the study program, and the Method used to solve the task.

7.3. Questionnaire

Table 4 shows the respondents' assessment of the tasks' difficulty. The scale of the assessment of the tasks' difficulty on the Likert scale was as follows: very difficult=1… very easy=5, i.e., the higher the value, the

Table 1
Average scores for individual tasks, task types, and methods based on point evaluations.

	CDCP	BPMN	AD	EPC	CDCP	BPMN	AD	EPC
task	A1	A2	A3	A4	B1	B2	B3	B4
mean	4.163	3.673	4.098	4.432	3.935	3.161	3.207	3.086
Reading tasks	A1B1	A2B2	A3B3	A4B4				
mean	4.083	3.475	3.775	3.667				
task	C1	C2	C3	C4	D1	D2	D3	D4
mean	2.671	1.594	1.813	1.561	2.593	1.927	2.662	2.222
Drawing tasks	C1D1	C2D2	C3D3	C4D4				
mean	2.637	1.747	2.250	1.858				
method mean	**3.383**	**2.565**	**3.086**	**2.689**				

Table 3
Analysis of variance for tasks for three factors: grade, study program, Method.

		Study_year	Study_program	Method	Study_year *Study_program	Study_program *Method	Study_year *Method
P-Value for	Reading tasks	0.283	0.002	0.000	N	N	0.227
	Drawing tasks	0.000	0.000	0.000	N	N	0.710
	All tasks	0.003	0.013	0.000	N	N	0.340

N - The terms Study_year*Study_program and Study_program*Method cannot be estimated and were removed.

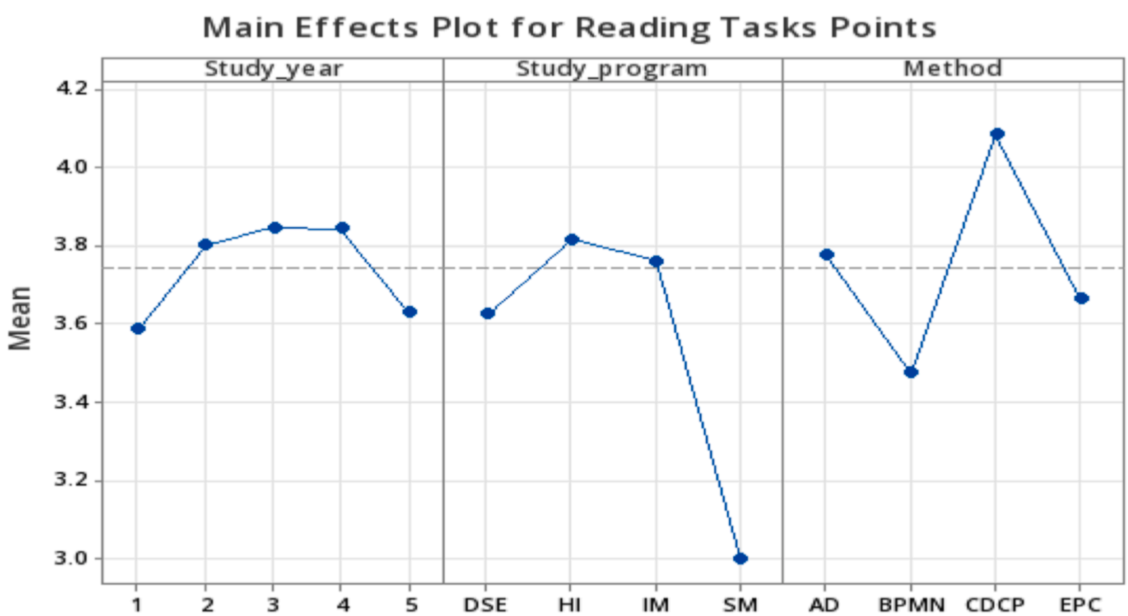

Fig. 9. Main effects plot for reading tasks points.

