Navigating the Industry 4.0 frontier: Unveiling perceived risk and cost moderators in technology adoption

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Abstract: *The advent of Industry 4.0 (I4.0) brought about significant transformations within the realm of business management. Industries are increasingly adopting innovative practices and implementing smart supply chain operations through the adoption of I4.0 technologies. Therefore, this study aims to investigate the factors that influence the adoption of I4.0 in supply chain operations. To accomplish this, an extended unified theory of acceptance and use of technology (UTAUT) model was applied, with perceived risk and cost acting as moderators in the context of the manufacturing sector. The study used a quantitative research methodology, with a sample size of 276 participants who held managerial positions at various levels within the sector. The data were obtained through the use of a structured questionnaire employing a judgmental sampling technique. The findings of the study revealed that both social influence and facilitating conditions had a significant impact on the adoption of I4.0. However, the relationship between social influence and I4.0 adoption was only moderated by perceived risk and cost. The aforementioned findings indicate that it is imperative that firms give precedence to the establishment of a conducive environment and culture that nurture innovation and promote the assimilation of cutting-edge technologies. Furthermore, it is essential for individuals to prioritize the establishment of strong networks and collaborations in order to effectively leverage the advantages offered by the I4.0. The implications of this study offer valuable insights for policymakers, practitioners, and researchers in the field of I4.0 and technology adoption. These insights pertain to the significant factors that influence the decision to adopt I4.0 and the anticipated applications of I4.0 within the supply chain.*

Keywords: *Industry 4.0, technology adoption, UTAUT, manufacturing firms, SDG17.*

JEL Classification: *M11, M15, L60.*

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Introduction

Industry 4.0, also known as I4.0, is a modern manufacturing strategy that involves the implementation of digital and interconnected industrial value generation models (Senna et al., 2022; Tortorella & Fettermann, 2018). There are multiple benefits associated with this strategy, such as enhanced utilization of resources, increased levels of personalization, and the emergence of novel business models

(Senna et al., 2022). As I4.0 takes hold, disruptive technologies such as blockchain, big data, and the internet of things (IoT) are transforming multiple supply chain components (Jum'a et al., 2022; Khan et al., 2022). Logistics is an essential part of supply chain management, and the success of I4.0 is dependent on its digital transformation in logistics operations. In this context, the current logistics system must be modernized with I4.0 technology in order to become logistics 4.0 (Khan et al., 2022). There is currently little knowledge on how these technologies may be used in enterprises' established production facilities and what the benefits are to firms making an informed decision to transition to I4.0 (Kumar et al., 2022). Many firms are hesitant to adopt I4.0 because they do not completely understand the potential changes to their operations and organizational structure (Hamada, 2019).

Despite the fact that I4.0 is associated with the aforementioned benefits, many studies have shown variances in adoption intensity and scale (Hamada, 2019; Kumar et al., 2022; Tortorella & Fettermann, 2018). Previous studies in the field of technology management have shown similar findings, indicating that different technologies have similar patterns. The adoption of technology by businesses is influenced by a variety of factors (Jum'a et al., 2022; Senna et al., 2022; Shi et al., 2022). For example, Khin and Kee (2022) demonstrated that knowing the vital elements to consider might help manufacturing companies decide whether to engage in I4.0. Decision-makers are more likely to be driven to take action if they are convinced of the benefits rather than deterred by the drawbacks. As a result, understanding the advantages and disadvantages of I4.0 will enable them to weigh the benefits and drawbacks of adopting it. According to Narula et al. (2020), the fact that many organizations are not even familiar with the critical aspects driving I4.0 adoption is still troubling, even though businesses are aware of its potential. This has resulted in a slow and unequal speed of change across industries, regardless of the country of origin. Emerging and developing markets face distinct challenges when it comes to investing in I4.0. For example, Tortorella et al. (2019) highlighted several notable initiatives undertaken by various countries to embrace I4.0. The Mexican Ministry of Economy has presented a comprehensive framework outlining the steps required for the adoption of I4.0 in Mexico. Similarly, the Brazilian National Confederation of Industry has identified and documented the existing challenges and obstacles hindering the successful implementation of I4.0 in Brazil. Furthermore, the Indian Government has introduced a strategic plan aimed at positioning the country as a prominent global production hub in the context of I4.0 (Tortorella et al., 2019). Moreover, the COVID-19 pandemic has exerted significant pressure on developing and emerging countries to devise a digital computing infrastructure capable of remote operation, thereby reducing the need for in-person human interaction (Khin & Kee, 2022). In light of these challenges, manufacturers are actively seeking more flexible and efficient operational protocols, made possible by advanced digital technologies commonly referred to as I4.0 or smart manufacturing (Khin & Kee, 2022). According to Kumar Bhardwaj et al. (2021) and Jum'a (2023), the integration of blockchain technology within the supply chains of small and medium-sized enterprises (SMEs) is expected to enhance operational processes, overall performance, and efficiency. The adoption of I4.0 is contingent upon the mindset of influential decision-makers within organizations, as these individuals are inclined to embrace risk-taking and make substantial investments in future endeavors when their companies demonstrate successful performance (Kumar et al., 2022). Decision-makers who have a strong preference for innovation and are prepared to accept the risks involved in adopting novel information systems can facilitate the successful implementation of I4.0 (Hamada, 2019). Despite the numerous benefits associated with I4.0, several studies have identified disparities in the level of adoption (Kijsanayotin et al., 2009; Senna et al., 2022).

The investigation of adoption intention towards I4.0 can be conducted using various acceptance models. For instance, the study of Puriwat and Tripopsakul (2021) confirmed what the unified theory of acceptance and use of technology (UTAUT) model said about the relationships between performance expectancy (PE), effort expectancy (EE), social influence (SI), facilitating conditions (FC) and the intention to use information technology, as well as the direction of those relationships. Another model is the TOE framework that incorporates adoption variables that are intrinsic to the adopting organization, including factors such as the size of the firm, managerial support, and the ability to recognize the value of new information, assimilate it, and utilize it to achieve business objectives (Senna et al., 2022). However, the UTAUT is a prevalent theoretical framework employed to elucidate the factors influencing the adoption of emerging technologies. According to Venkatesh et al. (2003), the UTAUT model proposes that there are four constructs, namely PE, EE, SI, and FC, which directly influence both behavioral intention and behavior. The UTAUT has garnered substantial empirical support from a wide range of studies (Afifa et al., 2022; Hewavitharana et al., 2021; Pieters et al., 2022). Furthermore, this model has the potential to yield intriguing findings. The UTAUT model provides a more rational framework for examining the process of technology adoption. The captured aspects include the alignment between technology and task requirements, the impact on society, and the availability of resources as facilitating conditions (Dissanayake et al., 2022). In comparison to other models and theories, this particular model demonstrates a superior level of explanatory power (Dissanayake et al., 2022).

