Risk assessment of business models driven by Industry 4.0

Kristina Kovaitė* and Jelena Stankevičienė

Faculty of Business Management,
Department of Financial Engineering,
Vilnius Gediminas Technical University,
Saulėtekio 11, LT-10223, Vilnius, Lithuania
ORCID: 0000-0003-4362-8001
ORCID: 0000-0002-5600-5842
Email: kristina.kovaite@vgtu.lt
Email: jelena.stankeviciene@vgtu.lt
*Corresponding author

Abstract: Industry 4.0 changes business models and in so doing presents new risks that need to be addressed. Research presented in this paper developed a risk assessment for business model digitisation (RADi) matrix which consists of technical, competences, employee and customer consent, data security, and financial risk. The expert evaluation uses the FARE method as a multi-criteria decision support approach. The results determine which parts of a business model driven by the Industry 4.0 are most affected by different risks. The results indicate the greatest impact is on customer channels, key resources, revenue stream, and customer segments, whilst key partners are the least impacted. Our research demonstrates that the RADi model can be used by firms to identify and plan for critical risks as well as to implement the digitisation of business models. Policymakers will find the RADi approach useful to anticipate risks and prioritise public support and regional development.

Keywords: Industry 4.0, digitalisation, risk assessment, business model, multi-criteria methods.

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Biographical notes: Kristina Kovaitė is researching the economy of BMs driven by Industry 4.0 and their economic impact on business, society and environment as her topic for PhD studies at Vilnius Gediminas Technical University, Lithuania. She lectures on digital economy and entrepreneurship, project and risk management. She undertook internships in Ecole Polytechnique Federale de Lausanne, University College London, Universidad Politecnica de Madrid, etc. She also has been involved in the research on social entrepreneurship, digital transformations, co-creation networks. She has presented in the international conferences. She is active in international research project development and professional networks.

Jelena Stankevičienė, Dr., Professor, Dean of the Faculty of Business Management at Vilnius Gediminas Technical University, Lithuania. She holds an excellent record as an entrepreneurship, economics and finance expert.

Her main research topics include financial management for value creation and value engineering. She is the Editor-in-Chief of periodical peer-reviewed scientific journal abstracted by international databases and a chairman and a member of the scientific committee of international conferences. She is the author of more than 50 scientific publications indexed in the Web of Science, Scopus, Ebsco, Emerald and other databases.

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1 Introduction

Industry 4.0 is a novel, fast-developing phenomenon that is rapidly changing the way businesses capture the value, and in moving us from the Third Industrial Revolution represents a paradigm shift. The digital technologies driving Industry 4.0 are being applied at such a rate as to produce the unpredictable result which goes far beyond traditional risks associated with changes in business models. The digital impact encompasses data value, cybersecurity, function criticality and failure scalability, ownership misuse, the cost of error, and more besides.

Industry 4.0 demonstrates the fusion between physical and digital processes (Kagermann et al., 2013; Schwab et al., 2018) and covers usage of cyber-physical systems (CPS) as well as a variety of technological drivers. These include the internet of things (IoT), big data, artificial intelligence, and the decentralisation of communication between people and machines, and. Recent research by Li (2018), Roblek et al. (2016) and Xu et al. (2018), also explores related areas, including the role of collaboration between the 'industrial and societal impact' and the strategic advantages of collaborative scientific activities; and research from different business factors such as R&D, outsourcing, a collaboration between industries and universities, and patents, and joint venture with the research institutions.

The risks inherent in Industry 4.0 should sound a note of caution to all stakeholders involved in the decision-making and obliged them to carefully consider every facet of risk assessment. Yet, predicting the outcome of digitisation is problematic on account of a lack of historical experience in dealing with the same. Whilst there is published research on risk assessment, rarely does one read about the methods for testing sustainability and robustness of the changes in the business models that have emerged due to Industry 4.0.

Research questions:

RQ1 – Which business model canvas block is more exposed to specific risks when a business model is transformed due to Industry 4.0 drivers?

RQ2 – What are the main risk areas for enterprises when business models are transformed due to Industry 4.0 drivers?

The research aims to identify the most significant risks to the business model when digitisation in the company is implemented.

This paper maps areas of risk that present when business models are obliged to change due to the impact of Industry 4.0. In highlighting the level of risks it offers a means to assess risk in the planning and implementation of business model digitisation. Further, the research may be applied to downstream economic or management decisions.

Accordingly, the paper is organised into seven chapters. Section 1 introduces the context and the problem of the research, the research questions, and the structure of the paper. Section 2 reviews the scientific literature on risk, Industry 4.0 and business models and its relationship. Section 3 presents the research methodology and the design of the 6-step risk assessment model. Section 4 presents the results of the study. Section 5 introduces the research discussion and conclusions. Section 6 presents the limitations, and guidelines for further research. Section 7 discusses recommendations for use at the political and business levels.

2 Literature review

Three main areas were examined in the literature review: Industry 4.0 as a phenomenon in research and business; business models digitised by Industry 4.0 drivers; and related risk assessment and their combination. The topics reviewed bring research to the model of risk assessment which map areas of risks when a business model is transformed due to Industry 4.0 drivers. A short review of each as follows.