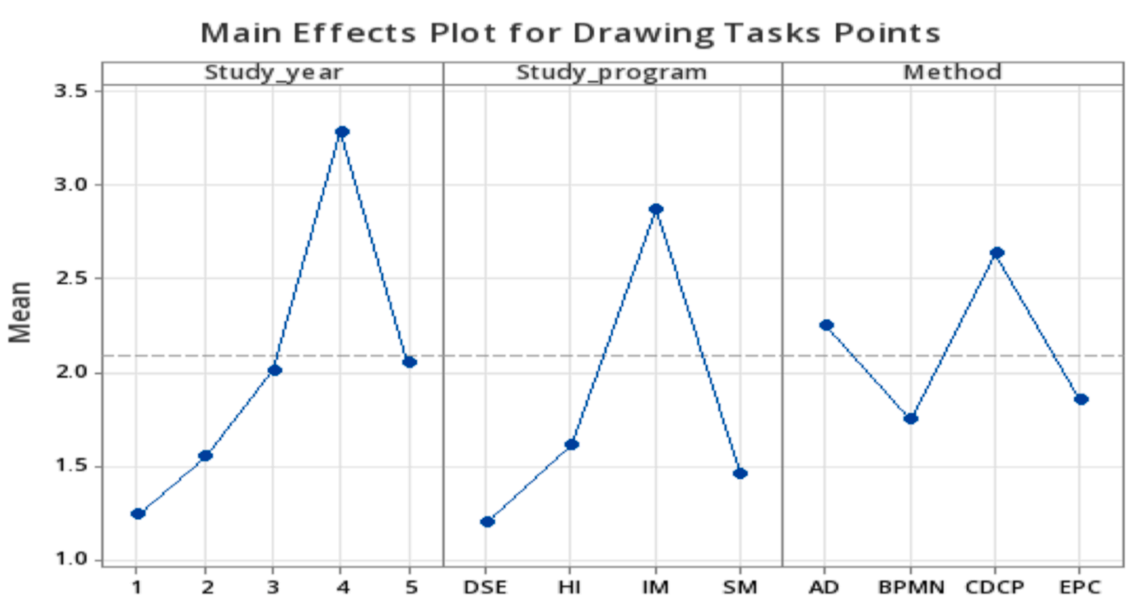

Fig. 10. Main effects plot for drawing tasks points.

easier the respondents considered the task.

Table 5 contains the same fixed factors as Table 2, but the Skill_level factor has been added, which has a strong influence on task assessment. The skill level factor indicates respondents' self-assessment of their ability to understand and draw diagrams of business processes.

7.4. Analysis of variance of the questionnaire data

The data in Table 6 show that none of the factors affected the reading tasks statistically significantly. However, the effect of skill level and Method on the drawing tasks was statistically significant, indicating that these two factors significantly influenced the respondents' diagramming ability.

For all tasks combined, skill level was the most significant factor,

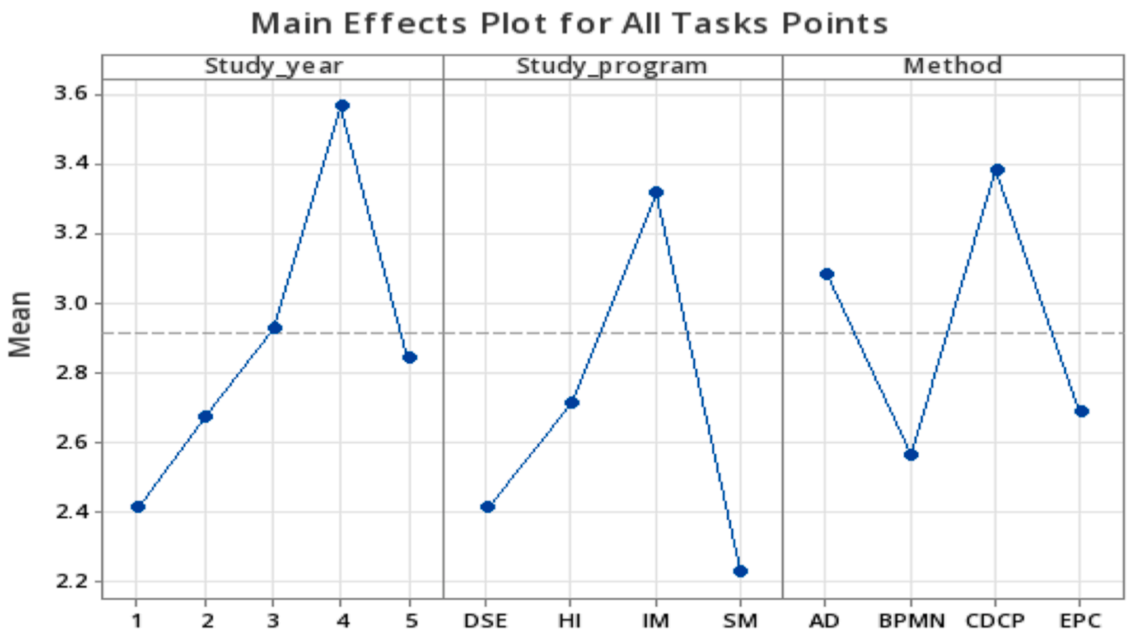

Fig. 11. Main effects plot for all tasks points.