As demonstrated by Khin and Kee (2022), multiple research investigations have yielded findings suggesting that the presence of FC, such as governmental support, may accelerate the process of technology adoption. Hence, the present study endeavors to expand upon the UTAUT model and tackle its limitations by examining the other key factors, namely perceived cost and risk, that may impact the adoption of I4.0. In summary, the objective of this study was to employ the extended UTAUT model in order to simulate individuals' inclination to adopt I4.0 technologies, with perceived cost (PC) and perceived risk (PR) serving as moderating factors. Therefore, this study addresses the existing knowledge gap regarding the human aspect of digitalization in the manufacturing industry based on an extended UTAUT framework. The rationale for employing the UTAUT framework in this study stems from its recognized comprehensiveness in evaluating individual-level technology acceptance (Afifa et al., 2022; Tusyanah et al., 2021). It serves as a foundation for identifying and resolving the challenges that have arisen during the process of digital transformation within the industry. Moreover, the research has developed an expanded framework that can be effectively utilized to methodically incorporate the human factor into the process of digitally transforming I4.0. Furthermore, this facilitates the examination of evolving human requirements in digitally altered settings, such as I4.0 environments, and contributes to a prosperous digital transformation that circumvents the drawbacks of innovation conducted without consideration for human factors (Hewavitharana et al., 2021; Puriwat & Tripopsakul, 2021).

The literature reviews of previous, relevant research are included in the literature review section, as is a table with a summary of the findings from earlier studies on how I4.0 is helping supply chain management. Following that, the conceptual model and hypotheses are presented. The methodology of the investigation is then presented. The study's findings are also provided. The appropriate theoretical and managerial implications and conclusions are then used to get the result.

1. Theoretical background

1.1 UTAUT model and adoption of I4.0

In the contemporary digital era, a multitude of advanced communication systems, such as blockchain, the IoT, and cloud computing, have emerged (Veile et al., 2020). These systems have been designed to provide extensive capabilities across various applications and scenarios (Kumar Bhardwaj et al., 2021). Insufficient understanding of the societal and technical aspects of information technology, specifically the integration of digital technologies by individuals and organizations, is a significant contributing factor to failures (Dissanayake et al., 2022; Pieters et al., 2022; Puriwat & Tripopsakul, 2021). Manufacturing companies frequently exhibit a sense of prudence when it comes to embracing I4.0 for the purpose of digitally transforming their operational procedures. Despite the various benefits I4.0 presents and its increasing significance within the realm of supply chain management, there are various additional factors that need to be considered prior to allocating funds for its costly implementation (Khin & Kee, 2022). The UTAUT model shows an approach that is more effective than previous models (Afifa et al., 2022; Dissanayake et al., 2022; Pieters et al., 2022) at finding the factors that cause differences in IT behavioral intention and use behavior.

Puriwat and Tripopsakul (2021) conducted a study applying the UTAUT model to assess individuals' intentions and actual usage of social media platforms. The findings of this study indicate that PE and EE, as well as SI, have a significant impact on the likelihood of adopting social media for business purposes. The presence of FC significantly influenced the actions taken by users. Another study was conducted by Pieters et al. (2022) with the aim of obtaining insights into the adoption of blockchain technology. In the organizational context, hedonic motivation proved to be a significant factor that influences the adoption of blockchain technology. PE, SI, and FC emerged as significant predictors for adoption. The lack of EE significance indicates that the perceived complexity of blockchain technology does not discourage potential users.

Moreover, the research conducted by Afifa et al. (2022) employed the UTAUT model, incorporating several external factors. The findings of the study indicate that both PE and EE positively impact the intention to adopt blockchain technology. However, it was observed that SI has a comparatively weaker influence on the intention to use blockchain. Furthermore, it is worth noting that trust plays a significant role in influencing both PE and EE, as well as the intention to utilize blockchain technology. The lack of correlation between the intention to utilize blockchain technology and compatibility adds to its inherent intrigue. In an empirical study, Hamada (2019) sought to determine the factors influencing decision-makers' perceptions of the adoption of I4.0. The study utilized data obtained from a sample of Japanese manufacturers. The results suggest that there is no significant association between the adoption of I4.0 by enterprises and the company's size. In addition, decision-makers who hold the belief that their company is achieving satisfactory performance tend to hold positive opinions regarding the adoption of I4.0. Encouraging decision-makers to develop a positive attitude towards the adoption of I4.0, enhancing their adoption of relevant information, and addressing any deficiencies in capabilities can serve as catalysts for promoting adoption.

In their study, Kijsanayotin et al. (2009) employed a modified UTAUT model to examine the factors influencing the acceptance of health information technology (IT) in community clinics in Thailand. The aim was to validate the applicability of the existing IT adoption model within the healthcare context of a developing nation. The results of the study revealed that the inclination to utilize health information technology (IT) is contingent upon various factors. These factors encompass the belief that health IT will be advantageous in terms of performance (PE), the belief that it will be uncomplicated to operate (EE), the belief that influential individuals will endorse the use of health IT (SI), and the belief that individuals have the freedom to decide how to employ IT (voluntariness). The aforementioned four variables exhibited a significant level of predictive capacity and accounted for more than 50% of the variability in the intention to use information technology. The most influential predictor among these four contributing factors was PE. In a recent study conducted by Ronaghi and Forouharfar (2020), the primary objective was to ascertain the key factors that contribute to the adoption and subsequent implementation of IoT technology in the context of smart farming. The findings of the study highlighted and confirmed the significant effects of PE, EE, SI, FC, and individual factors on the intention to adopt IoT technology. Finally, the study by Tusyanah et al. (2021) identified a number of factors that influence behavioral intention, including EE, PE, SI, and FC. The study also revealed that an individual's level of experience moderates the relationship between EE and intention. In their study, Hewavitharana et al. (2021) identified PE as the primary driving force behind individuals' inclination towards digital transformation using the analytical hierarchy process approach. Finally, a study by Kwarteng et al. (2023) employed an extended UTAUT framework as the basis for a research model examining the factors influencing the adoption of digitalization in European SMEs. The model incorporates PE, EE, FC, and competitive pressure as potential influential factors. All of the aforementioned factors were found to have a significant impact on the digitalization of SMEs, with the exception of EE.

