How the Knowledge of the Major Researchers Is Forging the Business Strategy Paths: Trends and Forecasts from the State of the Art

DOI: 10.12776/QIP.V24I3.1404

Luís C.F.M. Barbosa, Maria A.S. Mathias, Gilberto Santos, Otávio J. de Oliveira

Received: 2020-02-21 Accepted: 2020-08-24 Published: 2020-11-30

ABSTRACT

Purpose: Given its large number of publications, the subject "strategy" stands out as an important field of scientific literature with multidisciplinary characteristics, involving the most varied research areas. The aim of this paper is to analyse the state of the art on business strategy, which have enabled the identification of the characteristics of the most influential articles and authors.

Methodology/Approach: This article is a literature review based on bibliometric parameters, which the main novelty has been the identification of specific characteristics of the main publications and researchers on business strategy during the peak production period of 1998-2017.

Findings: The main contribution of this article is to guide researchers interested in developing studies related to business strategy, highlighting the subject's chronological evolution and the correlations analyses among publications.

Research Limitation/Implication: The searches and selection of bibliometric parameters have been limited to two of the most relevant databases (Scopus and Web of Science). Another restriction was that only articles and reviews containing the term "business strategy" in their respective titles were considered.

Originality/Value of paper: Although bibliometric studies have already been published in managerial and strategic areas and subareas, the scientific literature still lacks articles with the same level of details and analysis performed in this paper, which portrays the main novelty of this research.

Category: Literature review

Keywords: strategy; business strategy; bibliometric analysis; state of the art; review

1 INTRODUCTION

Strategy is a word originated from the Greek word strategia, which means plan, method, process, maneuvers, or decisions used to achieve a specific goal or outcome. It has its origin in the military area and referred to "the general art", in which the psychological and behavioural skills of the general of the army concerned the planning and execution of the troops' movements during a conflict (Dalby, 2007; Zott and Amit, 2008; Ghemawat, 2016). In an organisational context, strategy started to stand out in a more effective manner after the Second World War, intensifying after the economic globalisation, creation of several trading blocs, technological progresses, new market demands, and scarce natural resources, compelling organisations to constant operational and managerial changes (de Oliveira, 2013; Araújo et al., 2019; Bravi, Murmura and Santos, 2018; Barbosa, de Oliveira and Santos, 2018; Santos, Murmura and Bravi, 2019; Santos et al., 2014; Costa et al., 2019; Talapatra et al., 2019; Carvalho, Santos and Gonçalves, 2020; Sá et al., 2020).

The elaboration of a business strategy is pivotal for the organisation's planning and success (Rodrigues et al., 2019; Marinho, Silva and Santos,2020; Félix et al., 2019). Therefore, the formulation of the competitive strategy must be adjusted to the environmental conditions surrounding an organisation (Abraham, 2013; Zgodavova and Bober, 2012; Zgodavova et al., 2020). The strategic planning constitutes an administrative effort that, based on the evaluation of the company's condition and environmental situation, results in a critical acknowledgement of its opportunities, threats, strengths and weaknesses to fulfil its mission, establishing structured and formal guidelines to orient the organisation (Agarwal, Grassl and Pahl, 2012; Salavou, 2015; Santos et al., 2019; Bravi, Murmura and Santos, 2019).

The great amount of publications on strategy attests to its relevance to the scientific literature. Strategy-related researches present multidisciplinary features and involve the most varied research areas (Zhuang et al., 2013; Coombes and Nicholson, 2013). These features are even more explicit when searched in the literature using the term "business strategy", be it on the articles title, abstract, keywords, chapter, or congress articles, resulting in 77,498 publications until December 31st, 2017 (Scopus, 2017).

Articles and reviews published in indexed journals ensure greater reliability to the researches (Campanario, 2014). Thus, it has been decided that only the articles' and reviews' titles should be used in the queries for "business strategy" to obtain accurate and academic relevant results.Until December 31st, 2017 there were 2,269 articles in the literature, with the first publications dating back to the end of the 1950's, and an intensification in the production through time (Scopus, 2017; Web of Science, 2017).

Coincidently, the number of publications regarding business strategy started to grow with the beginning of the competition era, by end of the 1970's and beginning of the 1980's (Scopus, 2017; Web of Science, 2017). One of the

pioneers in introducing this concept to the scientific literature was Michael Porter, whose thinking is based on the importance of the external environment and the positioning of the company in this environment (Magretta, 2012; Tansey, Spillane and Meng, 2014). This fact has also contributed to the increase in the number of publications (Scopus, 2017; Web of Science, 2017). Although bibliometric studies have already been published in managerial and strategic areas and subareas, the scientific literature has not witnessed a study with the same level of details and analysis of this article, which identified the characteristics of the main publications and the major researchers on business strategy during the period of 1998 to 2017 (Agarwal, Grassl and Pahl, 2012; Salavou, 2015).

In light of these arguments and based on the established scientific gap, the research question that guided the development of this article is: how can the bibliometric analysis on business strategy provide a global perspective of the field, thus correlating the existing interactions among the main countries, institutions, journals, articles and authors with the highest impact? Therefore, these bibliometric analyses allowed the identification of the characteristics of the main publications and the major researchers on business strategy in the scientific literature, which stands as this paper's objective and main novelty.

This article is divided into five sections. The first section have presented the introduction and justified the relevance of business strategy, as well as the research question and the article's objective. The second section is composed by the research method, while the third section exposes the results analysis. The main characteristics of the most influential articles and authors related to the theme shall be presented in the fourth section. At last, the paper's conclusion can be found in the fifth section.

2 METHODOLOGY

This article is a literature review designed to identify the contributions regarding business strategy through an overarching bibliometric analysis. Literature reviews report the current knowledge about a topic and is based on the summary of researches previously published, providing a comprehensive view of the subject (Garousi and Mäntylä, 2016). Its goal is to keep the reader updated about the latest findings and substantiate the formulation of new proposals, facilitating future researches (Carnwell and Daly, 2001).

Bibliometric studies are used to inquire the standards and trends published about a certain theme, thus, helping explore and organise the state of the art as a whole (Coombes and Nicholson, 2013). The most recent bibliometric analyses have evolved to incorporate interrelations analyses among major authors, institutions and countries, as well as convergence analysis among prominent journals and the most cited articles (Zhuang et al., 2013; Ferreira et al., 2014).

To conduct an analysis compatible with the purpose of this article, the articles have been searched in both the Scopus and the Web of Science platforms. These databases are able to provide multidisciplinary scientific articles from a wide range of journals of different publishers, guaranteeing the access to a great part of the internationally published literature and allowing the export of metadata for a proper bibliometric analysis (Guerrero-Bote and Moya-Anegón, 2012; Garousi and Mäntylä, 2016).

The types of documents used in this study include only articles and reviews published in internationally indexed journals. In accordance with Salavou (2015), these are the most reliable documents for literature reviews, since they adopt a blind review criteria, thus ensuring a higher reliability. Moreover, only English-written publications were assessed for their global reach (Scopus 2017; Web of Science, 2017). Figure 1 presents the methodological flow and sequence of activities related to the research.

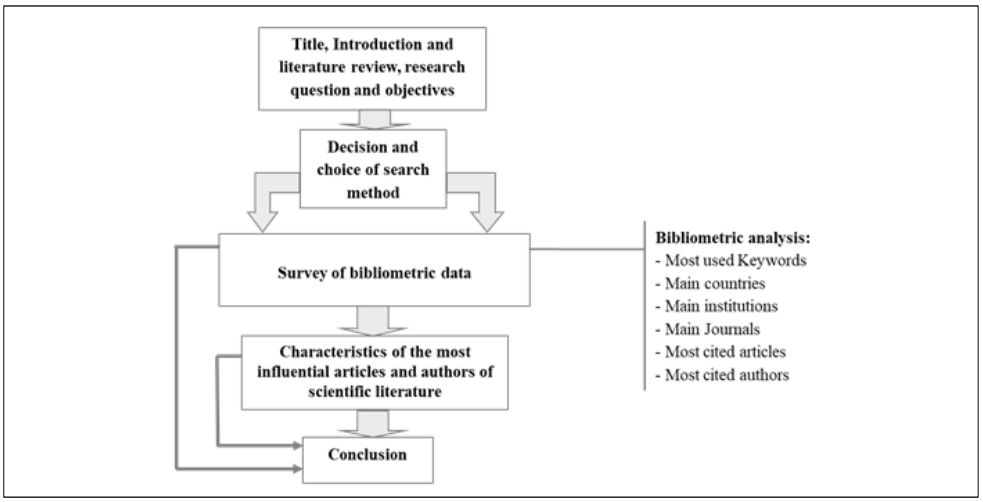


Figure 1 – Research Methodological Flow

This study used basic bibliometric parameters, namely: number of accumulated citations, number of documents and a calculation of the quocient of the citations by the amount of documents, so to avoid past years' measurement of scientific quality based solely on the number of citations (Campanario, 2014). Therefore, this paper's analyses were centered around the publications' total number of citations accumulated in the period (C), the total number of documents in the period (N) and the impact of this publications (C/N = number of aggregated citations by the amount of published documents). These parameters reflect the scientific literature published until December 31st, 2017, and were combined to identify the relevance of keywords, countries, institutions, journals, articles and authors.

It should also be highlighted that the analyses of the main institutions, journals, and most cited articles and authors have taken into account a minumum of five publications related to business strategy. This minimal condition has been applied to exclude institutions, journals, articles and authors with low productivity, despite their respectives high numbers of citations in a sole publication. Regarding the analysis of the most cited articles, it is also possible to identify their corresponding impact factors, which indicate the publications' importance and prestige for a determine field (Chung, 2007; Campanario, 2014).

Microsoft Excel, Microsoft PowerPoint and VOSviewer softwares were employed to develop the tables, graphics, charts and figures necessary to the bibliometric analysis of the collected data from the Scopus and Web of Science databases. Furthermore, the VOSviewer software also allowed the identification of correlation networks among the main countries and authors on business strategy.

3 FINDINGS

This article goes beyond the traditional bibliometric analysis commonly found in the scientific literature for this field. External parameters to the publications were considered, among them: international trade relations, human development indexes, participations in trade blocs and international groups, and international competition and innovation rankings (Dutta, Lanvin and Wunsch-Vincent, 2017; Schwab and Sala-i-Martín, 2017). Figure 2 exhibits the subject's keywords and their frequencies in the published papers. Since it is the object of this article, the keyword "business strategy" has not been included in this analysis (Scopus, 2017).