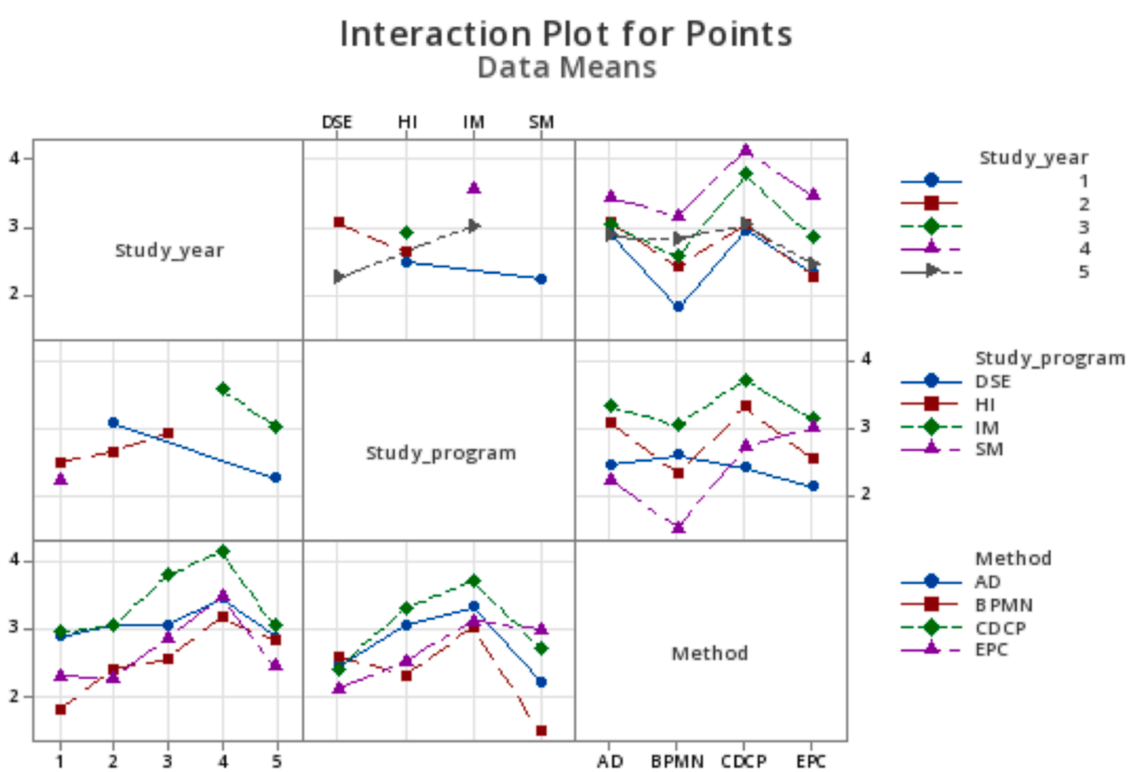

Fig. 12. Interaction plot for points.

significantly influencing overall results. In contrast, other factors, including Method and year of study, did not show a significant effect.

Respondents' experience and the type of task they solved had a statistically significant effect on their reported opinions on difficulty of tasks (see Table 6). Fig. 13 clearly shows that the perceived difficulty of the tasks was influenced by the respondents' reported experiences as statistical analysis proved. Those with the most experience found the tasks very easy, unlike respondents with limited experience. Comparing to Table 4, it is clear that, in general, respondents rated the reading tasks as easier compared to the drawing tasks, with a difference of about one grade.

According to the respondents, CDCP and AD methods were perceived as the easiest to understand, while BPMN and EPC were considered more difficult. Especially for drawing tasks, respondents' experience with other methods was shown to lead them to rank CDCP as the third most comprehensible. However, the objective results showed that the respondents achieved the best results using the CDCP method.

Table 7 shows that respondents rated the perceived difficulty of the diagram reading tasks more harshly than are the actual results they achieved, except for the BPMN method, whose results were the weakest

Table 4
Average scores for individual tasks, types of tasks and methods based on respondents' questionnaire evaluations.