1.2 Influence of UTAUT factors on I4.0 adoption

The fundamental UTAUT model comprises various components or constructs that are hypothesized to be associated with the intention to adopt information technology, including expected performance, expected effort, social impact, and FC (Pieters et al., 2022; Puriwat & Tripopsakul, 2021). These components play a significant role in the decision-making process regarding the adoption of technology. In the study conducted by Hamada (2019), significant and positive results were observed in relation to the impact of "Performance" on the adaptation of the company to I4.0. In a study conducted by Kijsanayotin et al. (2009), it was found that several factors play a significant role in determining an individual's likelihood of adopting health IT. These factors include the perceived usefulness of health IT, the perceived ease of use, the SI exerted by important individuals in one's life, and the perception of personal autonomy in the decision to use IT. The explanatory power of these four variables was found to account for over 50% of the variance in the intention to utilize information technology, indicating a robust predictive ability. According to Khin and Kee (2022), the facilitation of digital transition can be supported by academic institutions through their assistance in developing the requisite technologies or solutions. Business enterprises could potentially achieve cost savings by collaborating with academic institutions, thereby obviating the need for direct acquisition of requisite solutions. The adoption of I4.0 is subject to notable influences stemming from technological, organizational, and environmental factors. The adoption of I4.0 is positively influenced by factors such as relative advantage, senior management support, and competitiveness. In their study, Kwarteng et al. (2023) observed that the two components of the UTAUT model, namely PE and FC, exert a substantial influence on the digitalization efforts of companies. The subsequent hypotheses have been formulated.

H1: PE positively influences I4.0 adoption.

H2: EE positively influences I4.0 adoption.

H3: SI positively influences I4.0 adoption.

H4: FC positively influences I4.0 adoption.

1.3 Moderating role of perceived cost

The decision for embracing new technology is influenced by two key cost elements: perceived costs and cost reductions (Salim, 2022; Shi et al., 2022). These two cost factors exhibit contrasting effects on the inclination to utilize. As shown by Salim (2022), there is a negative correlation between the desire to adopt a technology and the perceived financial burden associated with its implementation. According to Chulkov's (2017) findings, the permanence or reversibility of the decision to adopt a technology is contingent upon the level of efficiency in managing switching costs. According to Schmidthuber et al. (2020), the permanence of technology adoption is contingent upon the presence of high costs associated with transitioning from one IT solution to another. Moreover, Salim (2022) suggested that the PC does not function as a mediator, but rather as a moderator in the relationship between the enablers and inhibitors of the technology readiness index (TRI) and the desire for embracing blockchain technology. Finally, according to the findings of Rahi and Ghani (2016), it can be inferred that consumer perceived value and the moderating factor of switching cost exert a substantial influence on customer loyalty within the online banking domain of the banking sector. Consequently, the following hypotheses have been formulated.

H5a: PC moderates the relationship between PE and I4.0 adoption.

H5b: PC moderates the relationship between EE and I4.0 adoption.

H5c: PC moderates the relationship between SI and I4.0 adoption.

H5d: PC moderates the relationship between FC and I4.0 adoption.

1.4 Moderating role of perceived risk

There are numerous risks associated with the adoption of novel technologies. PR encompasses various dimensions, including monetary, security, mental, emotional, time, and performance risks (Suroso et al., 2022). The acceptance of technology by industries and companies can be facilitated by minimizing the PRs through the pursuit of excellence in performance, the application of minimal effort, the influence of societal factors, and the presence of favorable circumstances (Khin & Kee, 2022; Kumar Bhardwaj et al., 2021; Senna et al., 2022). Hence, Jangir et al. (2022) discovered a statistically significant positive relationship between individuals' intention to persist in utilizing FinTech services and their perceptions of utility, contentment, and confirmation. The findings of this study reveal that the PR factor plays a moderating role in the relationship between satisfaction and both continuation intention and confirmation of contentment. Nevertheless, their findings also indicated that the influence of PR on the relationships between perceived value and the intention to sustain technology usage was minimal. In the study conducted by Im et al. (2008), it was found that PR plays a significant moderating role in the relationship between different variables and the intention to use technology. The results highlight the importance of including PR as a critical element in the UTAUT model. In order to investigate the moderating effect of PR on the relationship between UTAUT elements and the intention to adopt I4.0, following hypotheses have been formulated.

H6a: PR moderates the relationship between PE and I4.0 adoption.

H6b: PR moderates the relationship between EE and I4.0 adoption.

H6c: PR moderates the relationship between SI and I4.0 adoption.

H6d: PR moderates the relationship between FC and I4.0 adoption.

The conceptual model is shown in Fig 1.