2.1 Industry 4.0

The phenomenon of Industry 4.0 was first mentioned in the literature in 2011 by German scholars and is now mainstream research in global policy and business. In emphasising the fusion between physical and digital worlds when vertical and horizontal interconnection using CPS, Industry 4.0 differs markedly from the Third Industrial Revolution. CPS is presented as a key technological drive which using sensors and microprocessors allow "autonomously exchange information, trigger actions and control each other independently" as Kagermann et al. (2013), say in real-time from anywhere. Schwab et al. (2018) assert that it encompasses technologies such as the IoT (Nurse et al., 2017), Big data (Niesen et al., 2016), cloud computing, robotics, artificial intelligence, exploring social issues (Roblek et al., 2016) related to the decentralisation of communication between people and machines. Scholars like Stremousova and Buchinskaia (2019) following Schwab et al. (2018) also offer a wider understanding of Industry 4.0 as an "integral model that is based on the convergence of nanotechnology, biomedicine, information technology and cognitive science". The digitisation of production is only one of the critical elements of the new model.

Different parts of business models are also being researched, including the supply chain (Revilla and Saenz, 2017; Chopra and S.Sodhi, 2014), value creation and capture or revenue stream (Ibarra et al., 2018; Müller et al., 2018; Orellano et al., 2017). The debate on servitization for manufacturing companies is often observed in the researches and explores the focus shift from product to service (PSS) which is also facilitated by IoT and real-time interconnectivity as Frank et al. (2019), Kohtamäki et al. (2019) and Müller et al. (2020) argue.

The benefits of Industry 4.0 are widely discussed (Zheng et al., 2015) from different perspectives, and the risks and uncertainties from the transformation are mentioned (Stremousova and Buchinskaia, 2019). Industry 4.0 describes its risks that all the stakeholders involved in the decision-making should be cautious. The risks involved in deciding on alternatives to the business models promoted by Industry 4.0 are rarely studied.

2.2 Business models

Researchers, Chesbrough (2007), Gordijn et al. (2005), Teece (2017), Zott and Amit (2010, 2013), Zott et al. (2010, 2011) regard the business model as a business logical sequence that involves a set of instruments, more or less separate relationships of instruments between suppliers and customers, and the creation and capture of enterprise value. It is a description of customer value, a way of communicating, and a "partner network that creates, sells, and delivers this value to generate profitable revenue streams" says (Osterwalder et al., 2005).

Amit and Zott (2012), Arnold et al. (2017) and Remane et al. (2017) analyse the taxonomies of business models and introduce different types of business models influenced by digitalisation, e.g., 3 e-value, novelty and efficiency-oriented, etc. Several researchers suggest we should change business models from product-based to service-based (PSS) and discuss data-based and cloud models. Gassmann et al. (2013) identified 22 out of 55 business models that were influenced by digitalisation. As noted in the literature review, most researchers use the Osterwalder (Osterwalder and Pigneur, 2010; Osterwalder et al., 2005) business model canvas as the basis for their research. Thus, in this paper, we refer to Osterwalder's (2004) business model canvas.

2.3 Risk and risk assessment

There is no shortage of research into the many aspects of risk management, simply because the field is extremely wide and each solution in business is to a greater or lesser extent related to uncertainty about future results.

Risk is generally understood to mean the likelihood of a transition from an expected injury, loss, or other negative consequences that can be prevented by preventive action. Risk often relates to a degree of uncertainty that goes hand in hand with innovation and changes as refer Dellermann et al. (2017). The definitions accepted by researchers for terminology in this field are closely aligned.

Reim et al. (2016) define risk "as a combination of the likelihood of loss and the impact of loss on events".

$$R = P_n * I_n \tag{1}$$

(according to Reim et al. (2016))

where

R – risk

P – the probability of loss of n events

I – the impact of a loss of *n* events for the results of the enterprise

n – number of different events, risks, losses, or impacts.

The next step risks are systemised and grouped to assess (Haaker et al., 2017) the significance of the risk for the result. One tool is a heat map which allows us to map risks comparing their impact and possibility to appear and prioritise them accordingly. The risk evaluation methods are sued later and management plan produced.

2.4 Risk assessment in business models driven by Industry 4.0

A review of the literature for this paper covered three main areas: Industry 4.0, business models digitalised due to Industry 4.0 drivers and risk assessment in this area and their combination.

Table 1 is an overview of types of risks related to Industry 4.0 is described.

Table 1 Overview of types of risks related to Industry 4.0 (created by authors, 2019)

Researcher	*Types of risks proposed*
Reim et al. (2016)	• Behavioural • Technical • Competence risks
Tupa et al. (2017)	Scarcity of human resource: new competency needed changes are fast and development
Tupa et al. (2017)	Information security, data loss, loss of integrity of information, errors of data processing, risk of cyber-attacks.
Reim et al. (2016)	The behaviour of customers aboutcontract signing and the consequences
Birkel et al. (2019)	Economic, ecological, social, technical and IT, legal and political dimensions. All dimensions are a mixture of micro and macro-level risks. The focus is on the sustainability issues of Industry 4.0 driven changes in the enterprise

Table 2 expands our understanding of the risks of business models driven by Industry 4.0. The findings are based on the literature review conducted by the authors and provide a basis for the risk assessment model for part/all of the business model for digitisation processes.