	CDCP	BPMN	AD	EPC	CDCP	BPMN	AD	EPC
task	A1	A2	A3	A4	B1	B2	B3	B4
mean	3.625	3.605	3.489	3.186	3.667	3.567	3.636	3.500
Reading tasks	A1B1	A2B2	A3B3	A4B4				
mean	3.639	3.588	3.565	3.361				
task	C1	C2	C3	C4	D1	D2	D3	D4
mean	2.515	2.211	2.571	2.621	2.273	2.273	2.548	2.444
Drawing tasks	C1D1	C2D2	C3D3	C4D4				
mean	2.418	2.239	2.559	2.553				
Method-mean	**3.060**	**2.899**	**3.074**	**2.904**				

Table 5
Factor information.

Factor	Type	Levels	Values
Study_year	Fixed	5	1, 2, 3, 4, 5
Study_program	Fixed	4	DSE, HI, IM, SM
Skill_level	Fixed	5	1, 2, 3, 4, 5
Method	Fixed	4	AD, BPMN, CDCP, EPC

among all methods.

Respondents rated the drawing tasks as significantly more complex than the reading tasks with difference about one point. This is also reflected in the actual results, except for the CDCP method, which are slightly worse than students' perceived difficulty. For the CDCP method, students performed slightly better than was their assessment of the difficulty.

A comparison of the actual results and the difficulty ratings in questionnaire (see Table 7) shows, that the respondents perceived the CDCP and AD methods as easier to understand and use. For the AD method, the difference was minimal, while for the CDCP method, the difference was more significant. This suggests that although respondents did not consider the CDCP method easy, the results exceeded their expectations. This is understandable, as even respondents with more experience in business process modelling had not encountered this Method before the experiment.

Based on a more detailed analysis of the experimental results, the following conclusions can be made:

- The CDCP method achieved the highest average score of 3.383, indicating that it was the most effective and easiest Method for the participants to use when solving tasks.
- The AD (Activity Diagram) method, with a score of 3.086, was rated as the second most effective. AD was perceived as relatively accessible and user-friendly.

Table 6
Analysis of variance for tasks for four factors: grade, study program, skill level, Method.

		Study_year	Study_program	Skill_level	Method	Study_year*Method
P-Value for	Reading tasks	0.509	0.059	0.068	0.390	0.856
	Drawing tasks	0.069	0.511	0.000	0.013	0.320
	All tasks	0.512	0.179	0.004	0.357	0.922

Table 6 The table shows only two combinations of factors. All other two and three factors interactions cannot be estimated and were removed.