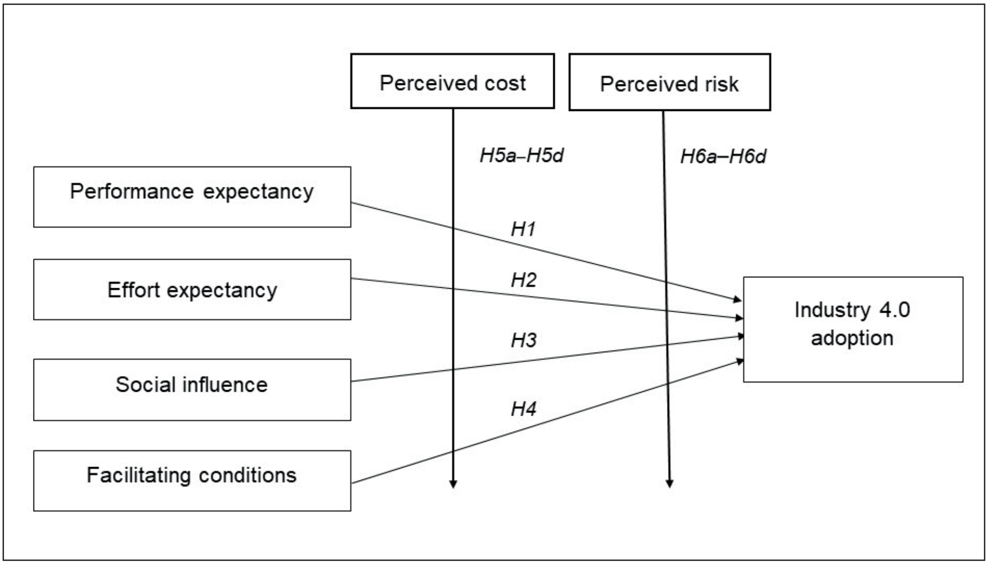

Fig. 1: The conceptual model

Source: own

2. Research methodology

2.1 Sampling procedures

This study focused on manufacturing companies in Jordan, specifically Amman. The individual manufacturing company served as the unit of analysis. To choose participants, the researchers utilized a judgmental sampling technique under non-probability sampling methods due to cost and time constraints. However, Malhotra (2010) shows that this method can still offer reliable estimations of population characteristics. The researchers used a structured questionnaire and a quantitative survey approach to collect data, which allowed for the objective evaluation of variable connections and the generalization of findings to a larger audience. A sample size of 200 or more was selected based on previous research recommendations (Hair et al., 2019), and the questionnaire was completed online by 276 respondents between March and June 2023. The information was cleaned and evaluated using proper statistical data analysis techniques.

2.2 Questionnaire measurement items

The measurement items used throughout this study were selected from relevant previous studies. The constructs of PE, EE, SI, and FC were derived from the studies of Puriwat and Tripopsakul (2021) and Pieters et al. (2022). The items pertaining to PC were derived from Lin et al. (2016), while the items concerning

PR were sourced from Im et al. (2008). Tortorella et al. (2019) conducted a study in which they adopted the items pertaining to the adoption of I4.0. The survey was structured into two sections, with the initial section encompassing demographic information and the subsequent section comprising measurement items. Participants were instructed to assess their level of agreement and disagreement about I4.0 in the context of supply chain operations using a five-point Likert scale, which ranged from 1 (indicating strong disagreement) to 5 (indicating strong agreement) as shown in Appendix 1.

2.3 Profile of the respondents

Gender, age, years of experience, education level, position, number of employees, and firm type were all demographic characteristics used in the study. The findings revealed that the majority of participants (91.7%) were male and between the ages of 31 and 40 (45.7%). The majority of participants (39.5%) had 5–10 years of experience and (81.9%) had a Bachelor's degree. The majority of participants (72.8%) were in first-line management positions and worked in companies with 20–99 employees (59.1%). Food and supply (34.1%) had the most enterprises represented,

Tab. 1: Demographic profile of the respondents

Category	Subcategory	Frequency (*n*)	Percent (%)
Gender	Male	253	91.7
	Female	23	8.3
Age (years)	21–30	73	26.4
	31–40	126	45.7
	41–50	45	16.3
	Above 50	32	11.6
Years of experience	Less than 5	74	26.8
	5–10	109	39.5
	More than 10	93	33.7
Education level	Diploma degree	8	2.9
	Bachelor degree	226	81.9
	Master's degree and above	42	15.2
Position	First line managers	201	72.8
	Middle managers	48	17.4
	Top managers	27	9.8
Number of employees	Less than 20	23	8.3
	20–99	163	59.1
	100 and more	90	32.6
Type of firm	Printing and paper	33	12.0
	Therapeutics	30	10.9
	Chemicals	50	18.1
	Plastic products	69	25.0
	Food and supply	94	34.1

Source: own

followed by plastic products (25.0%), chemicals (18.1%), printing and paper (12.0%), and therapeutics (10.9%) as shown in Tab. 1.

3. Results and discussion

3.1 Results

The means and standard deviations for several constructs connected to I4.0 adoption are provided by this descriptive analysis. In terms of mean, the PC had the highest value (M = 4.25, SD = 0.985), followed by FC (M = 4.08, SD = 0.886) and PR (M = 4.07, SD = 0.878). EE had the lowest mean (M = 2.41, SD = 1.008) of all the constructs as illustrated in Tab. 2. Overall, these findings imply that while EE may be a barrier to adoption, PC and FC may be significant factors influencing I4.0 adoption.

Tab. 2: Descriptive statistics (*N* = 276)

Constructs	Mean	Std. deviation	Skewness	Std. error	Kurtosis	Std. error
PE	3.53	1.261	−0.921	0.147	−0.567	0.292
EE	2.41	1.008	0.963	0.147	−0.124	0.292
SI	3.95	0.872	−1.672	0.147	3.344	0.292
FC	4.08	0.886	−2.156	0.147	4.063	0.292
PC	4.25	0.985	−1.983	0.147	2.877	0.292
PR	4.07	0.878	−1.387	0.147	2.440	0.292
I4.0 adoption	3.75	0.965	−1.616	0.147	2.004	0.292

Source: own

Tab. 3: Multicollinearity test

Latent variables	Collinearity statistics	
	Tolerance	VIF
PE	0.889	1.125
EE	0.978	1.022
SI	0.924	1.082
FC	0.857	1.166

Source: own

The estimated path coefficients may be impacted by the presence of multicollinearity among the independent variables. To identify multicollinearity, the researchers calculated the tolerance values and variance inflation factor (VIF). The results indicated that there was no multicollinearity among the independent variables since all the VIF values were less than 5 and the tolerance values were above 0.10 (Hair et al., 2019). Tab. 3 provides further details on these findings.

SmartPLS version 3 was utilized for performing the structural equation modelling (Ringle et al., 2015). There were two phases including measurement model analysis and structural model analysis.

Constructs' reliability was assessed with the values of Cronbach's alpha and composite reliability. The results showed that all the values were above the recommended level (>0.70) and thus acceptable (Hair et al. 2019). Moreover, a convergent validity assessment was performed with the values of factor loading above 0.70 and average variance extracted (AVE) values above 0.50. The results indicated that all the values of factor loading and AVE fall under the recommended level (Hair et al. 2019) as shown in Tab. 4.