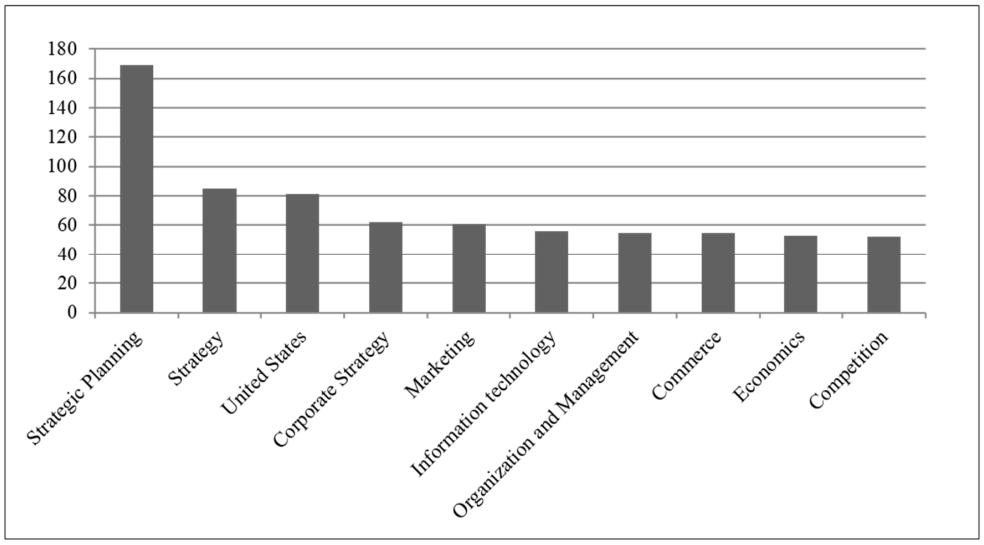


Figure 2 – Most used Keywords in Researches about "Business Strategy"

Still in Figure 2, it is possible to observe that 9 out of the 10 most cited keywords are directly related to the managerial and strategic areas, except for the keyword "United States". Additionally, Table 1 exposes the countries that publish the most and, thus, stands out in business strategy. The United States and United Kingdom are the two biggest influences on this field, totalling 708 out of the 2,269 articles found, which represent 31.21% of the total of publications. The United States only are responsible for 500 articles, representing a little more than one fifth or 22.03% of all the publications (Scopus, 2017).

Table 1 – The Ten Most Influential Countries on "Business Strategy"

#	*Country*	*Accumulated citations (C)*	*Number of documents (N)*	*Impact (C/N)*
1	United States	17,092	500	34.2
2	United Kingdom	5,165	208	24.8
3	Canada	1,930	56	34.5
4	Netherlands	1,872	45	41.6
5	Germany	1,744	57	30.6
6	France	1,216	44	27.6
7	Sweden	1,071	30	35.7
8	Hong Kong	1,059	21	50.4
9	Australia	922	68	13.6
10	Taiwan	635	47	13.5

It is important to highlight that, together, the ten most relevant countries add up to 1,076 articles, which represent 47.42% of the total of publications regarding "business strategy" (Scopus, 2017). It is important to notice that all ten countries mentioned in Table 1 are part of the World Trade Organization, an intergovernmental organisation that regulates and controls the international trade among countries. Moreover, these ten countries present the highest levels of the Human Development Index (HDI), ranging between 0.800 and 1.00 (Dutta, Lanvin and Wunsch-Vincent, 2017; Schwab and Sala-i-Martín, 2017).

Among them, only Taiwan and Hong Kong belong to the list of nations known as G20, a group formed by government representatives of the nineteen biggest world economies, plus the European Union. The G20 represent 80% of the world trade (including the intra-European trade market), two thirds or 66.67% of the world population, and 90% of the world GDP. In this context, the United States stands out again with the biggest world economy, being responsible for a GDP of $17.95 trillion, which alone represents almost one fourth or 24.53% of the world GDP (Dutta, Lanvin and Wunsch-Vincent, 2017; Schwab and Sala-i-Martín, 2017). United States, United Kingdom, Germany, Canada and France integrate

the G7, which is the group of the seven biggest world economies as per the International Monetary Fund (Dutta, Lanvin and Wunsch-Vincent, 2017; Schwab and Sala-i-Martín, 2017).

All of the ten cited countries in Table 1 are among the 25 leading nations in terms of competition index (Schwab and Sala-i-Martín, 2017). The competition index is an increasing trend relevant to the organisations with regard to the structure of their business strategies, since it indicates their main weaknesses, as well as their best opportunities, taking into account their strengthens and features (Tansey, Spillane and Meng, 2014). In order to highlight the importance of those ten countries in Table 1, Figure 3 displays the correlation network of the most influential countries to the theme in which the same ten countries previously analysed are present.

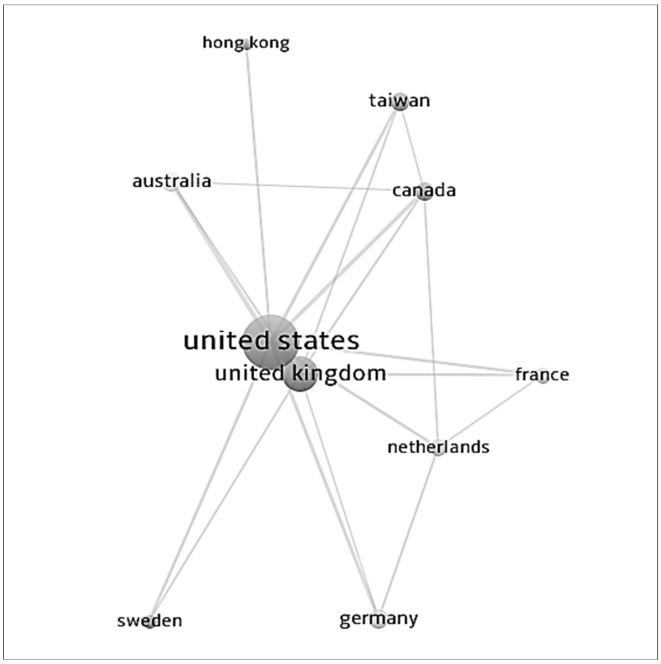


Figure 3 – Network of the Most Influential Countries on "Business Strategy"

The United States and the United Kingdom wield the greatest influence on this theme, since they possess the largest number of publications and the most cited articles and, consequently, contribute the most with research (Scopus, 2017). New bibliometric studies aim to analyse the possible interrelationships among the main countries, institutions and authors (Ferreira et al., 2014). Therefore, Table 2 presents the ten institutions with the best performances on business strategy in the scientific literature. It is worth mentioning that nine of the ten institutions listed in Table 2 are also among the most relevant countries to this topic.

Table 2 – The Ten Main Institutions on "Business Strategy"

#	*Institution*	*Country*	*Accumulated citations (C)*	*Number of documents (N)*	*Impact (C/N)*
1	Harvard Business School	United States	5,673	11	515.73
2	UC Berkeley	United States	2,231	9	247.89
3	Pennsylvania State University	United States	1,873	6	312.17
4	University of Texas at Dallas	United States	1,455	5	291.00
5	Boston University	United States	1,389	6	231.50
6	University of Michigan State	United States	1,238	8	154.75
7	University of Cambridge	United Kingdom	833	11	75.73
8	University of Manchester	United Kingdom	809	15	53.93
9	Erasmus University Rotterdam	Netherlands	776	14	55.43
10	National University of Singapore	Singapore	679	14	48.50

Only the "National University of Singapore", an institute from Singapore in Southeast Asia, does not belong to the list of the ten most relevant countries related to business strategy, despite presenting a high GDP, high levels of competitiveness and HDI, and expressive investments in research and technology. Pursuant to Zhuang et al. (2013), emerging bibliometric studies should also collect data on and examine the main periodics related to the researched topic. Thus, the ten main and most influential journals in the scientific literature are presented in Table 3.

Table 3 – The Ten Most Influential Journals on "Business Strategy"

#	*Journals (ISSN)*	*Country*	*Accumulated citations (C)*	*Number of documents (N)*	*Impact (C/N)*
1	Long Range Plannin (0024-6301)	United Kingdom	2,345	26	90.19
2	Academy of Management Journal (0001-4273)	United States	1,323	7	189.00

#	*Journals (ISSN)*	*Country*	*Accumulated citations (C)*	*Number of documents (N)*	*Impact (C/N)*
3	Journal of International Business Studies (0047-2506)	United Kingdom	1,238	8	154.75
4	Academy of Management Review (0363-7425)	United States	1,152	9	128.00
5	Management Decision (0025-1747)	United Kingdom	1,022	17	60.12
6	Journal of Operations Management (0272-6963)	Netherlands	896	7	128.00
7	Journal of Marketing (0022-2429)	United States	879	5	175.80
8	Business Strategy and the Environment (0964-4733)	United States	873	22	39.68
9	Strategic Management Journal (0143-2095)	United States	822	19	43.26
10	Industrial Marketing Management (0019-8501)	Netherlands	536	14	38.29

A simple cross-analysis of the ten journals mentioned in Table 3 confirm their presence among the most influential countries regarding business strategy, which also supports the previous interpretation of Table 1 and the analysis made by Tansey, Spillane and Meng (2014). Figure 4 provides the following data on the most scientifically influential articles: title, authors,year of publication, countries of the first authors, number of ISSN, impact factors, SJR, JCR, SNIP (all regarding the year of 2016), average of citations per year (C/N impact) and, finally, the evolution of these citations throughout the years. Figure 5 presents and classifies the most relevant authors of the business strategy literature in descending order, based on the total number of citations accumulated in the period. Figure 5 also shows the authors' citation average, the institutions they belong to, their publication interval, and h-index. Comparative charts with total of absolute and specific publications of each author are reported too.