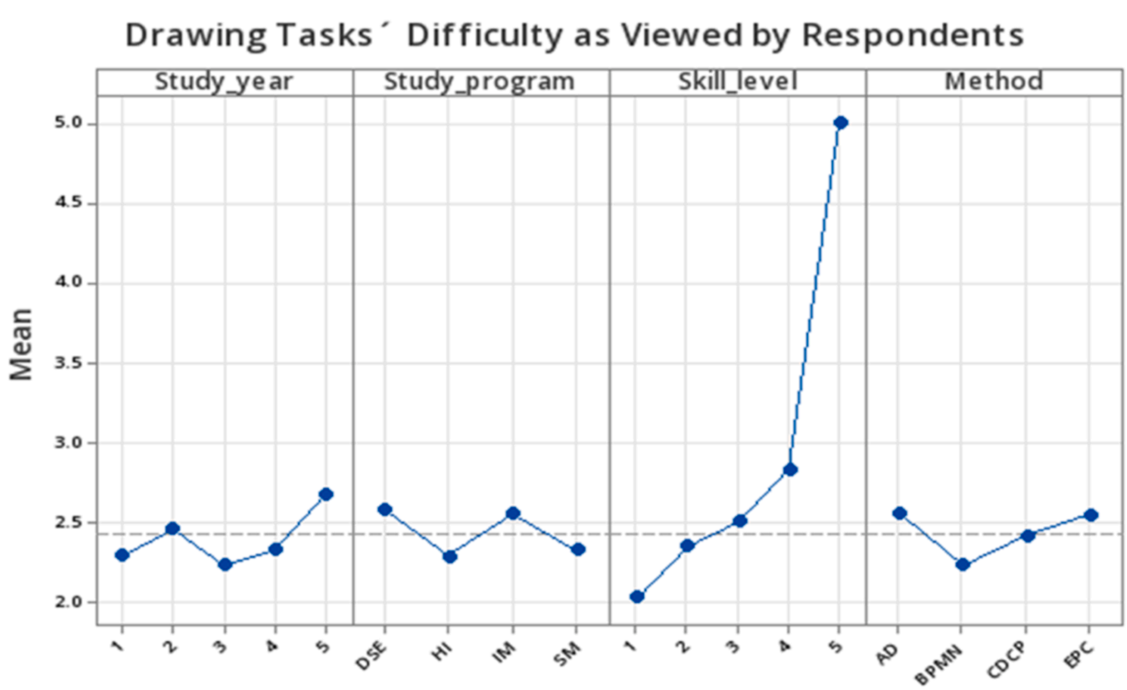

Fig. 13. Main effects plot for difficulty.

Table 7
Experimental Scores (E), Questionnaire Scores (Q), and Differences (D) for Reading, Drawing, and All Tasks Across Methods.

		CDCP	BPMN	AD	EPC
Reading tasks	**E**	4.083	3.475	3.775	3.667
	Q	3.639	3.588	3.565	3.361
	D	−0.444	0.113	−0.210	−0.306
Drawing tasks	**E**	2.637	1.747	2.250	1.858
	Q	2.418	2.239	2.559	2.553
	D	−0.219	0.492	0.309	0.695
All tasks	**E**	3.383	2.565	3.086	2.689
	Q	3.060	2.899	3.074	2.904
	D	−0.323	0.334	−0.012	0.215

- The EPC (Event-driven Process Chain) method scored 2.689, placing it in third place. The Method's higher difficulty may have been a challenge for the participants.
- The BPMN method, with the lowest average score of 2.565, was the most difficult in the experiment. This may suggest that despite its popularity and wide adoption in practice, BPMN might have been more difficult to understand and use in this context.

8. Conclusion

The experiment confirmed the effectiveness of the CDCP method for modelling business processes, especially for tasks requiring interpretation and creation of diagrams. CDCP proved more user-friendly than BPMN, AD, and EPC in terms of task completion, with participants achieving higher mean scores and reporting better user-friendliness. Statistical analysis confirmed that the study program and Method were significant factors influencing performance, while the year of study had a less effect. Notably, even participants with limited process modelling experience achieved favourable results with the CDCP, indicating that it is an intuitive and user-friendly tool. The findings suggest that CDCP simplifies the visualization of complex processes by integrating both vertical and horizontal dimensions. This makes it a promising alternative to traditional methods, especially for educational and practical applications in business process modelling. Future research should explore the application of CDCP in real-world scenarios and its potential to streamline complex process management in various industries.

You can download the CDCP stencil for MS Visio Professional and the CDCP object file for MS Visio 365 at https://oz5v.eu/jdownloads/zip/cdcp.zip.

CRediT authorship contribution statement

Pavol Jurik: Writing – original draft, Methodology. **Peter Schmidt:** Visualization, Conceptualization. **Martin Misut:** Validation, Investigation, Formal analysis. **Ivan Brezina:** Validation, Formal analysis. **Marian Reiff:** Funding acquisition, Formal analysis.

Declaration of competing interest

We, the authors of the article *The Composition Diagram of a Complex Process: Enhancing Understanding of Hierarchical Business Processes*, Pavol JURIK, Peter SCHMIDT, and Martin MISUT, Ivan BREZINA, Marian REIFF, hereby declare that we have no financial or personal relationships with other people or organizations that could inappropriately influence our work or influence its outcome.

We further declare that the work presented in this manuscript is original and has not been previously published in any journal, either in part or in whole, nor is it currently under consideration for publication elsewhere.

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Data availability

The experiment was carried out on 277 students from different study programs and grades to determine the effectiveness of the methods. All results are included in the article.