Different papers identify risk factors, which can be expressed as five categories: technical, competence, behavioural, data security and financial. The papers explain the risks differently and show their variety. All authors agree that internet technologies are rapidly changing the market and that the business model is too important to be left to random, unplanned decisions.

2.5 Model of risk assessment in business models driven by Industry 4.0

Further research identified models of risk assessment analysed in the literature. Table 3 describes these findings.

Table 2 Findings of the business models types of risks (created by authors, 2019)

Types of risks	*Authors*	*Findings*
Technical	Reim et al. (2016)	Businesses must acquire many new opportunities and resources to offer product and service solutions (PSS)
	Nurse et al. (2017)	The Internet of Things is dynamic and systems must adapt rapidly. Real-time risk identification and assessment are realistic due to technical improvements
	Orellano et al. (2017)	Data based solutions as value creation and proposition
	Yigitbasioglu (2015)	The cloud computing delivery model enables technology transfer and outsource service and demonstrates flexibility, deployment speed, and access to quality software. A cost-effective business model with a pay-per-use revenue stream
	Hassan (2017)	IT resources have a significant influence on the uptake in cloud computing
	Birkel et al. (2019)	Technical and IT are together
	Baecke and Bocca (2017)	The Internet of Things allows businesses to collect and process a greater volume of sensor-generated data.
Competence	Tupa et al. (2017)	Lack of human resource: new competence needed
	Yigitbasioglu (2015)	There is evidence that concerns the perceived risks of cloud computing… the lack of understanding to inhibit its adoption
	Nurse et al. (2017)	Processes by which devices are connected and information is transmitted without human intervention; new devices are very quickly integrated
		Rapid change requires more system thinking skills in answering how to do, rather than knowing what to do; rapid change and lack of knowledge can lead to important risks being missed
	Lee and Lee (2015)	Managing big industrial data ... covers all necessary steps from acquiring data, processing the information, presenting to the users and supporting decision making
	Birkel et al. (2019)	Organisation transformation, reduction of process steps, lacking understanding of data-driven business models, loss of core competencies in the enterprise and the structure of employees
	Chopra and S.Sodhi (2014)	Decentralisation of processes (e.g., building resilience by segmenting or regionalising supply chains, avoiding centralisation of resources thus limiting losses in performance), in the long run overinvesting in protection,could be more profitable than not investing enough
Behavioural	Reim et al. (2016)	Behavioural risks include less cautious behaviour when using a product that a customer does not own (e.g., virtual solutions, extensive usage of the product or service such as online booking, and possibilities for uncontrolled feedback opportunities on the social media)
		Affects customer relationships, value proposition, and cost structure by presenting an ownership vs. access-oriented business model and concept of 'Internet for everything' and issues related to purchasing

Table 2 Findings of the business models types of risks (created by authors, 2019) (continued)

Types of risks	*Authors*	*Findings*
Behavioural	Birkel et al. (2019)	Customer demands and acceptance. Power shifts between suppliers and partners. Internal communication in the enterprise between leaders and employees, the importance of awareness and information exchange
	Jacobsson et al. (2016)	High-classified risk is related to either the human factor and the competencies or software components of the system
Data security	Tupa et al. (2017)	Many common risk factors in manufacturing are related to information security, data loss, information integrity loss, data processing errors, risk of cyberattacks
	Yigitbasioglu (2015)	Concerns about privacy and confidentiality of data, as well as the lack of understanding of the technology, all of which impede the adoption of cloud computing services
	Müller et al. (2018)	CPS brings a much higher degree of transparency and efficiency and therefore raises new aspects in the debate of cybersecurity
	Birkel et al. (2019)	Integrated into technical risks. Covers cyberattacks, data possession, security and handling
	Nurse et al. (2017)	Possibility for cyber attacks, the security of data and information
Financial	Zhou et al. (2017)	Also ignored are 'organisational factors' in implementation due to the long-term nature of investment and the high risks involved
	Yigitbasioglu (2015)	These involve the hidden costs of contracting and executing contracts
		The impact on SMEs is greater, as they potentially do not have access to significant funds to invest in cutting-edge IT software and hardware
	Birkel et al. (2019)	Time and manner of investment, risk of false investment
	Hassan (2017)	IT requires a big investment and has a major impact

Table 3 Different models of risk assessment concerning the pillars of Industry 4.0 and the business model canvas (developed by authors, 2019)

Author, year, source	*Main findings*	*Relation to Industry 4.0*	*Relation to Business model canvas blocks (according to A. Osterwalder)*
Revilla and Saenz (2017)	Four-dimensional model and its relationship to the frequency of disruption of the supply chain	Internet of things	Key activities: supply chain
Schlüter et al. (2017)	Model using Monte Carlo and other risk assessment methods is developed	Internet of things	Key activities: supply chain
Tupa et al. (2017)	Model linking risks with KPIs and KPIs presented	Internet of things	Key activities: manufacturing
Reim et al. (2016)	Types of risks discussed: delivery competence, technical and behavioural risks. Risks management framework integrates risk categories, decision criteria, and risk responses into an integrated decision framework of PSS risk management	Internet of things/PSS operation	Value proposition: value delivery and capture