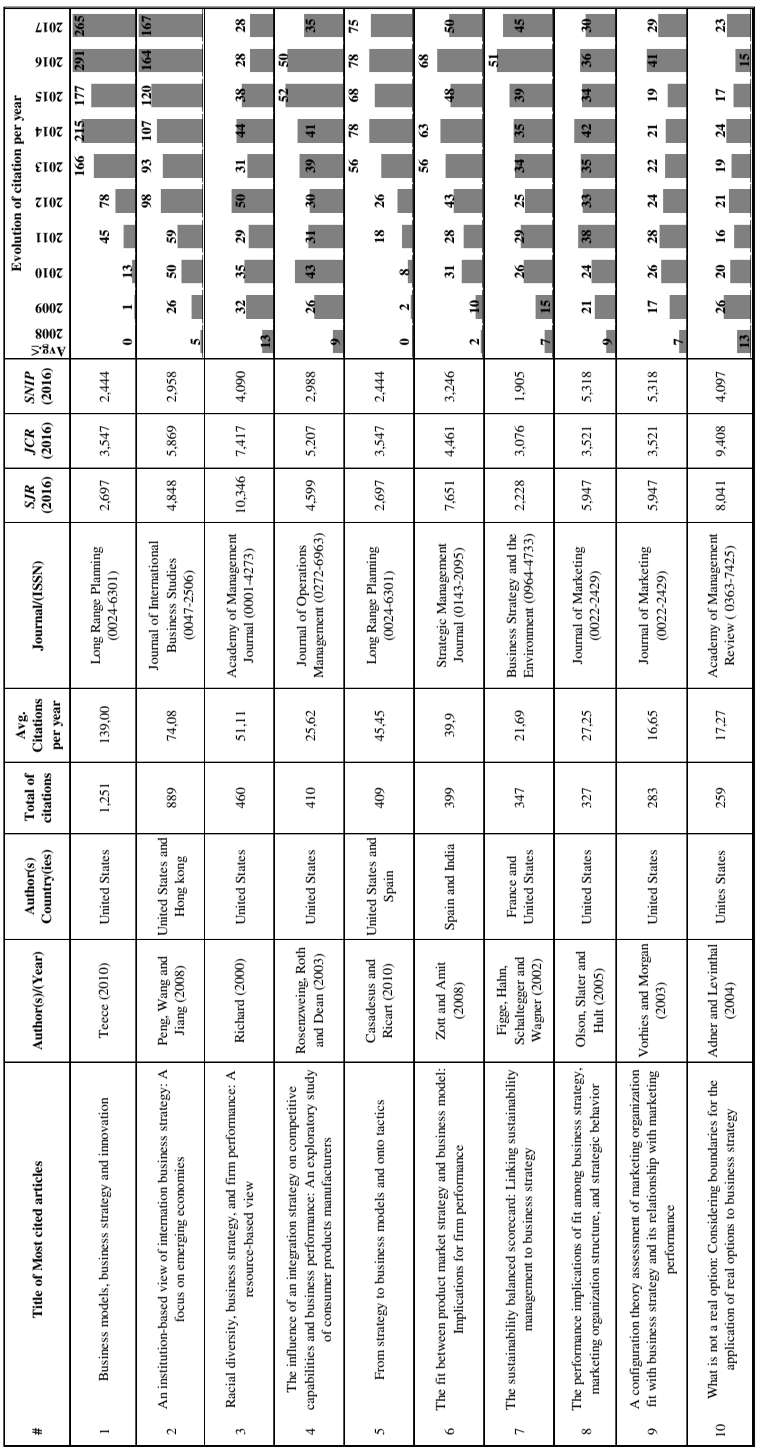


Figure 4 – The Ten Most Cited Articles Regarding "Business Strategy" (1998–2017)

#	Most cited authors	Institution(s)	Citations accumulated in the field (C)	Number of documents in the field (N)	Impact (C/N)	Publication range	*h-index*	Number of documents		Number of citations	
								Total	Business strategy	Total	Business strategy
1	Porter, Michael E.	Harvard Business School, Boston, United States	3,906	30	0,13	1986-2016	39	74	30	12854	3906
2	Teece, David J.	UC Berkeley Haas School of Business, Berkeley, United States	1,833	25	0,07	1977-2016	37	157	25	18025	1833
3	Dess, Gregory G.	University of Texas at Dallas, Richardson, United States	1,032	16	0,06	1982-2014	23	40	16	4225	1032
4	Hambrick, Donald C.	Pennsylvania State University, State College, United States	673	12	56,08	1981-2015	38	67	12	5438	673
5	Miller, Danny	University of Montreal, Montreal, Canada University of Alberta, Edmonton, Canada	653	8	81,63	1987-2016	17	106	8	5625	653
6	Prahalad, C. K.	University of Michigan, Ann Arbor, United States	568	7	81,14	1976-2012	24	45	7	5711	568
7	Venkatraman, N. Venkat	Boston University, School of Management, Boston, United States	518	9	57,56	1986-2013	24	49	9	4161	518
8	Mintzberg, Henry	McGill University, Quebec, Canada	493	18	27,39	1972-2015	24	70	18	2221	493
9	Snow, Charles C.	Pennsylvania State University, State College, United States	415	7	59,29	1978-2015	21	44	7	2725	415
10	Miles, Robert E.	University of Leeds, Leeds, United Kingdom School of Electrical and Electronic Engeneering, Leeds, United Kingdom	413	7	59,00	1982-2012	22	126	7	2577	413

Figure 5 – The Ten Most Cited Authors on "Business Strategy"

Although the publications' samples represent the period from 1998 to 2017, Figure 4 shows that the ten most cited articles have been published from the year 2000 on. This period coincides with the increase in the number of publications related to the field (Scopus, 2017). It also converges with the findings of Tansey, Spillane and Meng (2014), which outline the insertion of companies in an increasingly globalised market as one of the determining factors for the increase in the number of publications on the subject.

In addition, six of the ten most cited papers were published until 2007. Although they are not recent studies, their analyses and results remain current and relevant both for the academic and business worlds, given the high number of citations they have received over the past 10 years (Scopus, 2017). It is no coincidence that all ten articles in Figure 4 have been published by the ten most influential journals to business strategy.

Analyses of the main authors who published articles and reviews related to business strategy, either mentioning the term in the title, abstract, or keywords, have been carried out in order to identify the most cited authors. It should be emphasised that all of the most cited authors analysed in Figure 5 perform both in the academic environment, as professors and researchers, and in the corporate world, acting as external consultants, a fact that might have influenced the development of studies with great impact for the theme (Scopus, 2017).

The network of authors depicted in Figure 6 has been developed in order to further highlight the impact of the ten most relevant authors on the subject. It evidences the influence that Porter exerts on the theme and on the other analysed authors, since all nine authors cite him in their papers. Thus, it may be concluded that Porter is the most influential author on business strategy.

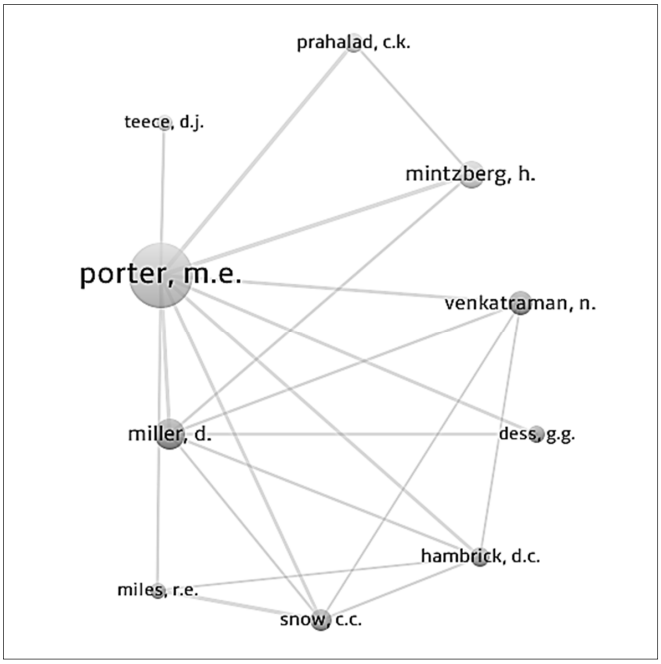


Figure 6 – Network Of The Most Cited Authors Regarding "Business Strategy"

4 MAIN CHARACTERISTICS OF THE ARTICLES AND THE MOST INFLUENTIAL AUTHORS

In this section, the main relevant characteristics of the most influential articles and authors on business strategy shall be discussed. In order to explain the most important features of the most cited articles on the theme, Table 4 shows the fundamental aspects that these influential papers have presented. These characteristics, or variables, have been gathered based on the bibliometric analyses previously presented in Section 3. The nine variables in Table 4 were considered, to reflect the common aspects making these articles influential and references to the business strategy theme.

Based on the bibliometric parameters presented in Section 3 and on the main characteristics of the most cited articles exhibited in Table 4, it can be inferred that the most influential articles on business strategy have characteristics contemplating some common aspects. First, they belong to prominent international groups (G7 and G20), besides being among the top 25 of the WEF competitiveness ranking and the countries with the highest levels of HDI (0.800 to 1). Additionally, they have been published in the top 10 most relevant journals to the topic, while also being produced in partnership with other authors, so that different points of view are contemplated within the researches' findings.

Table 4 – Main Characteristics of the Most Influential Articles Regarding "Business Strategy"

Most cited articles #		*1º*	*2º*	*3º*	*4º*	*5º*	*6º*	*7º*	*8º*	*9º*	*10º*	*Total Amount*	*% Total Amount*
Top 10 *countries* most relevant to the topic		x	x	x	x	x		x	x	x	x	9	90
International groups - G20		x	x	x	x	x	x	x	x	x	x	10	100
Top 25 of WEF's competitiveness ranking		x	x	x	x	x		x	x	x	x	9	90
HDI	(0.800-1)	x	x	x	x	x	x	x	x	x	x	10	100
	(0.700-0.799)	-											
	(0.600-0.699)	-											
Top 10 *institutions* most relevant to the topic		x		x								2	20
Top 10 *journals* most relevant to the topic		x	x	x	x	x	x	x	x	x	x	10	100
Top 10 *authors* most cited on the topic		x										1	10
Type of publication	Single	x		x								2	20
	Pair				x	x	x			x	x	5	50
	Group		x					x	x			3	30
Article classification	Theoretical	x			x					x	x	4	40
	Empirical		x	x		x	x	x	x			6	60

Notes: HDI – Human Development Index.

On the other hand, it is not essential to be affiliated to one of the main institutions to have a well-quoted article, nor is it necessary for the researcher to be one of the top 10 most cited authors on that theme. As for the articles' classification, the analyses verified that there is not a prevailing approach for their impact, since the applied research methods varied between theoretical and empirical. In terms of the most important characteristics of the most influential authors to the subject, Table 5 presents the seven variables that were considered while analysing the common aspects of their influence.