To achieve discriminant validity, all the square root values of AVE should be higher than the correlation coefficients between the particular constructs (Fornell & Larcker,

Tab. 4: Construct reliability and validity

Constructs	Items	Factor loadings	Cronbach's alpha	Composite reliability	AVE
I4.0 adoption	ADOP.INT1	0.932	0.981	0.983	0.856
	ADOP.INT2	0.927			
	ADOP.INT3	0.929			
	ADOP.INT4	0.951			
	ADOP.INT5	0.937			
	ADOP.INT6	0.911			
	ADOP.INT7	0.937			
	ADOP.INT8	0.918			
	ADOP.INT9	0.905			
	ADOP.INT10	0.902			
EE	E.EX1	0.999	0.943	0.951	0.869
	E.EX2	0.999			
	E.EX3	0.780			
FC	F.CON1	0.924	0.950	0.962	0.835
	F.CON2	0.923			
	F.CON3	0.922			
	F.CON4	0.916			
	F.CON5	0.882			
PC	P.COST1	0.944	0.938	0.960	0.890
	P.COST2	0.943			
	P.COST3	0.943			
PE	P.EX1	0.977	0.973	0.980	0.925
	P.EX2	0.954			
	P.EX3	0.941			
	P.EX4	0.973			
PR	P.RK1	0.953	0.966	0.975	0.907
	P.RK2	0.925			
	P.RK3	0.970			
	P.RK4	0.959			
SI	S.INF1	0.956	0.934	0.957	0.882
	S.INF2	0.923			
	S.INF3	0.939			

Source: own

Tab. 5: Discriminant validity

Constructs	1.	2.	3.	4.	5.	6.	7.
1. EE	0.932						
2. FC	0.060	0.914					
3. I4.0 adoption	0.104	0.488	0.925				
4. PC	0.070	0.589	0.528	0.943			
5. PR	0.079	0.445	0.344	0.408	0.952		
6. PE	0.096	0.317	0.231	0.301	0.141	0.962	
7. SI	0.120	0.247	0.264	0.291	0.375	0.140	0.939

Source: own

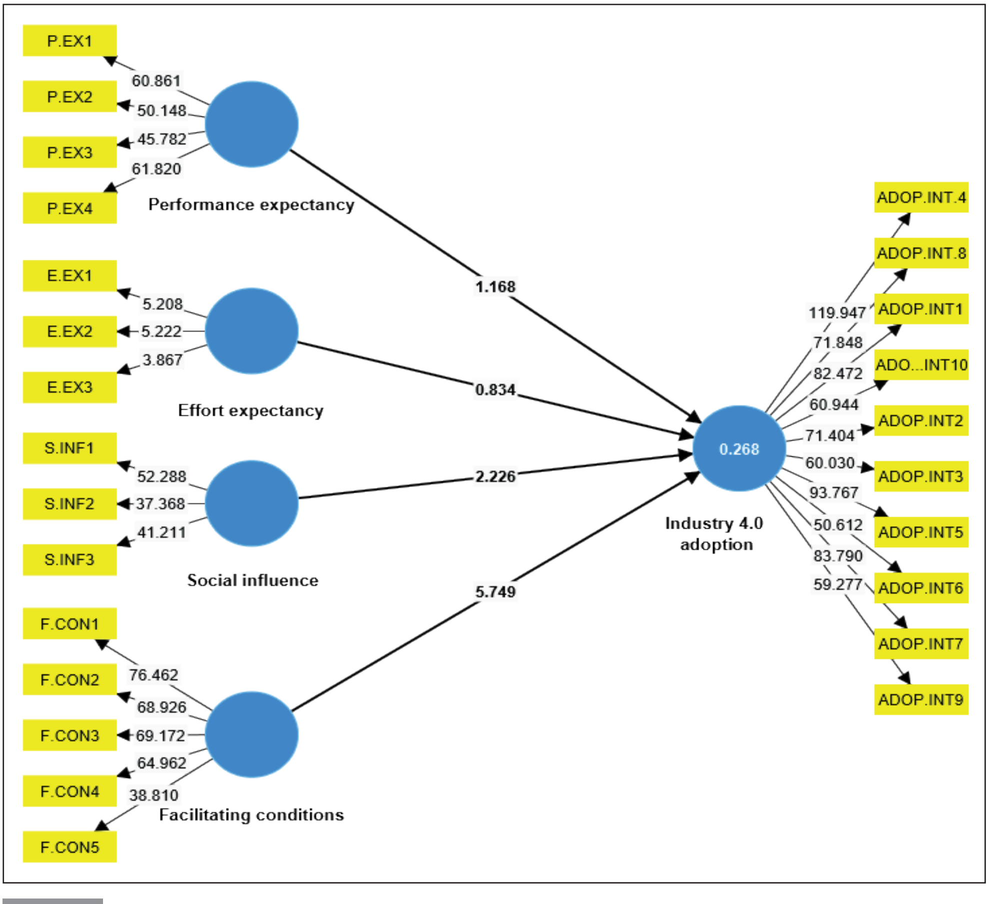

Fig. 2: Structural model diagram 1

Source: own

1981). The results suggested that the study's constructs had sufficient discriminant validity as the square root values of AVE were greater than the inter-construct correlations, as shown in Tab. 5.

After confirming the accuracy of the measurement model, as stated by Hair et al. (2019), the structural model is then evaluated to test the hypotheses proposed in the theory. In this particular study, the structural model was estimated using a bootstrapping method with a subsample of 1,000, as indicated by Ringle et al. (2015). The model explained a 34.2% variation in I4.0 adoption as indicated by the value of *r*-square as shown in Fig. 2.

The fitness of the model was evaluated using SRMR (0.032) and NFI (0.861) values, and it was found that the SRMR value was less than 0.09, and the NFI value was close *t* 0.90, which suggests that the model's fitness was adequate according to Byrne's (2013) standards. Fig. 3 shows structural model with the two moderator variables to test the hypotheses proposed in the extended UTAUT model.