Table 3 Different models of risk assessment concerning the pillars of Industry 4.0 and the business model canvas (developed by authors, 2019) (continued)

Author, year, source	*Main findings*	*Relation to Industry 4.0*	*Relation to Business model canvas blocks (according to A. Osterwalder)*
Zheng et al. (2015)	A specialised IPS2 risk management supporting software integrated into enterprise information decision systems and have computing abilities for large-scale data	Internet of things	The overall model
Haaker et al. (2017)	Stress testing is a practical approach to evaluate the robustness of business model components. The method builds upon concepts from business model innovation and scenario planning. The heat map allows testing the robustness of business models against future uncertainties	Industry 4.0	The overall model

All of the papers include technological and methodological approaches to risk assessment. Some papers analyse challenges related to software implementation into the overall enterprise decision system. Others research the use of different risk assessment methods such as stress testing, scenario planning or heat map, and can be used separately in addition to each other.

Following the analysis of the literature, the model of five areas of risk was expanded to six areas, more explained in the Section 3. Risk assessment for business model digitisation (RADi) model specifying six dimensions of risks was developed and are presented in this paper. RADi must be used to plan and implement Industry 4.0 pillars into operating or emerging business models.

Here are the dimensions of the risks in the RADi model described:

Technical risks refer to infrastructure and software necessary to offer product and service solutions, use the IoT, big data, data-based solutions, cloud computing, artificial intelligence in value creation and capture, and also, improvement of processes due to real-time process monitoring and risk identification.

Competence risks refer to the organisational structure, responsibilities, procedures and qualifications of personnel as well as knowledgebase and know-how in the company.

Behavioural risks in RADi model are split into two dimensions: behavioural risks related to acceptance by partners and customers and risks related to acceptance by staff.

Acceptance by partners and customers risks refer to change in decision-making behaviour such as being less cautious when using a product or service which do not owe, impulse purchasing and return, uncontrolled feedback on the social media, habits of use of services.

Acceptance by staff risks refers to the habits of organising work and customer service processes, organisational culture, perception and social skills in the company, human factor of software use.

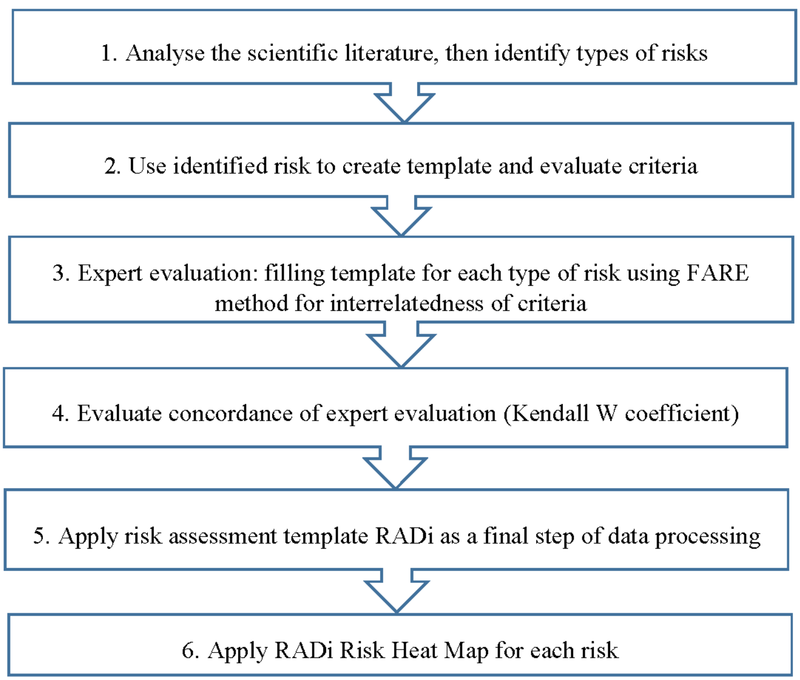
Data security risks refer to possible data loss, information integrity loss, data processing errors, risk of cyberattacks, privacy and confidentiality of data, as well as possible misinterpretation of the cyberattacks and fraud.

Financial risks refer to the fact that digital transformations require a big investment, lack of history of financial impact, long term and short term investment decisions, cash flow management are different from the usual.

3 Research methodology

The study aims to create a model that assesses the impact of a particular risk on the patterns of a business model as determined by Industry 4.0. The research was organised in three stages which then is divided into six step process, explained in Figure 1.

Figure 1 A six step process of risk assessment for RADi (developed by authors, 2019) (see online version for colours)



At the first stage, the scientific literature review was conducted.

Databases and period – The literature search was conducted mainly on Clarivate Analytics for the period, 2014–2019.

Keyword search – The search in the Clarivate Analytics database used the following integrated, complex keywords, e.g., 'risk'; 'digitisation'; 'business model'. These were combined using the Boolean operator AND or OR with the second keyword 'Industry 4.0'.