Table 5 – Main Characteristics of Most Influential Authors Regarding "Business Strategy"

Most cited authors #		*1º*	*2º*	*3º*	*4º*	*5º*	*6º*	*7º*	*8º*	*9º*	*10º*	*Total Amount*	*% Total Amount*
Top 10 *countries* most relevant to the topic		x	x	x	x	x	x	x	x	x	x	10	100
International groups - G20		x	x	x	x	x	x	x	x	x	x	10	100
Top 25 of WEF's competitiveness ranking		x	x	x	x	x	x	x	x	x	x	10	100
HDI	(0.800 - 1)	x	x	x	x	x	x	x	x	x	x	10	100
	(0.700 - 0.799)	-											
	(0.600 - 0.699)	-											
Top 10 *institutions* most relevant to the topic		x	x									2	20
Top 10 *articles* most cited on the topic			x									1	10
Field of activity	Professor/ Researcher	-											
	Consultant	-											
	Both	x	x	x	x	x	x	x	x	x	x	10	100

Notes: HDI – Human Development Index.

Once again taking as a basis the previous bibliometric parameters and analyses, it could be determined some common aspects among the most influential authors on business strategy. All of them have been working in the top 10 most influential countries and are part of main international groups (G7 and G20). Besides that, they belong to the top WEF 25 competitiveness rank and represent the countries with the highest levels of HDI (0.800 to 1). Finally, these ten authors work both in the academic and the business areas, which probably adds value to their publications by correlating their theoretical knowledge and their practical experiences in the field. Furthermore, it is not necessary to work for the main institutions, nor have an article among the top 10 most cited articles in order to become an influential author on business strategy.

5 CONCLUSION

This article analysed the literature on business strategy through a bibliometric study. The aim of this paper, which was to characterise the most influential articles and authors related to the theme, has been achieved. The article limited the searches and selection of bibliometric parameters to two databases, namely Scopus and Web of Science. Another restriction concerned the mandatory presence of the term "business strategy" in the titles of the articles and reviews.

Consequently, other articles would probably be included had this limitation not been imposed.

Although bibliometric studies have already been published in managerial and strategic areas and sub-areas, studies contemplating the bibliometric characteristics specifically and solely related to the term "business strategy" have not been found in the international scientific literature. Ergo, the main academic contribution of this article was filling this particular scientific gap. The study's main practical contribution and the main novelty of this research has been the presentation of common aspects considered instrumental for the most influential articles and authors on business strategy.

These analyses shall allow researchers to have a more comprehensive perspective of the subject's state of the art, and serve as benchmarking for other researches related to this and other branches of scientific research. Ultimately, new studies could take advantage of this research when exploring new topics that have not yet been investigated.

ACKNOWLEDGEMENTS

This work was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001, the São Paulo Research Foundation (FAPESP) [grant number 2017/18304-7] and by the Brazilian National Council for Scientific and Technological Development (CNPq) [grant number PQ 312894/2017-1].

REFERENCES

Abraham, S., 2013. Will business model innovation replace strategic analysis? *Strategy & Leadership* [e-journal], 41(2), pp.31-38. doi: 10.1108/10878571311318222.

Agarwal, R., Grassl, W. and Pahl, J., 2012. Meta-SWOT: introducing a new strategic planning tool. *Journal of Business Strategy* [e-journal], 33(2), pp.12-21. doi: 10.1108/02756661211206708.

Araújo, R., Santos, G., da Costa, J.B. and Sá, J.C., 2019. The quality management system as a driver of organizational culture: An empirical study in the Portuguese textile industry. *Quality Innovation Prosperity* [e-journal], 23(1), pp.1-24. doi: 10.12776/qip.v23i1.1132.

Barbosa, L.C.F.M., de Oliveira, O.J. and Santos, G., 2018. Proposition for the alignment of the integrated management system (quality, environmental and safety) with the business strategy. *International Journal for Quality Research* [e-journal], 12(4), pp.925-940. doi: 10.18421/IJQR12.04-09.

Bravi, L., Murmura, F. and Santos, G., 2018. Manufacturing labs: Where new digital technologies help improve life quality. *International Journal for Quality Research* [e-journal], 12(4), pp.957-974. doi: 10.18421/IJQR12.04-11.

Bravi, L., Murmura, F. and Santos, G., 2019. The ISO 9001:2015 quality management system standard: Companies' drivers, benefits and barriers to its implementation. *Quality Innovation Prosperity* [e-journal], 23(2), pp.64-82. doi: 10.12776/qip.v23i2.1277.

Campanario, J.M., 2014. Analysis of the distribution of cited journals according to their positions in the h-core of citing journal listed in Journal Citation Reports. *Journal of Informetrics* [e-journal], 8(3), pp.534-545. doi: 10.1016/j.joi.2014.04.007.

Carnwell, R. and Daly, W., 2001. Strategies for the construction of a critical review of the literature. *Nurse Education in Practice* [e-journal], 1(2), pp.57-63. doi: 10.1054/nepr.2001.0008.

Carvalho, F., Santos, G. and Gonçalves, J., 2020. Critical analysis of information about integrated management systems and environmental policy on the Portuguese firms' website, towards sustainable development. *Corporate Social Responsibility and Environmental Management* [e-journal], 27(2), pp. 1069-1088. doi.org/10.1002/csr.1866.

Chung, H.K., 2007. Evaluating Academic Journals using Impact Factor and Local Citation Score. *Journal of Academic Librarianship* [e-journal], 33(3), pp.393-402. doi: 10.1016/j.acalib.2007.01.016.

Coombes, P.H. and Nicholson, J.H., 2013. Business models and their relationship with marketing: A systematic literature review. *Industrial Marketing Management* [e-journal], 42(5), pp.656-664. doi: 10.1016/j.indmarman.2013.05.005.

Costa, A.R., Barbosa, C., Santos, G. and Alves, M.R., 2019. Six sigma: Main metrics and r based software for training purposes and practical industrial quality control. *Quality Innovation Prosperity* [e-journal], 23(2), pp.83-100. doi: 10.12776/qip.v23i2.1278.

Dalby, S., 2007. Regions, strategies and empire in the global war on terror. *Geopolitics* [e-journal], 12(4), pp.586-606. doi: 10.1080/14650040701546079.

Dutta, S., Lanvin, B. and Wunsch-Vincent, S., 2017. *Global Innovation Index 2017: Who Will Finance Innovation?* [pdf] Cornell University, INSEAD, the World Intellectual Property Organization. Available at: <http:// www.globalinnovationindex.org> [Accessed 03 May 2018].

Félix, M.J., Silva, S., Santos, G., Doiro, M. and Sá, J.C., 2019. Integrated product and processes development in design: A case study. *Procedia Manufacturing* [e-journal], 41, pp. 296-303. doi.org/10.1016/j.promfg.2019.09.012.

Ferreira, M.P., Santos, J.C., Almeida, M.I.R. and Reis, N.R., 2014. Mergers & acquisitions research: A bibliometric study of top strategy and international business journals, 1980-2010. *Journal of Business Research* [e-journal], 67(12), pp.2550-2558. doi: 10.1016/j.jbusres.2014.03.015.

Garousi, V. and Mäntylä, M.V., 2016. Citations, research topics and active countries in software engineering: A bibliometrics study. *Computer Science Review* [e-journal], 19, pp.56-77. doi: 10.1016/j.cosrev.2015.12.002.

Ghemawat, P., 2016. Evolving ideas about business strategy. *Business History Review* [e-journal], 90(4), pp.727-749. doi: 10.1017/S0007680516000702.

Guerrero-Bote, V.P. and Moya-Anegón, F., 2012. A further step forward in measuring journals' scientific prestige: The SJR2 indicator. *Journal of Informetrics* [e-journal], 6(4), pp.674-688. doi: 10.1016/j.joi.2012.07.001.

Magretta, J., 2012. Michael Porter answers managers FAQs. *Strategy & Leadership* [e-journal], 40(2), pp.11-15. doi: 10.1108/10878571211209305.

Marinho, A., Silva, R.G. and Santos, G., 2020. Why most university-industry partnerships fail to endure and how to create value and gain competitive advantage through collaboration – a systematic review. *Quality Innovation Prosperity* [e-journal], 24(2), pp. 34-50. doi:10.12776/QIP.V24I2.1389.

de Oliveira, O.J., 2013. Guidelines for the integration of certifiable management systems in industrial companies. *Journal of Cleaner Production* [e-journal], 57, pp.124-133. doi: 10.1016/j.jclepro.2013.06.037.

Rodrigues, J., de Sá, J.C.V., Ferreira, L.P., Silva, F.J.G. and Santos, G., 2019. Lean management "quick-wins": Results of implementation. A case study. *Quality Innovation Prosperity* [e-journal], 23(3), pp. 3-21. doi: 10.12776/QIP.V23I3.1291.

Sá, J.C., Amaral, A., Barreto, L., Carvalho, F. and Santos, G., 2019. Perception of the importance to implement ISO 9001 in organizations related to people linked to quality-an empirical study. *International Journal for Quality Research* [e-journal], 13(4), pp. 1055-1070. doi:10.24874/IJQR13.04-20.

Salavou, H.E., 2015. Competitive strategies and their shift to the future. *European Business Review* [e-journal], 27(1), pp.80-99. doi: 10.1108/EBR-04-2013-0073.

Santos, G., Gomes, S., Braga, V., Braga, A., Lima, V., Teixeira, P. and Sá, J.C., 2019. Value creation through quality and innovation – a case study on Portugal. *TQM Journal* [e-journal], 31(6), pp.928-947. doi: 10.1108/TQM-12-2018-0223.

Santos, G., Murmura, F. and Bravi, L., 2019. Developing a model of vendor rating to manage quality in the supply chain. *International Journal of Quality and Service Sciences* [e-journal], 11(1), pp.34-52. doi: 10.1108/IJQSS-06-2017-0058.

Santos, G., Rebelo, M., Barros, S., Silva, R., Pereira, M., Ramos, G. and Lopes, N., 2014. Developments regarding the integration of the Occupational Safety and Health with Quality and Environment Management Systems. In: G.I. Kavouras and M.-C.G. Chalbot, eds. 2014. *Developments Regarding the Integration of the Occupational Safety and Health with Quality and Environment Management Systems*. New York: The Nova Science Publishers. Chapter 6.

Schwab, K. and Sala-i-Martín, X., 2017. *The Global Competitiveness Report.* [pdf] Geneva: World Economic Forum. Available at: <http://www3.weforum.org/docs/GCR2017-2018/05FullReport/TheGlobalCompetitivenessReport2017%E2%80%932018.pdf> [Accessed 03 May 2018].

Scopus, 2017. *Welcome to Scopus Preview.* [online] Available at: <http://www.scopus.com> [Accessed 05 July 2017].