According to Byrne (2013), a *t*-value in a two-tailed test is considered statistically significant if it falls outside the range of −1.96 to +1.96, and if the *p*-value is less than 0.05. Tab. 6 presents the results of a structural model test, which includes path coefficients (β), *t* statistics, and *p*-values. The direct effects of the model indicate that the two hypotheses were significant at a *p*-value less than 0.05. This means that SI and FC significantly influenced I4.0 adoption. Therefore, hypotheses *H3*, *H4*, *H5c*, and *H6c* were supported and significant, while other hypotheses were not supported and were insignificant.

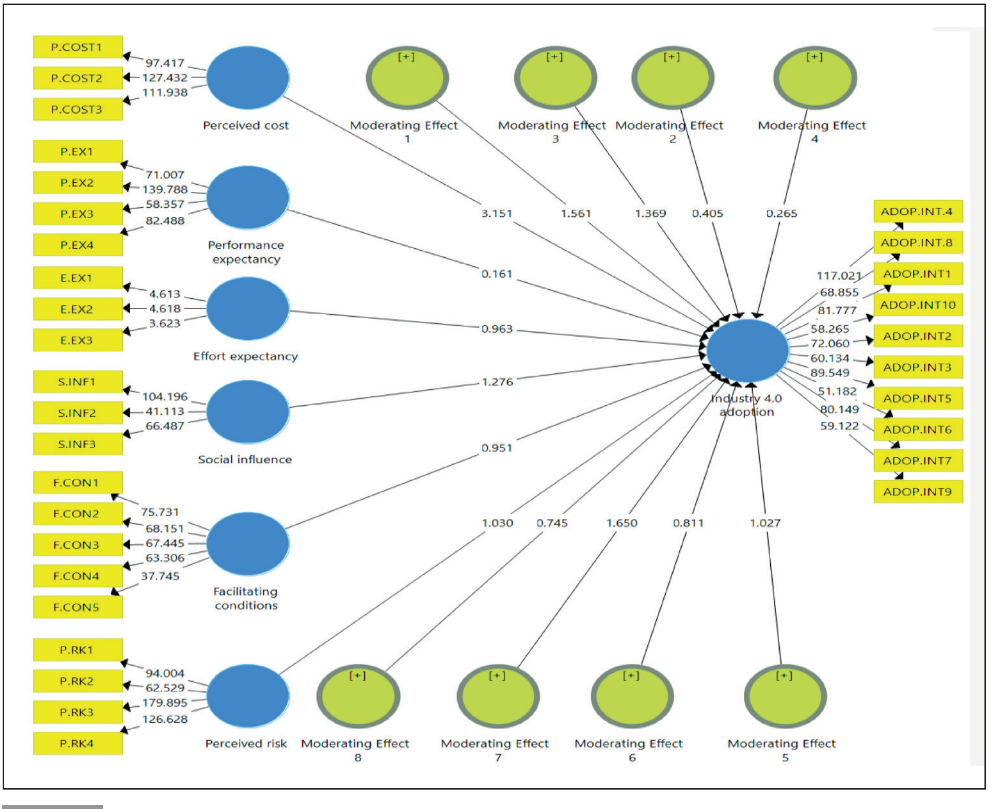

Fig. 3: **Structural model diagram 2**

Source: own

3.2 Discussion

The purpose of this study was to investigate the adoption of I4.0 technology by manufacturing firms, specifically in relation to supply chain operations. The study employed an extended UTAUT framework to analyze the factors influencing the adoption process. In recent years, a number of studies have endeavored to establish a connection between I4.0 technology and various aspects of manufacturing, supply chain management, and related domains (Khin & Kee, 2022). The study focused on the development of a model based on UTAUT, while also examining the moderating effects of PR and cost. The findings were consistent with certain previous studies, although there were discrepancies observed in certain outcomes.

Initially, it should be noted that despite the existence of certain studies that have observed a potential relationship between PE and the triggering or downturn of I4.0 technology (Catherine et al., 2017; Zeqiri et al., 2021), the evidence suggests that PE alone is not sufficient to elicit such effects. The degree to which employees express a desire to embrace a particular technology is significantly impacted by their perception of the technology's capability to effectively perform and improve overall performance. This phenomenon is commonly referred to as PE. The concept of I4.0 promotes the adoption of information and communication technology (ICT) to drive process innovation, enabling the integration of production processes across the value chain, value network, and product lifecycle. Additionally, it emphasizes product innovation through the utilization of intelligent sensor and actor systems, which facilitate context-sensitive manufacturing processes (Prause, 2019). Therefore, the concept of PE extends beyond the boundaries of the actual performance map, resulting in a noticeable gap within the sector.

Furthermore, it is interesting to note that the impact of EE on I4.0 adoption was found to be insignificant, similar to the effect of PE. This lack of influence can be attributed to various potential factors. According to Kang (2014), there is a consumer preference for technology that is both efficient and user-friendly, and the likelihood of its adoption increases when these two criteria are fulfilled. The adoption

Tab. 6: Results of the structural model

	Beta	*t*-statistics	*p*-values	Results
Paths				
PE → I4.0 adoption	0.070	1.168	0.243	Rejected
EE → I4.0 adoption	0.055	0.834	0.404	Rejected
SI → I4.0 adoption	0.141	2.226	0.026	Supported
FC → I4.0 adoption	0.427	5.749	0.000	Supported
Moderating effects of PC and PR				
PE → PC → I4.0 adoption	−0.136	1.561	0.119	Rejected
EE → PC → I4.0 adoption	0.028	0.405	0.685	Rejected
SI → PC → I4.0 adoption	−0.068	1.369	0.001	Supported
FC → PC → I4.0 adoption	0.022	0.265	0.791	Rejected
PE → PR → I4.0 adoption	−0.059	1.027	0.305	Rejected
EE → PR → I4.0 adoption	0.066	0.811	0.418	Rejected
SI → PR → I4.0 adoption	0.070	1.650	0.009	Supported
FC → PR → I4.0 adoption	−0.048	0.745	0.457	Rejected

Source: own

of I4.0 in this particular scenario was a multifaceted concept that was developed by professionals in the fields of software engineering and information technology. Despite its considerable impact on financial activities, consumers were not yet actively embracing this technological advancement. Notably, various scholars have conducted extensive research and have reported noteworthy findings on this subject (Catherine et al., 2017).