Some papers address approaches to risk assessment of the overall business model, whereas others address specific elements of the business model, e.g., supply chain, value capture, etc., or separate pillars of Industry 4.0 such as the internet, big data, etc. Only 15 papers were found that cover all aspects during the period from 2014 to 2019.

Inclusion and exclusion criteria – The following criteria were used to search on relevant publications. The full paper was presented in a scientific peer-reviewed journal indexed in Clarivate Analytics which was published between 2014 and 2019. The papers had to cover all three concepts: business models, Industry 4.0 and risk assessment. Empirical research results only in social sciences (without integration with health issues, disaster and environmental issues, computer science, engineering, etc) were included.

Even more, papers are retrieved for this period when terms such as big data, IoT, Cloud, additive manufacturing are used instead of Industry 4.0. This suggests that interest among researchers has increased in the course of the last few years, which further implies an obvious gap in research on risk assessment of business models driven by Industry 4.0.

The second stage was devoted to constructing the risk assessment model. The areas of risks were revised and the area 'behavioural risks' was divided into two: acceptance by staff and acceptance by partners. The division of the area was done following numerous scholars such as Birkel et al. (2019), Vahidi et al. (2018) and ISO 31000 Risk management (Purdy, 2010) who suggest using a twofold approach: inbound and outbound the company, to assess risk, split the process when describing the business model as a value chain and also distinguish internal and external communication (Yigitbasioglu, 2015; Felix et al., 2017) in any changing situation. This way six areas finally were identified and presented to experts to evaluate during the second stage.

The third stage was devoted to test the risk assessment model and identify the most and least affected business model parts when implementing Industry 4.0. FARE (Factor relationship) as a multicriteria decision-making method for expert evaluation was selected.

Method selection. FARE method is based on the interrelationships between all the criteria compared to each other towards the object considered. FARE method is described by Ginevičius (2011) and further explored by Stankevičienė and Vaiciukevičiūtė (2016), Kraujalienė (2019) and other researchers. As "the difference between the weights calculated by FARE and the criteria weights obtained by AHP technique is the smallest compared to other methods" Ginevičius (2011) FARE method is selected as an expert evaluation method.

Determination of the number of experts and expert selection. For the research 10 experts were selected through the purposive sampling. Experts were eligible according to the criteria:

- each expert represents a different economic area
- each has at least 10 years of experience in a management position in the respective industries in Lithuania
- each of them has competencies related to Industry 4.0 issues.

Ten experts were selected according to the requirements of the methodology.

Ethics. Ethical issues are met ensuring anonymous and confidential participation. Experts participated in the research independently. Confidentiality is ensured not only on an individual level but also on the company level as neither personality nor respective industry is revealed in this paper.

Experts should complete a template for each type of risk, calculate the average, and finally include the pooled data in the risk assessment matrix (Table 4).

Table 4 Risk assessment for digitalisation of business models RADi (created by authors, 2019)

Business model canvas blocks	*Technical*	*Competence*	*Acceptance by staff*	*Acceptance by customers and partners*	*Data security and privacy*	*Financial risks*
Key partners						
Key activities						
Key resources						
Value proposition						
Customer relationship						
Customer channels						
Customer segments						
Revenue stream						
Cost structure						

The research design is described below.

1 Analyse scientific literature. Select papers from Clarative Analytics for the period 2014–2019. The six areas of risks for 9 business model canvas blocks were explained and the RADi risk assessment model consisting of a six step process was developed.

2 Develop template.

The number of relationships between criteria should be reasonable and can be calculated when developing an expert evaluation template.

$$R = \frac{m(m-1)}{2} \tag{2}$$

An increase of several relationships *m* when increasing the number of criteria at least by one is observed, e.g., 10 criteria create 45 relationships while nine criteria bring 36 relationships.

3 Experts were introduced with the method of research. The template matrix is presented in Table 4. Each expert received six tables representing each risk in a separate table.

Experts are given instructions and asked to answer which business model canvas block between the two (listed vertically vs. one horizontally) is more exposed to specific risks. The scale for quantifying the relationship between system criteria is 0 to 5, with 0 representing no difference between the two criteria and 5 is a very large difference between the two criteria. The effect on business model canvas of each of identified risk was assessed in a separate comparison.

Experts complete a template for each type of risk answering a question to assess: "which block of business model is more effected by specific risks". Data from the templates are transferred to the final risk assessment matrix RADi calculating the average values (Table 4).

The normalisation of the potential values of the total impact of the criteria to the effect on the test object is calculated:

$$w_i = \frac{P_i^f}{P_S} = \frac{P_1 - ma_{1i} + S(m-1)}{mS(m-1)} \tag{3}$$

The total potential required to determine the criteria weights, calculated from the data collected by the expert judgement from the summary of the criteria potential equilibrium matrix:

$$P_i = P_1 - m{*}a_{1i} \tag{4}$$

where P_i is the total impact of the ith criterion.

The sum of the total impact values (P_i) of the individual system's criteria on the research object is equal to zero:

$$\sum_{i=1}^{m} P_i = \sum_{i=1}^{m} (P_1 - ma_{1i}) = mP_1 - m\sum_{i=1}^{m} a_i = mP_i - mP_1 = 0 \tag{5}$$

P_i is the total impact

m is the number of relationships

a_{1i} is the value of the matrix element of the ith row of the jth column; a_{1j} and a_{1i} are the first row elements.