Talapatra, S., Santos, G., Uddin, K. and Carvalho, F., 2019. Main benefits of integrated management systems through literature review. *International Journal for Quality Research* [e-journal], 13(4), pp. 1037-1054. doi: 10.24874/IJQR13.04-19.

Tansey, P., Spillane, J.P. and Meng, X., 2014. Linking response strategies adopted by construction firms during the 2007 economic recession to Porter's generic strategies. *Construction Management and Economics* [e-journal], 32(7-8), pp.705-724. doi: 10.1080/01446193.2014.933856.

Web of Science, 2017. *Clarivate Accelerating innovation*. [online] Available at: <http://www.webofknowledge.com> [Accessed 18 February 2017].

Zgodavova, K. and Bober, P., 2012. An innovative approach to the Integrated Management System development: SIMPRO-IMS WEB based environment. *Quality Innovation Prosperity* [e-journal], 16(2), pp.59-70. doi: 10.12776/qip.v16i2.69.

Zgodavova, K., Bober, P., Majstorovic, V., Monkova, K., Santos, G. and Juhaszova, D., 2020. Innovative methods for small mixed batches production system improvement: The case of a bakery machine manufacturer. Sustainability [e-journal],12(15), pp. 1-20. doi: 10.3390/su12156266.

Zhuang, Y., Liu, X., Nguyen, T., He, Q. and Hong, S., 2013. Global remote sensing research trends during 1991–2010: a bibliometric analysis. *Scientometrics* [e-journal], 96(1), pp.203-219. doi: 10.1007/s11192-012-0918-z.

Zott, C. and Amit, R., 2008. The fit between product market strategy and business model: implications for firm performance. *Strategic Management Journal* [e-journal], 29(1), pp.1-26. doi: 10.1002/smj.642.

ABOUT AUTHORS

Luís César Ferreira Motta Barbosa – (L.C.F.M.B) Federal Centre for Technological Education Celso Suckow da Fonseca (CEFET-RJ), Maracanã, Rio de Janeiro, Brazil, Department of Production Engineering (DEPRO), Prof., e-mail: luiscesarfmb@gmail.com, Author's ORCID: 0000-0003-4739-4556.

Maria Augusta Siqueira Mathias – (M.A.S.M.) São Paulo State University-UNESP, São Paulo, Brazil, Ph.D., e-mail: mas_mathias@yahoo.com, Author's ORCID: 0000-0002-8525-0249.

Manuel Gilberto Freitas Santos – (M.G.F.S.) Design School at the Polytechnic Institute of Cávado Ave (IPCA), Barcelos, Portugal, Prof., e-mail: gsantos@ipca.pt, Author's ORCID: 0000-0001-9268-3272.

Otávio José de Oliveira – (O.J.O.) Production Engineering Post Graduation Programme at São Paulo State University FEG/UNESP, Guaratinguetá - SP, Brazil, Ph.D., e-mail: otaviodeoliveira@uol.com, Author's ORCID: 0000-0002-5192-3644.

AUTHOR CONTRIBUTIONS

L.C.F.M.B. – investigation, data curation, original draft preparation, review and editing; M.A.S.M., M.G.F.S. – review and editing; O.J.O. – methodology, data curation, project administration, funding acquisition; L.C.F.M.B, M.A.S.M. – visualization, funding acquisition; M.G.F.S., O.J.O. – conceptualization, validation; M.G.F.S., O.J.O. – supervision; L.C.F.M.B, M.A.S.M., M.G.F.S., O.J.O. - formal analysis, resources.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Social Entrepreneurship as a Tool of Sustainable Development

DOI: 10.12776/QIP.V24I3.1463

Jozef Bľanda, Nataša Urbančíková

Received: 2020-05-18 Accepted: 2020-05-18 Published: 2020-11-30

ABSTRACT

Purpose: The article deals with the analysis of the perception of social entrepreneurship in Slovakia by social entrepreneurs. The main aim is to identify how social entrepreneurs perceive individual aspects of social entrepreneurship in Slovakia, including the role of social entrepreneurship in sustainable development.

Methodology/Approach: The analysis was based on data obtained from a questionnaire survey conducted among social entrepreneurs in Slovakia. The survey was attended by representatives of 35 social enterprises from Slovakia. A seven-point rating of Likert scale used within the questionnaire. The mode, median and interquartile range of answers were used to evaluate the questionnaire.

Findings: Social entrepreneurs pointed out that social entrepreneurship is still in development in Slovakia and several obstacles causing this situation. They also agreed that the most important benefit of social entrepreneurship in Slovakia is the effort to solve social problems. The research results show that the priority of social entrepreneurs in Slovakia is not to support sustainable development.

Research Limitation/implication: The research was limited by the number of social entrepreneurs who participated in the survey. More than half of social enterprises, registered in Slovakia were not willing to participate in the survey.

Originality/Value of paper: The article brings important findings in the field of social entrepreneurship, which are based on the practical experience of social entrepreneurs in Slovakia.

Category: Research paper

Keywords: social entrepreneurship; social entrepreneurs; sustainable development

1 INTRODUCTION

Nowadays, many countries, not only in Europe but also in the world, are constantly striving for progress and development. These countries focus mainly on supporting economic growth, sustainable development and improving the quality of life. Therefore, they need to find tools that can support the development of these areas. One of the most important tools for supporting sustainable development is social entrepreneurship. One of the most important tools in this field is social entrepreneurship, which is an important tool for sustainable development (Seelos and Mair, 2005a). Social entrepreneurship brings many benefits and solves many social, economic and environmental problems. The social economy and social enterprises employ more than 11 million people in the European Union, which is around 6% of total EU employment (European Commission, 2020b; Barna, 2012). Because of these positive benefits, it is necessary to analyze social entrepreneurship and provide support for social enterprises.

According to the European Commission's Social Business Report in Slovakia, low awareness and understanding of the concept of social entrepreneurship can be a major barrier to the development of social entrepreneurship in Slovakia (European Commission, 2014). This is the main reason why the focus should be given on the analysis of perception and awareness of social entrepreneurship is Slovakia. One of the most important stakeholders who play an important role in the development of social entrepreneurship is social entrepreneurs. The analysis of the perception of social entrepreneurship by social entrepreneurs can provide important information about social entrepreneurship in the county. Based on this information, it will be possible to evaluate the overall level of social entrepreneurship and to develop strategies designed to support the development of social entrepreneurship in Slovakia.

2 THEORETICAL BACKGROUND

To have a good understanding of the role of social entrepreneurship in sustainable development, it is necessary to define social entrepreneurship and its role in sustainable development. This section describes social entrepreneurship and its goals, social entrepreneurs and the role of social entrepreneurship in sustainable development.

2.1 Social Entrepreneurship

Social entrepreneurship is the process of creating value by finding new combinations of resources. These combinations are primarily aimed at creating social value by stimulating social change or meeting social needs (Lepoutre et al., 2013). Social entrepreneurship can take many forms and can exist in the form of small local businesses as well as large multinationals. The social benefits of

antisocial entrepreneurship can be targeted at small local communities or communities around the world (Brooks, 2009).

The social mission of social entrepreneurship is related to the fact that social enterprises must have a clearly defined social goal that they want to achieve (Certo and Miller, 2008). Social entrepreneurs and social enterprises develop products and services that directly meet basic human needs that other social institutions and enterprises are unable or unwilling to provide (Seelos and Mair, 2005a). The main difference between commercial entrepreneurship and social entrepreneurship is that social entrepreneurship focuses the creation of social value as its priority, while others focus more on making a profit (Mair and Martí, 2006). Commercial companies try to create added high value for their customers, but the task of social entrepreneurship is to create social value for their clients (Dees, 2007).

Ssocial entrepreneurship can be characterized as a process that helps accelerate social change and addresses the social needs in a way that is not focused in direct financial benefits for entrepreneurs (Mair and Martí, 2006). Zahra et al. (2009) associate social entrepreneurship with activities and processes that focus on defining, discovering and exploiting opportunities to strengthen social welfare by creating new enterprises or innovative managing existing enterprises. Innovation and innovative solutions are very important features of social entrepreneurship. In advanced economies, social entrepreneurs have become important actors, who are significantly involved in implementing changes to society by seeking innovative and cost-effective methods to solve social issues such as poverty or gender inequality (Zahra et al., 2008).

For other authors, such as Paredo and McLean (2006) and Emerson (2003), the most important for social entrepreneurship is recognizing, exploiting and creating opportunities. They also consider social entrepreneurship as an activity where individuals or groups of people focus on creating social value while being able to recognize and exploit business opportunities. The main feature of social entrepreneurship is the use of business innovations and the risk-taking ability associated with such entrepreneurship. Social entrepreneurs usually deal with areas where they see a lack of social needs or create new social opportunities that the public or private sector has failed to solve adequately.

According to Nicholls (2008), social entrepreneurship focuses mainly on the following priorities:

- the provision of goods and services that the market and the public sector do not want or are unable to provide;
- skills development;
- job creation;
- supporting the process of integration of socially excluded people back into society.

Santos (2012) points out on the possible significant impact of social entrepreneurship on the country's economic system because it can contribute to the development of new industries, introduce new business models, and try to redirect resources to solve social issues that are neglected by the state and society.

2.2 The Role of Social Entrepreneurship in Sustainable Development

Sustainable development is generally defined as development that aims to meet the needs of the current generation without compromising the needs of future generations. The concept of sustainable development was initially associated only with the protection and preservation of the environment. Nowadays, its interdisciplinary nature comes to the fore, which includes social, economic and environmental areas that are mutually reinforcing (European Commission, 2020a). In general, three basic aspects of sustainable development have been identified. It includes economic, social and environmental development (Bawa and Seidler, 2009). Sustainable development focuses on several objectives across different areas of development.

The main goal of sustainable development is to achieve long-term stability of the economy and the environment. It is necessary to ensure that economic, environmental and social factors are taken into account to achieve this goal. Sustainable development also aims to create and maintain prosperous and resilient social, economic and environmental systems (Pisano, 2012).

Several authors and studies emphasize the role of social entrepreneurship in sustainable development. Social entrepreneurship is considered an important tool for supporting sustainable development, as it contributes to the achievement of the internationally recognized goals of sustainable development (Seelos and Mair, 2005a). The role of social entrepreneurship in sustainable development is mostly based on the great potential of business ideas and activities in the social field (Jouen, 2012). In addition to social benefits, social enterprises also pursue environmental and economic sustainability (Barrutia and Echebarria, 2012).