References

[1] A. Abbad Andaloussi, A. Burattin, T. Slaats, A.C.M. Petersen, T.T. Hildebrandt, B. Weber, Exploring the understandability of a hybrid process design artifact based on DCR graphs. Enterprise, Business-Process and Information Systems Modelling, Springer, 2019, pp. 69–84, https://doi.org/10.1007/978-3-030-20618-5_5.
[2] R.S. Aguilar-Savén, Business process modelling: review and framework, Int. J. Prod. Econ. 90 (2004) 129–149, https://doi.org/10.1016/S0925-5273(03)00102-6.
[3] L. Aldin, S. de Cesare, A comparative analysis of business process modelling techniques, in: Proceedings of the 14th Annual Conference U.K. Academy for Information Systems (UKAIS 2009), Oxford, 2009, pp. 1–17.
[4] Y. Alotaibi, Business process modelling challenges and solutions: a literature review, J. Intell. Manuf. 27 (2016) 701–723, https://doi.org/10.1007/s10845-014-0917-4.
[5] P. Antunes, D. Simões, L. Carriço, J.A. Pino, An end-user approach to business process modelling, J. Netw. Comput. Appl. 36 (6) (2013) 1466–1479, https://doi.org/10.1016/j.jnca.2013.03.014.
[6] T.H. Davenport, J. Short, The new industrial engineering. information technology and business process redesign, Sloan Manage Rev. 31 (4) (1990) 11–27. Retrieved from, http://dspace.mit.edu/bitstream/handle/1721.1/48613/newindustrialeng00dave.pdf.
[7] R.M. Dijkman, M. Dumas, C. Ouyang, Semantics and analysis of business process models in BPMN, Inf. Softw. Technol. 50 (12) (2008) 1281–1294, https://doi.org/10.1016/j.infsof.2008.02.006.
[8] B. Fatima, K. Shahzad, Process model abstraction: identifying business significant activities, in: Proceedings of the International Conference on Intelligent Technologies and Applications, 2018.
[9] K. Figl, Comprehension of procedural visual business process models, Bus. Inf. Syst. Eng. 59 (1) (2017) 41–67, https://doi.org/10.1007/s12599-016-0460-2.
[10] C.V. Geambaşu, BPMN vs. UML activity diagram for business process modelling, in: Proceedings of the 7th International Conference Accounting and Management Information Systems AMIS, 2012, pp. 934–945.
[11] N. Genon, P. Heymans, D. Amyot, Analyzing the cognitive effectiveness of the BPMN 2.0 visual notation, in: Proceedings of the International Conference on Software Language Engineering, Berlin, Heidelberg, Springer Berlin Heidelberg, 2010, pp. 377–396, https://doi.org/10.1007/978-3-642-19440-5_25.
[12] J. Jeston, Business Process Management: Practical guidelines to Successful Implementations, 4th ed., Taylor & Francis Group, 2018.
[13] Jurik, P. & Schmidt, P. (2020). Composition diagram of a complex process: a contribution to business process Modelling. TIEES 2020: trends and innovations in E-business, education and security: eighth international scientific web-conference of scientists and PhD. Students or Candidates., 8, 81–92.
[14] Kirchmer, M., Benedict, T., Scarsig, M., Frantz, P., Saxena, R., Morris, D., & Hilty, J. (2019). Bpm Cbok version 4.0: guide to the business process management common body of knowledge. INDEPENDENTLY PUBLISHED.
[15] Korherr, B. (2008). Business process modelling-languages, goals, and variabilities (Doctoral dissertation).
[16] B. List, B. Korherr, An evaluation of conceptual business process modelling languages, in: Proceedings of the 2006 ACM Symposium on Applied Computing, 2006, pp. 1532–1539, https://doi.org/10.1145/1141277.1141633.
[17] Ministry of Interior of the Slovak Republic. (2020). Metodika Optimalizácie Procesov – Konvencie Modelovania. minv.sk. Retrieved May 31, 2022, fromhttps://www.minv.sk/swift_data/source/mvsr_a_eu/fabianova/np_optimalizacia/Metodika%20optimalizacie%20procesov%20-%20konvencie%20modelovania%20(januar%202020).pdf.
[18] Object Management Group. (2005). Unified Modeling Language: Superstructure. UML Superstructure Specification v2.0, formal/05-07-04.
[19] A. Polyvyanyy, S. Smirnov, M. Weske, The triconnected abstraction of process models, in: Proceedings of the International Conference on Business Process Management, 2009.
[20] M. Ramos-Merino, L.M. Álvarez-Sabucedo, J.M. Santos-Gago, F. de Arriba-Pérez, A pattern based Method for simplifying a BPMN process model, Appl. Sci. 9 (11) (2019) 2322, https://doi.org/10.3390/app9112322.
[21] M. Robson, P. Ullah, Praktická Príručka Podnikového Reengineeringu, 1st ed., Management Press, Praha, Czech Republic, 1998.
[22] I. Salieiev, Organization of processes for complex mining and processing of mineral raw materials from coal mines in the context of the concept of sustainable