When creating a template, the same criteria should be horizontal and vertical.

$$w_i = \frac{P_i^f}{P_S} = \frac{P_1 - ma_{1i} + S(m-1)}{mS(m-1)} \tag{6}$$

4 To evaluate the compatibility of experts' valuations Kendall's coefficient (Kendall, 1955; Podvezko, 2005) is used. The Kendall W coefficient values vary from 0 to 1. A value close to 1indicates that the experts' valuations are unanimous. The Kendall W concordance coefficient being close to 0 indicates the considerable variation in expert judgement.

The Kendall W coefficient calculation is computed for each rated item.

The Kendall coefficient is calculated using the following formula:

$$W = \frac{12S}{r^2 n(n^2 - 1) - r\sum_{j=1}^{r} T_j} \tag{7}$$

r – number of experts

n – number of objects to evaluate

$$S = \sum_{i=1}^{m} \left(e_i - \overline{e} \right) \tag{8}$$

S – a sum-of-squares statistic over the row sums of ranks m_i

e_i – sum of ranks

$\overline{e}$ – average of sums of ranks

$$T_j = \sum_{k=1}^{Hj} \left(t_k^3 - t_k \right) \tag{9}$$

T – an indicator of tied ranks of j expert

H – number of ranks of the same value of the j expert

t_k –number of equal tied ranks in each (k) group of ties

$$ChiSq = Wr\left(m - 1 \right) \tag{10}$$

5 Data that is collected after the estimation of the relationship between the criteria using the FARE method are evaluated in the risk assessment model RADi.

6 The risk heat map is developed and presented.

4 Results

After analysing the scientific literature, the risk assessment model was developed. Six areas of risks related to the business model changes due to Industry 4.0 drivers were specified: technical, competence, acceptance by staff, acceptance by clients, data security and financial risks. The empirical research gave implications to the issue: which business model canvas blocks can be more affected by different types of risks during the processes of digitalisation.

The expert evaluation identified *customer channels* as a main criterion and results are presented in Table 5. In the row, "*Relationship between main criterion and other criteria*": blue colour indicates a positive relationship between the main criterion and a specific criterion; red colour indicates a negative relation of the same, and a number means the strength of the relation. A positive relation here means that a specific criterion is seen as less effected by risks than the main criterion. Negative relations here means that a specific criterion is seen as being more affected by risks than the main criterion. In addition to colour, a numeric evaluation is also provided to make it easier to understand.

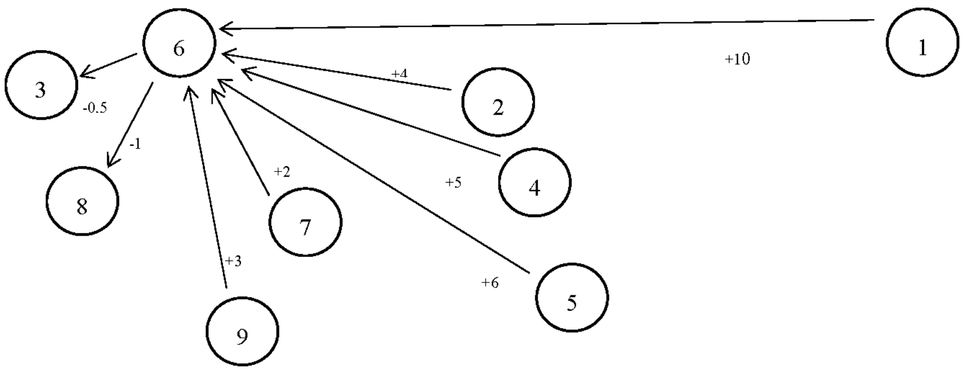
E.g. *Key partners* has the weakest relationship with the main criterion and is least affected, with the valuation 10. *Revenue stream and key resources* – the strongest relationship with the main criterion and is most affected with the valuation –1.

Table 5 The relationship between the main criterion and other criteria and weights (developed by authors, 2019) (see online version for colours)

Criteria	1. Key partners	2. Key activities	3. Key resources	4. Value proposition	5. Customer relationship	6. Customer channels	7. Customer segments	8. Revenue stream	9. Cost structure	Total
Relationship between main criterion and other criteria	10	4	-1	5	6	0	2	-1	3	28
Weight	0,07	0,1	0,05	0,08	0,11	0,22	0,15	0,09	0,13	1

Figure 2 visualises the relationship between the main criterion, other criteria and the weights. The direction of the arrow indicates the relationship between the criteria, i.e., the arrow goes from the stronger criteria, i.e., a criterion which has less risk.

Figure 2 The relationship between the main criterion and other criteria and weights (developed by the authors, 2019)



The results are shown in Tables 6 and 7.