Social entrepreneurship incorporates innovative approaches to addressing the environment issues and human rights and is widely regarded as an important element of countries' sustainable development (Mair and Noboa, 2003). Besides, social entrepreneurship addresses issues that are identified in the context of sustainable development as one of the most important. This includes poverty alleviation, the fight against climate change, inclusive growth, access to education for all and tackling social problems and so on. Social entrepreneurship is also concerned with providing products and services for organizations, individuals, society as a whole and future generations. It is well known that sustainable development cannot be achieved if the basic needs of poor and disadvantaged groups remain unsatisfied. Here, social entrepreneurship plays an important role, as it focuses primarily on alleviating the most serious problems of these groups of the population (Seelos and Mair, 2005b).

3 METHODOLOGY

The aim of the article is to analyze the perception of individual aspects of social entrepreneurship in Slovakia by social entrepreneurs. These aspects include the general perception of social entrepreneurship, benefits of social entrepreneurship, obstacles that hinder the development of social entrepreneurship and measures that can support the development of social entrepreneurship in Slovakia. The aim of the article is also to identify appropriate measures to support the development of social entrepreneurship in Slovakia.

The analysis of the perception of social entrepreneurship by social entrepreneurs was based on data obtained from a questionnaire survey conducted among social entrepreneurs in Slovakia. The questionnaire was based ed on questions used in the studies Mataboge (2014) and Swee-Sum (2016).

The questionnaire consisted of 14 questions, which were focused on various aspects of social entrepreneurship in Slovakia. The first group of questions concerned the general perception of social entrepreneurship by social entrepreneurs. Social entrepreneurs evaluated aspects of social entrepreneurship related to the tasks, priorities and goals of social entrepreneurs, the position and perception of social entrepreneurship by society. The second group of questions focused on the benefits that social entrepreneurship can bring to the individuals and society as a whole. The third group of questions concerned the evaluation of identified possible obstacles that hinder the development of social entrepreneurship and the establishment of social enterprises in Slovakia. Another group of questions concerned measures that would support the development of social entrepreneurship in Slovakia. Respondents were also asked what their motivation was to engage in social entrepreneurship and what real problems they faced. The questionnaire survey was conducted during February and March 2020 in the form of an electronic questionnaire and a telephone interview. Representatives of all social enterprises that were officially registered in the register of social enterprises of the Ministry of Labor, Social Affairs and Family of the Slovak Republic until 10th February 2020 were asked to participate in the survey. A total of 85 social enterprises were contacted. Out of the total number of 85 contact social entrepreneurs, we received answers from 35 of them.

The analysis used a 7-point Likert scale, on which respondents evaluated aspects of social entrepreneurship, where 1 means strong disagreement and 7 means strong agreement. Mode, median, IQR, and average of responses were used to evaluate responses. The mode indicates which response occurred the most frequently. The median gives the mean value of the answers and divides all the answers in half, sorted from the lowest value to the highest. IQR (inter-quartile range) represents the difference between the 3rd and 1st quartile of response distribution and indicates the variability of responses. In this case, the IQR can take values from 0 to 6. A lower IQR value means a higher degree of response variability and, conversely, a higher value means a lower rate of response

variability. A higher mode and median value indicates a higher rate of agreement and vice versa.

The questionnaire also contained open-ended questions. The questionnaire also contained open-ended questions concerning the practical experience of social entrepreneurs in the field of social entrepreneurship.

Based on the most important findings from the previous analysis, the measures for support development of social entrepreneurship were identified. These measures have been supplemented by opinions provided by selected experts for social entrepreneurship in Slovakia. Opinions of these experts were obtained by personal interviews. The experience of social entrepreneurship and qualifications were taken into account in the selection of experts who took part in the expert interviews. At the same time, the selection was based on the inclusion of experts from various fields of social entrepreneurship from the public, private and non-profit sectors and with different views on this field.

4 RESULTS AND FINDINGS

Based on the results, it can be summarized the perception of social entrepreneurs on selected aspects of social entrepreneurship in Slovakia. It covers preception of general characteristics of social entrepreneurship, benefits, barriers of development and measures to support social entrepreneurship.

4.1 Motivation to Establish a Social Enterprise

Social entrepreneurs can be motivated to start a social business by various factors. Germak and Robinson (2013) point out the basic factors that influence social entrepreneurs, such as internal motivation, helping society and non-financial goals.

The most frequently mentioned reason for setting up a social enterprise was to help disadvantaged people and solve social problems in their region. This is in line with the findings of Ghalwash, Tolba and Ismail (2017). They found out that social entrepreneurs are motivated mainly by social problems and challenges. The second most common reason is related to the benefits of the transition of a sheltered workshop to a social enterprise. Most social enterprises in Slovakia were created by the transformation from a sheltered workshop. The reason is the possibility of obtaining better government support, subsidies and possible help to a larger number of people in the case of a social enterprise compared to a sheltered workshop. According to the respondents, the advantage of social enterprises over sheltered workshops is that they do not have to keep separate accounts and employees are no longer tied to the workplace, they can also work from home and in another position. According to social entrepreneurs, the Ministry of Labor, Social Affairs and Family of the Slovak Republic itself also issued suggestions for sheltered workshops to transform themselves into social enterprises. Entrepreneurs also mentioned that they had a disadvantaged person

or a person with special needs as a significant factor that motivated them. A total of 63% of all social entrepreneurs participating in the survey said they had such a person in their family. The presence of a disadvantaged person in the family has a significant effect on the motivation of individuals to engage in social entrepreneurship.

Previous entrepreneurial experience has also played an important role in motivating to start a social business. As many as 81.5% of all social entrepreneurs who participated in the survey already had experience with entrepreneurship. Ghalwash, Tolba and Ismail (2017) also point to the importance of previous experiences. Mahmud et al. (2011) state that the presence of an entrepreneur in the family is also an important element. In this case, the presence of the entrepreneur in the family was not so important, as the ratio between the social entrepreneurs who had an entrepreneur in the family and those who did not was balanced. In the total number of respondents, 51.9% of social entrepreneurs had an entrepreneur in the family, and 48.1% did not.

4.2 The General Perception of Social Entrepreneurship

All respondents agreed that social entrepreneurship is a good idea with great potential, but in Slovakia, it is still in development. They observe shortcomings in this field, mainly related to low awareness and institutional arrangements.

Only 37% of social entrepreneurs consider social entrepreneurship in Slovakia to be well developed, and 63% think that there is not enough awareness of this entrepreneurship in Slovakia. According to social entrepreneurs, the most important characteristic of social entrepreneurship in Slovakia is new jobs creation. With this statement, the highest agreement of the answers of social entrepreneurs in Slovakia was observed. This is indicated by the IQR value, which is at the level of 0.5, and it means a minimum degree of variability of respondents' answers. Both mode and median of responses were 6, which means a high level of overall agreement of the respondents.

Social entrepreneurs also agreed with the statements such as the priority of social entrepreneurship is to reinvest profits to achieve social goals, social enterprises are good employers, social entrepreneurship is intended for people who want to change the unfavourable social situation.

Social entrepreneurs have agreed that social enterprises can compete with commercial enterprises. The level of agreement was not as significant here as in previous statements, but even so, a low level of variability of respondents' responses is observed. This is indicated by the IQR value, which is at the level of 1.5 and value of mode which is 6. This is an interesting finding, as the extent to which social enterprises can compete with commercial enterprises is debatable, as social enterprises are limited by focusing on their social goals. In addition, most of these enterprises employ disadvantaged people and people with special needs, who require a special approach and do not achieve high labour productivity compared to regular employees. On the other hand, the social

entrepreneurship experts who participated in the expert interviews disagreed with this statement. For example, Eva Havelková, a national analysis of the European Commission for gender and social issues and an expert in the field of social entrepreneurship, stated in an expert interview that social enterprises cannot compete with commercial enterprises. She argued that social enterprises achieve low productivity and flexibility compared to commercial enterprises. Marek Rakoš, the founder and director of one of the most successful social enterprises in Slovakia, is also of the opinion that social enterprises are not able to compete with commercial enterprises. He points out that social enterprises should focus primarily on areas and sectors that are not attracted to commercial enterprises due to low financial returns. However, abroad we can also find the opposite views of social entrepreneurship experts. Thust (2012), Deloitte's Director of Corporate Social Responsibility, points out that social enterprises have the potential to be competitive with mainstream businesses, but only with sufficient government support. Therefore, more attention should be given to the issue of the competitiveness of social enterprises.

4.3 Perception of the Benefits of Social Entrepreneurship

The value of the median and mode of response for all identified benefits of social entrepreneurship was 6, which means the overall consent of the respondents. The IQR value for all benefits was 1, which indicates a low degree of variability of responses. Table 1 shows the mode, median, IQR and mean of responses related to the perception of the benefits of social entrepreneurship in Slovakia.

Table 1 – Perception of the Benefits of Social Entrepreneurship

Benefit	*Mode*	*Median*	*IQR*	*Mean*
Integration of disadvantaged citizens into society	6	6	1	5.85
Addressing social inequality	6	6	1	5.48
Increasing employment	6	6	1	5.44
Sustainable development	6	6	1	5.30
Development of social services	6	6	1	5.22

The most important benefit of social entrepreneurship in Slovakia, identified by social entrepreneurs is the integration of disadvantaged people into society. This is also based on their motivation to establish a social enterprise. Most social entrepreneurs were motivated to establish a social enterprise because of the opportunity to help disadvantaged groups. The second most important benefit was the effort to address social inequality in the region. This benefit was important especially for the representatives of social enterprises founded by municipalities. The most vulnerable groups identified by social entrepreneurs were unskilled people, under-educated people, Roma people, and older people.

Social entrepreneurs agreed that the benefit of social entrepreneurship in Slovakia is also the support of sustainable development. However, this benefit was not as important as the previously mentioned benefits. Social entrepreneurs have placed support for sustainable development in the penultimate place. Based on these results, we can assume that social entrepreneurship in Slovakia is not considered an important tool to support sustainable development. However, social entrepreneurship is generally considered to be an important tool that can support sustainable development. Many authors and studies such as Seelos and Mair (2005b), Jouen (2012), Barrutia and Echebarria (2012), Mair and Noboa (2003), and Azmat (2013) point to the importance of social entrepreneurship in support sustainable development.

Based on this, it is necessary to focus on raising awareness of this role of social entrepreneurship among social entrepreneurs in Slovakia. This approach would help develop the potential of social entrepreneurship in the implementation of activities and strategies for sustainable development in Slovakia.