In addition, it is worth noting that FC have been identified as statistically significant factors influencing the adoption of I4.0 technology, as supported by recent scholarly publications (Kumar et al., 2022; Wang et al., 2017; Zeqiri et al., 2021). The factors that are perceived to either facilitate or hinder an individual's evaluation of the simplicity or complexity of an activity are referred to as environmental facilitators or obstacles (Teo, 2010). In the realm of technology adoption, there exists a set of FC that can be categorized as either internal or external to organizations. Internally, these conditions encompass factors such as technological expertise, a skilled workforce, and adequate infrastructure. Externally, FC include governmental support in the form of financial resources, training opportunities, and technological guidance. According to Wang et al. (2017), favorable conditions serve as a catalyst for individuals to engage in the exploration of novel technologies. These conditions are perceived as positive signals that promote the utilization of such technologies, facilitating early adoption by consumers and mitigating potential challenges associated with their implementation. Individuals who encounter difficulties in utilizing technology may experience a heightened sense of ease if they receive sufficient assistance. According to Veile et al. (2020), it is crucial to consider financial resources, personnel skills, education, and training assistance as significant factors in the context of I4.0.

In addition, it is interesting to note that the SI factor has a significant and positive impact on the adoption of I4.0 technology. The aforementioned findings align with the research conducted by Mustaqim et al. (2018), and Ronaghi and Forouharfar (2020). Based on scholarly investigations, it has been observed that SI, encompassing the influence exerted by friends, family, coworkers, and peers, significantly contributes to the formation of behavioral intentions in individuals (Ab Jalil et al., 2022; Shen et al., 2019). Individuals hailing from collectivist societies, such as those in Jordan, tend to place greater reliance on subjective evaluations of innovation, which are conveyed by individuals who share similar perspectives and have already embraced the innovation. In contrast, individuals from individualistic cultures prioritize more direct and formal sources of knowledge (Ab Jalil et al., 2022).

The present study investigated the moderating influence of PR and PC on the relationship between UTAUT theory and I4.0 adoption. However, neither PR nor PC demonstrated any significant effects, with the exception of one factor: SI. Several plausible and pragmatic reasons were presented for this outcome. The findings support the assertions made by Veile et al. (2020) that the key resources required for the successful implementation of I4.0 are skilled employees, qualified personnel with a comprehensive understanding of I4.0, and adequate financial resources. The significance of lower PE was found to be critical in effectively implementing technology-based programs. Consequently, the relationship between PE and the adoption of I4.0 was weak and insignificant when considering PC and risk factors within the UTAUT model. Moreover, the adoption of I4.0 technology is not burdened by concerns regarding PC and PR, as it is already a substantial investment and digitalization is already prevalent in the industry. Consequently, there is a significant likelihood of transitioning from a traditional system to a digital-based working environment (Hewavitharana et al., 2021).

According to Schmidthuber et al. (2020), an additional moderator was observed to incur the financial burden of utilizing technology, encompassing costs related to transactions, equipment, application downloads, and access. The notion that the PC of technological innovation can influence its adoption has garnered support from numerous researchers (Shamout et al., 2022; Yadav et al., 2016). The PC does not exhibit a significant moderation effect, with the exception of the SI factor. This implies that the extent to which users perceive the importance of utilizing technology or innovation can vary, influenced by their peers in the industry. As a result, the consideration of cost becomes a significant factor due to the imperative requirement of implementing these technologies, which is influenced by companies operating within the market. Hence, the primary objective of implementing intelligent machines and autonomous equipment has been to minimize expenses and enhance operational effectiveness. Finally, Hsu et al. (2014) suggested that a significant number of the enterprises involved in the study lack essential technical and proactive skills, specifically in the areas of engineering, information technology, digital capabilities, and the skills necessary for I4.0. This finding suggests that the influence of social factors on the adoption of I4.0 is significantly influenced by the perceived level of risk. This implies that companies will face risks when their peers and senior management contemplate the implementation of I4.0, as it will emerge as a distinguishing factor in the market.

3.3 Managerial and theoretical implications

Our study contributes to the practical and theoretical understanding of the factors that impact the behavior and adoption of new technologies within the context of I4.0. Specifically, we focus on the moderating role of perceived cost and risk in relation to the UTAUT model. This research enhances the existing knowledge base and provides valuable insights. The purpose of this study was to highlight the importance of managerial bodies embracing I4.0 technology. Several implications and insights were observed.

To begin with, the integration of disruptive technologies within the context of I4.0 has the potential to enhance firms' competitiveness by enabling them to adopt cost-effective and efficient manufacturing solutions (Fülöp et al., 2022; Tortorella & Fettermann, 2018). The transition associated with I4.0 occurs within industrial sectors and exerts influence on the broader global context by virtue of the continuous advancement of digital technologies that augment supply chain operations (Fülöp et al., 2022; Jum'a et al., 2022). The implementation of novel business models and services within the context of I4.0 has the potential to enhance overall performance. Manufacturing enterprises ought to give careful consideration to the implementation and utilization of various facets of I4.0. These include digital automation without sensors, digital automation with sensors, remote production monitoring and control using tools like manufacturing operational systems, corrective control systems, and data capture. Additionally, integrated engineering solutions for new product creation and production, additive manufacturing, swift prototyping or three-dimensional printing, modeling and analysis of visual representations (such as computational fluid dynamics) for design and other purposes, utilization of cloud services for products, and integration of digital services into products commonly known as the IoT should be taken into account.

Furthermore, the adoption of this technology can be facilitated by factors such as FC and SI, which can provide support and encouragement to managers. The FC that contribute to the digitalization of the construction industry and subsequently enhance production levels include the proficiency in hardware and software matters, the level of actual knowledge and skills, and the support from top-level management. However, the implementation of I4.0 poses novel challenges for enterprises, especially those operating in developing countries. The present study offers empirical support for the decision-making processes of managers. Specifically, it suggests that managers should give priority to the adoption of product/service-oriented technologies such as cloud services, IoT, or big data analysis, if they have already implemented multiple supply chain management (SCM) practices related to flow. This prioritization is expected to contribute to the attainment of high levels of operational performance (Tortorella & Fettermann, 2018). In the contemporary business landscape, organizations are presented with the opportunity to effectively amalgamate the benefits of real-time integration with the practice of minimizing waste across the entirety of their value chain. In addition, it is imperative to acknowledge the potential challenges associated with the perceived financial implications and uncertainties surrounding the adoption of I4.0. Nevertheless, it is crucial to avoid excessive emphasis on these two factors and instead conduct a thorough evaluation, particularly considering the potential benefits that firms may derive.