development, Min. Miner. Depos. 18 (1) (2024) 54–66, https://doi.org/10.33271/mining18.01.054.
[23] P. Schmidt, P. Jurik, Composition diagram of a complex process: a new method for displaying complex business processes, in: Proceedings of the Trends and Innovations in E-business, Education and Security: 9th International Scientific Web-conference of Scientists and PhD. students or candidates, Bratislava, The Slovak Society for Economic Informatics, 2021, pp. 148–159.
[24] A. Senderovich, A. Shleyfman, M. Weidlich, A. Gal, A. Mandelbaum, To aggregate or to eliminate? Optimal model simplification for improved process performance prediction, Inf. Syst. 78 (2018) 96–111, https://doi.org/10.1016/j.is.2018.04.003.
[25] V. Stein Dani, C.M. Dal Sasso Freitas, L.H. Thom, Ten years of visualization of business process models: a systematic literature review, Comput. Stand. Interfaces 66 (2019) 103347, https://doi.org/10.1016/j.csi.2019.04.006.
[26] S. Stein, C. Stamber, M. El Kharbili, ARIS for semantic business process management, in: Proceedings of the Business Process Management Workshops: BPM 2008 International Workshops, Berlin Heidelberg Milano, Italy, September 1-4, 2008, Springer, 2009, pp. 498–509, https://doi.org/10.1007/978-3-642-00328-8_50. Revised Papers 6.
[27] C. Tsagkani, A. Tsalgatidou, Process model abstraction for rapid comprehension of complex business processes, Inf. Syst. 103 (2022) 101818, https://doi.org/10.1016/j.is.2021.101818.
[28] W. Wang, T. Chen, M. Indulska, S. Sadiq, B. Weber, Business process and rule integration approaches—an empirical analysis of model understanding, Inf. Syst. 104 (2022) 101901, https://doi.org/10.1016/j.is.2021.101901.
[29] W. Wang, M. Indulska, S. Sadiq, B. Weber, Effect of linked rules on business process model understanding, in: Proceedings of the International Conference on Business Process Management, 2017.
[30] B. Weber, M. Reichert, J. Mendling, H.A. Reijers, Refactoring large process model repositories, Comput. Ind. 62 (5) (2011) 467–486, https://doi.org/10.1016/j.compind.2010.12.012.
[31] Weske, M. (2007). Concepts, languages, architectures. Business Process Management.
[32] Winter, M., Pryss, R., Probst, T., & Reichert, M. (2020). Learning to read by learning to write: evaluation of a serious game to foster business process model comprehension. JMIR. Serious. Games., 8(1), e15374. doi:10.2196/15374.
[33] M. Witsch, B. Vogel-Heuser, Towards a formal specification framework for manufacturing execution systems, IEEe Trans. Industr. Inform. 8 (2) (2012) 311–320, https://doi.org/10.1109/TII.2012.2186585.
[34] S.A. White, Introduction to BPMN. BPTrends, IBM Corporation, 2004. Retrieved March 29, 2022, from, http://yoann.nogues.free.fr/IMG/pdf/07-04_WP_Intro_to_BPMN_-_White-2.pdf.
[35] Workflow Management Coalition, Workflow Management Coalition Workflow Standard: Workflow Process Definition Interface – XML Process Definition Language (XPDL), Lighthouse Point, Florida, USA, 2002. Technical report, Workflow Management Coalition, 2002.
[36] J. Xinming, W. Haikun, Scenario-based comparison and evaluation: issues of current business process modelling languages, Proc. Inst. Mech. Eng. B J. Eng. Manuf. 220 (9) (2006) 1527–1538, https://doi.org/10.1243/095440505X32409.
[37] M. Zimoch, R. Pryss, T. Probst, W. Schlee, M. Reichert, Cognitive Insights Into Business Process Model comprehension: Preliminary results For Experienced and Inexperienced individuals. In Enterprise, Business-Process and Information Systems Modelling, a, Springer, 2017, pp. 137–152, https://doi.org/10.1007/978-3-319-59466-8_9.
[38] M. Zimoch, R. Pryss, J. Schobel, M. Reichert, Eye tracking experiments on process model comprehension: lessons learned. Enterprise, Business-Process and Information Systems Modelling, Springer, 2017, pp. 153–168, https://doi.org/10.1007/978-3-319-59466-8_10.