In addition to the benefits in Table 1, social entrepreneurship experts pointed to other important benefits of social entrepreneurship. They pointed out that the advantage of social entrepreneurship is also a better possibility of cooperation of several social enterprises, which can help each other. In commercially oriented companies, this form of cooperation is limited, as these companies usually only cooperate in cases where such cooperation is mutually beneficial.

4.4 Perception of Obstacles to the Development of Social Entrepreneurship

Social entrepreneurs have had to deal with many obstacles during the establishment and operation of social enterprises, and they have practical experience in this field. Table 2 shows the mode, median, IQR value and mean of responses of social entrepreneurs to individual obstacles to the development of social entrepreneurship in Slovakia. Table 2 shows the mode, median, IQR and mean of responses related to the perception of obstacles to the development of social entrepreneurship in Slovakia.

The most serious obstacle was the administrative complexity associated with social entrepreneurship. The value of the mode and median of the answers is 5, which indicates a high overall level of agreement of the respondents. The IQR value of this barrier is 3, which indicates a high degree of variability of responses. The reason is that several respondents do perceive the administrative burden as an obstacle but consider it to be also necessary to ensure transparency in this area. On the other hand, most social entrepreneurs perceive administration and bureaucracy to be a significant obstacle in setting up and managing a social enterprise.

Table 2 – Perception of Obstacles to the Development of Social Entrepreneurship

Benefit	*Mode*	*Median*	*IQR*	*Mean*
Administrative complexity	6	5	3.0	4.78
Unclear legislation	5	5	2.0	4.74
Lack of information on social entrepreneurship	6	5	3.0	4.58
Too much risk social entrepreneurs face	6	5	3.0	4.33
Social entrepreneurship is time-consuming	6	5	4.0	4.22
Fear of debt	5	5	2.0	4.19
High tax burden	4	4	3.5	4.11
Lack of personal preconditions of social entrepreneurs	5	4	2.0	4.04
Insufficient support from the government	3	3	2.5	3.70
Negative attitude to social entrepreneurship by society	2	4	3.0	3.62
Corruption in obtaining government support	2	2	2.5	2.67

Social entrepreneurs emphasized, for example, that the establishment of new social enterprises was planned rather than the transformation of sheltered workshops into social enterprises. All documents necessary for the registration and operation of a social enterprise have been prepared only for newly established enterprises and are not compatible with sheltered workshops, and it complicates their filling. Another problem is waiting times related to administrative. In some cases, the whole process of registration and other administrative duties takes up to 9 months. Entrepreneurs have to wait for confirmations and changes in the commercial register for up to 30 days.

The second most serious obstacle is the unclear legislation on social entrepreneurship. A high level of respondents' agreement was observed here. Entrepreneurs are often forced to seek legal advice on the interpretation of the law during the establishment of a social enterprise. Even lawyers sometimes have problems interpreting the law. Uncertainties in the legislation are reflected not only in the understanding of the law by entrepreneurs but mainly in the different interpretation of the legislation by various public institutions such as regional centres of social economy, labour offices and the Ministry of Labor, Social Affairs and Family of the Slovak Republic. It is not clear what the different types of contributions can be used for. For example, social entrepreneurs often find that the Public Procurement Office does not respect the possibility for public entities to reserve public contracts exclusively for registered social enterprises.

According to social entrepreneurs, another significant obstacle to the development of social entrepreneurship in Slovakia is the lack of public information and awareness about social entrepreneurship. This also corresponds

with the conclusions of the European Commission (2014) and social entrepreneurship experts, who also perceive low public awareness as one of the most serious obstacles.

The least serious obstacle to the development of social entrepreneurship in Slovakia is corruption in obtaining support. Social entrepreneurs pointed out that the whole system of support for social enterprises is more transparent as it was in the past. The administration associated with social entrepreneurship largely eliminates the possibility of corruption.

4.5 Perception of Measures to Support the Development of Social Entrepreneurship

In this part of the research, social entrepreneurs evaluated measures that could help in the development of social entrepreneurship in Slovakia. Table 3 shows the mode, median, IQR and mean of responses related to the perception of measures to support the development of social entrepreneurship in Slovakia.

Table 3 – Perception of Measures to Support the Development of Social Entrepreneurship

Benefit	*Mode*	*Median*	*IQR*	*Mean*
Financial support for social enterprises	6	6	0.75	5.85
Better access to public procurement for social enterprises	6	6	1.00	5.78
Raise public awareness of social entrepreneurship	6	6	0.50	5.65
Promotion of best practice examples	6	6	1.00	5.48
Support for municipalities in establishing social enterprises	6	6	1.00	5.37
Government award for social entrepreneurs	5	5	2.00	4.56
Incorporate information about social entrepreneurship into school curricula	5	5	3.50	4.15

Respondents included financial support and better access to public procurement for social enterprises as the most important measure that would help support the development of social entrepreneurship in Slovakia. Both the mode and the median of the responses in these measures indicate a strong agreement of the respondents. The IQR values indicate a low variability of the responses. According to social entrepreneurs, financial support should also take into account the overall resulting positive social impact of the social enterprise and not only the percentage of reinvested earnings.

Other measures proposed by social entrepreneurs related to financial support:

- Shortening the waiting period for reimbursement of wages costs;
- Increase in financial contributions in the initial phase of establishing a social enterprise;
- Tighter financial controls in companies and increased transparency (there are the cases that social enterprises receive contributions for more disadvantaged employees than they employ);
- The better setting of service vouchers, or their cancellation and provision of a direct subsidy for an invoice.

Although social entrepreneurs perceive financial support as the most important measure that will support the development of social entrepreneurship in Slovakia, significant financial support can be counterproductive. Social entrepreneurship experts who took part in expert interviews also pointed out that financial support from the government may not be an effective tool to support social entrepreneurship and social enterprises should strive for financial self-sufficiency. There are very successful entrepreneurship systems in developed countries where direct financial government support for social enterprises is limited.

Social entrepreneurs propose to increase the awareness of mayors of municipalities and other public entities about the possibilities of assigning public procurement contracts for social enterprises, as many of them are not aware of this possibility. An increase in the mandatory share of public procurements for social enterprises to cities, municipalities and self-governing regions would also help in the development of social entrepreneurship.

Incorporation of information on social entrepreneurship into school curricula is not perceived as an important tool to support the development of social entrepreneurship. It was ranked the last measure. On the other hand, the selected experts on social entrepreneurship emphasized the focus on incorporating the subjects of information about social entrepreneurship into the curricula of primary and secondary schools. Europpean Commission (2014) perceive the low awareness about social entrepreneurship as one of the biggest obstacles of development of social entrepreneurship in Slovakia. Education in this area of primary and secondary school pupils can be an important tool to improve this situation.

In addition to the measures listed in Table 3, social entrepreneurs also listed other practical measures that would help the development of social entrepreneurship in Slovakia. Inclusion of social enterprises and their activities in regional action plans would be an important tool. There have been attempts and efforts by social enterprises to do so, but they have been rejected by the relevant authorities. Simplifying the process of admitting disadvantaged people could help as well.

There is a problem that people with special needs often do not go to the employment office and therefore it is not possible to employ them.

5 CONCLUSION

This article was focused on the analysis of the perception of social entrepreneurship by social entrepreneurs in Slovakia. Based on the analysis, it may be concluded that social entrepreneurs in Slovakia perceive social entrepreneurship as a tool for solving social problems, but it is still in development in Slovakia. Only 37% of social entrepreneurs perceive social entrepreneurship in Slovakia to be well developed. One of the most important findings is related to the role of social entrepreneurship in sustainable development. Many authors and studies emphasize its importance in the application of sustainable development. However, social entrepreneurship in Slovakia is not perceived as a tool od sustainable development. Therefore, appropriate measures should be adopted to raise the awareness of social entrepreneurs about the potential of social entrepreneurship in this field.

REFERENCES

Azmat, F., 2013. Sustainable Development in Developing Countries: The Role of Social Entrepreneurs. *International Journal of Public Administration* [e-journal], 36(5), pp.293-304. doi: 10.1080/01900692.2012.756891.

Barna, C., 2012. Social economy: going local to achieve the Strategy Europe 2020. Romania Case. *Review of Applied Socio-Economic Research*, 3(1), pp.14-21.

Barrutia, J. and Echebarria, C., 2012. Greening regions: the effect of social entrepreneurship, co-decision and co-creation on the embrace of good sustainable development practices. *Journal of Environmental Planning and Management* [e-journal], 55(10), pp.1348-1368. doi: 10.1080/09640568.2012.657298.

Bawa, K.S. and Seidler, R., 2009. Dimensions of Sustainable Development. In: K.S. Bawa and R. Seidler, eds. 2009. *Dimensions of Sustainable Development*. EOLSS Publications. vol. I., chaper 1.

Brooks, A.C., 2009. *Social Entrepreneurship: A Modern Approach to Social Value*. Pearson Prentice Hall.

Certo, S. and Miller, T., 2008. Social entrepreneurship: Key issues and concepts. *Business Horizons* [e-journal], 51(4), pp.267-271. doi: 10.1016/j.bushor.2008.02.009.

Dees, J., 2007. Taking social entrepreneurship seriously. *Society* [e-journal], 44(3), pp.24-31. doi: 10.1007/BF02819936.

Emerson, J., 2003. The Blended Value Proposition: Integrating Social and Financial Returns. *California Management Review* [e-journal], 45(4), pp.35-51. doi: 10.2307/41166187.

European Commission, 2014. *A map of social enterprises and their eco-systems in Europe. Country Report: Slovakia*. [pdf] European Union. Availbable at: <https://ec.europa.eu/social/BlobServlet?docId=12999&langId=en> [Accessed 28 October 2020].

European Commission, 2020a. *Social Economy In The EU - Mercado Interior, Industria, Emprendimiento Y Pymes - European Commission*. [online] Available at: <http://ec.europa.eu/growth/sectors/social-economy_es> [Accessed 16 May 2020].

European Commission, 2020b. *Prístup EÚ k trvalo udržateľnému rozvoju 2020*. [online] Available at: <https://ec.europa.eu/info/strategy/international-strategies/sustainable-development-goals/eu-approach-sustainable-development_sk> [Accessed 10 March 2020].

Germak, A. and Robinson, J., 2013. Exploring the Motivation of Nascent Social Entrepreneurs. *Journal of Social Entrepreneurship* [e-journal], 5(1), pp.5-21. doi: 10.1080/19420676.2013.820781.

Ghalwash, S., Tolba, A. and Ismail, A., 2017. What motivates social entrepreneurs to start social ventures? *Social Enterprise Journal* [e-journal], 13(3), pp.268-298. doi: 10.1108/SEJ-05-2016-0014.