Table 6 The results of the risk matrix of RADi (developed by authors, 2019) (see online version for colours)

Business model canvas blocks	weight	Technical	Competence	Acceptance by staff	Acceptance by customers	Data security and privacy	Financial risks
key partners	0,07	8	10,5	10,5	22,5	12	15
key activities	0,1	-2,5	10,5	-7,5	2	1	-2
key resources	0,05	13	-6,5	-11	3	-10	-9,5
value proposition	0,08	3	3	-6,5	-13	9	12,5
customer relationship	0,11	1	1	-9	-2	1,5	3,5
channels	0,22	-10,5	-18,5	12	-11,5	-14,5	-5,5
customer segments	0,15	8,5	-14,5	-2,5	-8	1	-1,5
revenue stream	0,09	-17,5	9	9	-7,5	-8,5	-7,5
cost structure	0,13	-3	5,5	5	14,5	8,5	-5

Table 6 shows the effect of specific risk (horizontally) on each canvas block of the business model (vertical). *Red* indicates a higher risk in the business model canvas block and *blue* indicates a lower risk in the block.

Key partners have the lowest risk in each risk category and overall risk as all assessments are positive. Experts have a weight of (0.07) which is minimum and indicates that block *key partners* has the lowest risk if it is digitised.

Customer channels pose the highest risk in all risk categories except for acceptance by employees risk. With the highest weight given by the expert (0.22), this block becomes the biggest risk. Another major risk in *customer channels* is competence and data security. Acceptance by staff indicates a low risk to customer channels.

Experts place the second weight on customer segments (0.15). The greatest risks may be related to *competence, acceptance by customers,* the lowest – *technical*, *acceptance by staff, data security*. *financial risk* is considered as comparatively neutral.

The remaining risk categories have different effects on the canvas of the business model. The results can be interpreted using the same logic as above.

Table 7 The total effect (dependence) of the criteria describing the research object (developed by authors, 2019)

Risks	*Key partners*	*Key activities*	*Key resources*	*Value proposition*	*Customer relationship*	*Customer channels*	*Customer segments*	*Revenue stream*	*Cost structure*	*Total effect (dependence); P_i*	P_i^f	*Weight*
Key partners	0	–11.5	–9	–6.5	–13	–16	–7.5	–7	–8	–78.5	–27	0.07
Key activities	11.5	0	–0.5	2	–5	–7	–2	–2	1.5	–1.5	50.5	0.1
Key resources	9	0.5	0	–2.5	2	0.5	1	2.5	8	21	73	0.05
Value proposition	6.5	–2	2.5	0	–2	–9	–2	–4	2	–8	44	0.08
Customer relationship	13	5	–2	2	0	–9.5	–7	–1	3.5	4	56	0.11
Customer channels	16	7	–0.5	9	9.5	0	4	–1	4.5	48.5	101	0.22
Customer segments	7.5	2	–1	2	7	–4	0	–3	6.5	17	69	0.15
Revenue stream	7	2	–2.5	4	1	1	3	0	7.5	23	75	0.09
Cost structure	8	–1.5	–8	–2	–3.5	–4.5	–6.5	–7.5	0	–25.5	26.5	0.13
										0	468	1

Source: Authors elaboration based on expert evaluation using FARE method, 2019

Table 8 Risk heat map (developed by authors, 2019) (see online version for colours)

Business model canvas blocks	Technical	Competence	Acceptance by staff	Acceptance by customers	Data security and privacy	Financial risks
key partners	1,6393	0,0000	0,6522	0,0000	0,0000	0,0000
key activities	5,0820	0,0000	8,4783	5,7746	4,1509	6,9388
key resources	0,0000	5,8621	10,0000	5,4930	8,3019	10,0000
value proposition	3,2787	2,5862	8,0435	10,0000	1,1321	1,0204
customer relationship	3,9344	3,2759	9,1304	6,9014	3,9623	4,6939
customer channels	7,7049	10,0000	0,0000	9,5775	10,0000	8,3673
customer segments	1,4754	8,6207	6,3043	8,5915	4,1509	6,7347
revenue stream	10,0000	0,5172	1,3043	8,4507	7,7358	9,1837
cost structure	5,2459	1,7241	3,0435	2,2535	1,3208	8,1633

Table 7 shows the results of studies using the FARE method. The results show the relationship between business model blocks across all six risk categories. A positive number indicates a lower dependence of the horizontally labelled block relative to the vertical block. A negative number indicates a greater dependence of the horizontally labelled block relative to the vertical block.

Table 8 after the calculations forms risk heat map, green colour indicates the lowest risk area, yellow and orange – the moderate risk are and red – the highest risk area. Data for each of 6 risk areas in all 9 blocks of business model canvas are in Table 8. The Risk Heat Map in Table 8 is constructed using Excel function conditional formatting. Data for risk heat map was normalised and 10 represents the highest level of risk in the column when 0 represent the lowest level of risk in the column. E.g., the highest financial risk is seen for the block of business model canvas *key resources* (risk value 10 coloured in red) and the lowest financial risk is seen for the block *key partners*.

Table 9 shows the division of risks according to the degree of risk (high, moderate and low) and distributed among all nine blocks of business model. The table is based on calculations from Table 8. High risks are considered to be evaluated from 7.5 to 10, moderate risks are considered to be evaluated from 2.5 to 7.5 and low risks – from 0 to 2.5.