In conclusion, it would be prudent for manufacturers to consider the adoption of I4.0 in situations where they face heightened competitive pressures or encounter challenges such as limited performance knowledge, inadequate training capabilities, or a shortage of skilled personnel. Alternatively, failure to adopt I4.0 technologies may result in these enterprises lagging behind their competitors who strategically invest in such advancements to achieve a competitive advantage (Senna et al., 2022).

Therefore, our research provides valuable insights for managers and practitioners regarding the key factors to consider when implementing I4.0 technology in the manufacturing sector in order to enhance operational performance.

In addition to the managerial or practical implications discussed above, this study also highlights several theoretical implications. Scholars exhibit a significant level of interest in I4.0 and the various factors encompassed within the UTAUT that are anticipated to influence its adoption. The existing body of research examining the variables associated with the implementation of I4.0 (Khin & Kee, 2022; Narula et al., 2020) is predominantly characterized by a deficiency in comprehensive investigation and empirical validation. This study presents an empirical investigation of the I4.0 factors within the UTAUT model. The aim is to ascertain and authenticate the factors influencing the implementation of I4.0, as perceived by managers in the manufacturing industry. Consequently, we proposed an expanded UTAUT model that incorporates the factors of perceived risk and cost. The proposed model holds significant value as it addresses a research gap in the literature. While there have been numerous studies examining the acceptability of technology in manufacturing industries, our search yielded limited findings pertaining to the specific model under development. The successful competition of businesses is facilitated by the socio-technical organizational changes that are linked to technology-based environmental practices and behaviors (Kumar et al., 2022).

Conclusions

This study employed the UTAUT framework to examine the adoption of I4.0 technology. Two moderators, namely perceived risk and cost, were incorporated into the analysis. The study examined four factors within the model: perceived expectancy, EE, FC, and SI. These factors were treated as endogenous variables. Additionally, two moderators were incorporated to explore their relationship with the adoption of I4.0. Among the twelve hypotheses examined, a total of four hypotheses demonstrated statistical significance. The adoption of I4.0 was significantly and positively influenced by FC and SI. Furthermore, it was found that the perceived cost and risk variables exerted a significant impact on the relationship between SI and the adoption of I4.0. Hence, numerous scholarly discussions have highlighted the potential impact of these factors on the advancement or trajectory of the arising industrial revolution. This effectively communicates to regulatory bodies and policymakers the imperative to develop strategies and mechanisms that incentivize firms to embrace I4.0.

This study is subject to a small number of limitations. The present study employed a non-probability sampling technique to gather data from manufacturing companies in Jordan. It is important to note that this sampling method may restrict the generalizability of the findings. Moreover, the developed model can be effectively applied to both developing and developed countries. However, the interpretation of the results should be conducted within the specific context of developing countries, and it is crucial to exercise caution when interpreting the results within this context of developing countries. Moreover, this study holds promising prospects for scholars across various paradigms in the future. The study primarily focuses on manufacturing firms in Jordan, but it has the potential to be applied in various contexts by replicating the research in different sectors or countries. Additionally, it is worth noting that the data in this study are cross-sectional in nature. Future research endeavors may consider incorporating longitudinal studies, which would allow for a more comprehensive and extended analysis. In addition, researchers may explore alternative methodologies to further investigate the topic at hand (Kumar Bhardwaj et al., 2021; Tortorella & Fettermann, 2018). Furthermore, conducting cross-country studies could yield more comprehensive and insightful findings, particularly when incorporating developing as well as developed countries within the sample.

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Tab. 1: Constructs and measurement items

Constructs	Measurement items
PE	1. I would find the Industry 4.0 technologies useful in my job. 2. Using the Industry 4.0 technologies enables me to accomplish tasks more quickly. 3. Using the Industry 4.0 technologies increases my productivity. 4. If I use the Industry 4.0 technologies. I will increase my chances of getting a raise.
EE	1. My interaction with the Industry 4.0 technologies would be clear and understandable. 2. It would be easy for me to become skillful at using the Industry 4.0 technologies. 3. I would find the Industry 4.0 technologies easy to use. 4. Learning to operate the Industry 4.0 technologies is easy for me.
SI	1. People who influence my behavior think that I should use the Industry 4.0 technologies. 2. People who are important to me think that I should use the Industry 4.0 technologies. 3. The senior administration has been helpful in the use of the Industry 4.0 technologies.
FC	1. I have the resource necessary to use the Industry 4.0 technologies. 2. I have knowledge necessary to use the Industry 4.0 technologies. 3. The Industry 4.0 technologies are compatible with other systems I use. 4. I think that using Industry 4.0 technologies fits well with the way I like to work. 5. I have knowledge sources (e.g., books, documents, consultants) help me learn about Industry 4.0 technologies.
PC	1. Adopting the Industry 4.0 technologies will increase hardware equipment cost. 2. Adopting the Industry 4.0 technologies will increase operating cost. 3. Adopting the Industry 4.0 technologies will increase maintenance cost.
PR	1. It is probable that Industry 4.0 technologies would not be worth its cost. 2. It is probable that Industry 4.0 technologies would frustrate me because of its poor performance. 3. Comparing with other technologies, using Industry 4.0 technologies has more uncertainties. 4. It is uncertain whether Industry 4.0 technologies would be as effective as I think.
Industry 4.0 adoption	1. Digital automation without sensors. 2. Digital automation with process control sensors. 3. Remote monitoring and control of production through systems such as manufacturing execution system and supervisory control and data acquisition. 4. Digital automation with sensors for product and operating conditions identification, flexible lines. 5. Integrated engineering systems for product development and product manufacturing. 6. Additive manufacturing, rapid prototyping or 3D printing. 7. Simulations/analysis of visual models (finite elements, computational fluid dynamics, etc.) for design and commissioning. 8. Collection, processing and analysis of large quantities of data (big data). 9. Use of cloud services associated with the product. 10. Incorporation of digital services into products (internet of things or product service systems).

Source: own