Table 9 Division of blocks of business model canvas among risks (developed by authors, 2019)

Type of risk / *Degree of risk*	*Technical*	*Competence*	*Acceptance by staff*	*Acceptance by customers*	*Data security*	*Financial*
High	Revenue stream; customer channels	Customer channels; customer segments	Key resources; key activities	Value proposition; customer channels; customer segments; revenue stream	Customer channels; key resources; revenue stream	Key resources; revenue stream; customer channels
Moderate	Key activities; value proposition; customer relationship; cost structure	Key resources; value proposition; cost structure; customer relationship	Value proposition; customer segments; cost structure	Key activities; key resources; customer relationship;	Key activities; customer relationship; customer segments	Key activities; customer relationship; customer segments; cost structure
Low	Key partners; key resources; customer segments	Key partners; key activities; revenue stream	Customer channels; key partners; revenue stream	Key partners; cost structure	Key partners; value proposition; cost structure	Key partners; value proposition

5 Discussion and conclusions

Our analysis of the literature analysis reveals gaps, e.g., the risk assessment of digitisation of Industry 4.0 business models is not sufficiently researched, although it is an important step towards a major change and investment decision. The main theoretical contribution is that research takes different risks, identify only those that are related to Industry 4.0 implementation in wider and more focused understanding, separate internal risks from the rest and systemise them into six areas to be assessed. Scholars have developed the frameworks and guidelines but not a ready to use tool with data from empirical research to benchmark risks to assess risks for business model transformations. A matrix of risk assessment RADi is created after the literature analysis and validated empirically. RADi focuses on the internal risks that enterprises usually manage themselves rather than mixing – manageable and non-manageable risks.

The following blocks of the business model canvas are considered to be most affected by all categories of risk (in the sequence from the highest): customer channels, key resources, and revenue stream and customer relationship. Blocks such as key partners, value proposition and cost structure are least affected by the digitisation of business models.

The six areas for internal risks to be evaluated are found after the scientific literature review. The areas are the following: technical, organisational competence, acceptance by staff, acceptance by customers and suppliers, data security and financial risks.

The processing and analysing of research data raise several points. First, experts should compare the interrelationship of factors using the FARE method, which gives additional insights into the question of direct research. As scholars such as Kraujalienė (2019) and Ginevičius (2011) say a higher number of criteria would lead to complications in the process of data collection and interpretation. The research shows that the proposed RADi method is sufficient enough and covers necessary to evaluate risks at the enterprise level. RADi evaluates the relationship of two factors (two business model blocks) against a risk area and allows to see which block is riskier to change.

Risk types may vary at different stages of business model innovation as different challenges occur due to level of digital transformation (Ibarra et al., 2018) the direction of business model innovation (Khan and Wuest, 2019; Zott and Amit, 2010). The proposed model RADi is the basis of introducing main directions of risks and serves as a framework and benchmark for further individual enterprise or policy use.

6 Limitations and further research

The research presented in the paper has certain limitations. Firstly, The RADi matrix covers risks arising from micro and mezzo levels. The model does not separately assess macro-level risks such as potential inflation, unemployment, etc. Undetected macro-level risks can be integrated into RADi matrix during the further steps of development of the research.

Second, the RADi matrix is validated under the overall understanding of business model transformation and does not consider that transformation due to Industry 4.0 can be not only in different level but also in different configurations, e.g., more on key activities and less in customer channels or relationships.

Further research can focus on different configurations of the business model change as well as on different levels of transformation, especially focusing on situations when a business model is transformed or created completely in the Industry 4.0 direction, such as PSS, data-driven business models, mobility or software as a service, etc.

Further research can focus on different economic sectors as it is easily predicted that, e.g., high tech companies will have other major internal risks than a traditional manufacturing company. The matrix can be easily modified to the needs of specific industries or enterprises through additional research to test the validity.

The effect of risks on business models in non-profit, education and public sectors using RADi model should be also researched further to be used by different institutions.

7 Recommendations

At the practical level, the paper contributes by introducing a model of risk assessment RADi to companies as a decision support instrument. Firms can use the RADi model when planning and implementing changes in their business model or create a new business model(s). RADi identifies the types of risks that have a greater impact on specific blocks of business models and assesses which blocks may be more affected by changes. This information provides information for change, e.g., planning investment, structure, human resources or value proposition plan. Enterprises can use the RADi matrix not only to identify the current risk situation but also to monitor the possible changes as the matrix allows presenting and comparing the risk level in figures over time. This way using RADi has a managerial effect to plan, monitor and control changes in risks. Companies use their own or industry-specific data to make results of risk assessment tailored. Therefore RADi has an economic effect to reduce risks in the high investment demanding projects.

This is a tool to teams in the enterprises to strengthen collaborative decision-making processes which lead to higher engagement when a stage of implementation of business model change comes. This way using RADi affects to engage employees and partners to communicate potential risks, to prevent and reduce failures.

The paper contributes to the national level and can be used as a part of policy decision making methodologies. Policymakers can use the RADi model to prioritise the public budget distribution identifying projects with higher risk. Examples can be regional development, enterprises digitalisation projects or SME development support programmes.

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