Jouen, M., 2012. *The Cohesion Pact: Weathering the Crisis.* [pdf] Notre Europe - Jacques Delors Institute. Available at: <https://institutdelors.eu/wp-content/uploads/2018/01/cohesionpolicy_m.jouen_notreeurope_april2012.pdf> [Accessed 28 October 2020].

Lepoutre, J., Justo, R., Terjesen, S. and Bosma, N., 2013. Designing a global standardized methodology for measuring social entrepreneurship activity: the Global Entrepreneurship Monitor social entrepreneurship study. *Small Business Economics* [e-journal], 40(3), pp.693-714. doi: 10.1007/s11187-011-9398-4.

Mahmud, M.M.A., Mohamed, Z., Rezai, G. and Shamsudin, M.N., 2011. The Influence of Personality Traits and Demographic Factors on Agro-Entrepreneurship Education among Graduates. In: IEDRC (International Economics Development and Research Center), *International Conference on Innovation, Management and Service.* Singapore, Singapore, 16-18 September. Singapore: IACSIT Press. pp.343-347.

Mair, J. and Martí, I., 2006. Social entrepreneurship research: A source of explanation, prediction,f and delight. *Journal of World Business* [e-journal], 41(1), pp.36-44. doi: 10.1016/j.jwb.2005.09.002.

Mair, J. and Noboa, E., 2003. *Social Entrepreneurship: How Intentions to Create a Social Enterprise Get Formed*. IESE Working Paper No. D/521. Available at SSRN: <https://ssrn.com/abstract=462283> [Accessed 28 October 2020].

Mataboge, D.M., 2014. *Social entrepreneurship among Diepsloot youth*. Master thesis. University of the Witwatersrand. Available at: <http://wiredspace.wits.ac.za/bitstream/handle/10539/14899/DINAH%20MATABOGE%20%20RESEARCH%20REPORT%20FINAL%20revised%209%20June%202014.pdf?sequence=2> [Accessed 28 October 2020].

Nicholls, A., 2008. *Social entrepreneurship: New models of sustainable social change*. OUP Oxford.

Peredo, A. and McLean, M., 2006. Social entrepreneurship: A critical review of the concept. *Journal of World Business* [e-journal], 41(1), pp.56-65. doi: 10.1016/j.jwb.2005.10.007.

Pisano, U. 2012. Resilience and Sustainable Development: Theory of resilience, systems thinking. *European Sustainable Development Network (ESDN)*, 26, 50p.

Santos, F., 2012. A Positive Theory of Social Entrepreneurship. *Journal of Business Ethics*, 111(3), pp.335-351.

Seelos, C. and Mair, J., 2005a. Social entrepreneurship: Creating new business models to serve the poor. *Business Horizons* [e-journal], 48(3), pp.241-246. doi: 10.1016/j.bushor.2004.11.006.

Seelos, C. and Mair, J., 2005b. *Social Entrepreneurship - The Contribution of Individual Entrepreneurs to Sustainable Development*. IESE Business School Working Paper No. 553. Available at SSRN: <https://ssrn.com/abstract=701181> [Accessed 28 October 2020].

Swee-Sum, L. and Weina, Z., 2016. *Public Perception Study on Social Enterprises in Singapore.* [pdf] Singapore: Asia Centre for Social Entrepreneurship & Philanthropy, NUS Business School. Available at: <https://www.raise.sg/images/resources/pdf-files/SE-Public-Perception-Study-Full-Report.pdf> [Accessed 28 October 2020].

Thust, B., 2012. Social Enterprise Can Compete With The Mainstream - But It Needs Tailored Support. *The Guardian*, [online]. 2 July 2012. Available at: <https://www.theguardian.com/social-enterprise-network/2012/jul/02/social-enterprise-compete-mainstream> [Accessed 17 May 2020].

Zahra, S.A., Gedajlovic, E., Neubaum, D.O. and Shulman, J., 2009. A typology of social entrepreneurs: Motives, search processes and ethical challenges. *Journal of Business Venturing* [e-journal], 24(5), pp.519-532. doi: 10.1016/j.jbusvent.2008.04.007.

Zahra, S.A., Rawhouser, H.N., Bhawe, N., Neubaum, D.O. and Hayton, J.C., 2008. Globalization of social entrepreneurship opportunities. *Strategic Entrepreneurship Journal* [e-journal], 2(2), pp.117-131. doi: 10.1002/sej.43.

ABOUT AUTHORS

Jozef Bľanda – (J.B.) Technical University of Košice, Košice, Slovak Republic, Department of Regional Sciences and Management, PhD. Student, e-mail: jozef.blanda@tuke.sk, Author's ORCID: 0000-0003-1063-7315.

Nataša Urbančíková – (N.U.) Technical University of Košice, Košice, Slovak Republic, Department of Regional Sciences and Management, Assoc. Prof., e-mail: natasa.urbancikova@tuke.sk, Author's ORCID: 0000-0002-2158-5517.

AUTHOR CONTRIBUTIONS

J.B. – formal analysis, investigation, resources, data curation, draft preparation; N.U. – validation, review and editing, supervision; J.B, N.U. – methodology.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Consistency of Pairwise Comparisons and Its Role in Optimal Detection of Customers' Preferences

DOI: 10.12776/QIP.V24I3.1475

Filip Tošenovský

Received: 2020-07-02 Accepted: 2020-10-12 Published: 2020-11-30

ABSTRACT

Purpose: This paper analyses a problem that originates in the weighted-average model, a mathematical construct introduced by the theory of multicriteria decision-making that can be used to detect what product a customer desires. The problem occurs because the model needs to know the weight the customer assigns to each product feature, aside from the levels of all the product characteristics, in order to calculate the overall value of the product. And since by one approach the weights can be estimated by optimization, the question arises which optimization criterion to select for the procedure, as different criteria will lead to different weights and thus to different product evaluations. The paper analyses the problem in connection with the so-called consistency of pairwise comparisons, which are utilized in the optimization and describe how much the customer prefers one product feature to another. The analysis shows that the problem of which criterion to use to calculate the weights can be eliminated if the pairwise comparisons are consistent. The analysis is performed within pre-defined criteria and is supplemented with case studies supporting the findings.

Methodology/Approach: Linear algebra, optimization techniques, case studies.

Findings: The results represent a prescription customers can use if they want to avoid the pitfalls of selecting a specific optimization criterion when informing the product maker about what they want based on the weighted-average model.

Research Limitation/Implication: The results are related to a specific decision-making model, although that model is still very general and natural.

Originality/Value of paper: The problem of selecting an optimization criterion to determine decision weights is not discussed in the theory.

Category: Technical paper

Keywords: customer product; decision-making weights; consistency

1 INTRODUCTION

In quality management, the role of customers is of paramount importance and many quality techniques are related to this concept (Zgodavova and Slimak, 2008). It has therefore been historically imperative to learn what they desire so that an appropriate product could be designed, manufactured and ultimately delivered. Since many aspects or product characteristics enter the design of such products, and they often fight each other in the sense that an improvement of one feature deteriorates another, one might think of employing a discipline that is capable of setting up these product characteristics in such a way so as to turn the product design to a reasonable compromise, when it comes to the customer's perceptions and desires. Among such disciplines, the theory of multicriteria decision-making (MDM) has had its sound position, having been tailored exactly for these kinds of problems. Generally speaking, as it doesn't have to concern only product designs, the theory tries to solve the problem of which decision to make, or which product design to choose in our context, when more decision-making criteria, or more product characteristics, are to be taken into account. The theory presents a variety of methods that try to pick a reasonably good decision, or product design. A class of these methods requires knowledge of weights or importance of the decision-making criteria, or product characteristics, in order to find a compromise among all the available decisions or product designs. These methods evaluate each decision, or product design, V by the expression $A_1(V)v_1 + \cdots + A_n(V)v_n$, where $A_i(V)$ is the level of the i-th product characteristic under the considered design V and v_i is the nonnegative weight of that characteristic. All weights sum to one. The higher the value of the summation, the more preferred the design V.

One of the fundamental questions the theory tries to answer is how to select the weights, without which the calculation cannot be obviously performed. Several classes of methods exist in this regard. In one class, the methods are deterministic (Ishizaka and Nemery, 2013), whereas in another class the methods are stochastic and deal with uncertainty (Levy, 2015). The latter, based on the probability theory, is suitable for finding typical weights for an entire group of decision-makers, or customers in our context, when the group is unknown as a whole and statistical principles must be applied to deduce the properties of that group on the basis of an analysis of its subsets. Yet another class of methods that model a different source of uncertainty in the decision-making process is the one employing the fuzzy set theory (Park et al., 2009; Wang, Kevin and Wang, 2009; Ye, 2010). Many of these methods use the so-called matrix of pairwise comparisons S which contains ratios of the unknown weights (Saaty, 2005). The ratios describe the magnitude of the weights when they are compared to one another. The higher the ratio, the more important the product characteristic represented by the weight in the numerator of the ratio, compared to the importance of the other characteristic represented by the weight in the denominator. If the ratio equals one, the two weights are the same, and the corresponding characteristics are equally important. The reason for this construct

is that it is usually simpler for the customer, and thus more accurate, one would expect, to state such a ratio than to provide the weights directly.

Let $S = s_{ij} = v_i/v_j$. Each element s_{ij} is usually defined using Saaty's scale of grades ranging from one to nine (Saaty, 2005). The grades describe to what extent one product characteristic is preferred to another. The bottom grade of one means the two corresponding characteristics, the i-th and the j-th, are equally important, whereas the upper grade of nine prefers as much as possible the i-th characteristic to the j-th. Each grade has its specific verbal description that details the extent to which one characteristic is preferred to another. Such a description enables the customer to better quantify their perceptions about what is important and what is not. The elements s_{ij} are inserted in the matrix S so as to make it reciprocal: $s_{ij} = 1/s_{ji}$. The main diagonal of the matrix naturally contains only ones. In the following text, it is assumed that the matrix has these properties and its size is at least 2×2, i.e. two or more product characteristics are involved in the analysis related to their weights.

Given the matrix of pairwise comparisons, containing information about the opinions of the customer on the importance of the product characteristics, diverse methods are subsequently applied to evaluate the matrix. The methods result in a set of weights v_i. These methods also include approaches that seek the weights by optimizing a mathematical expression which is a function of the elements of S. Such an optimization searches for the weights that, in a sense, bring the ratios v_i/v_j as close as possible to the provided values s_{ij}. In order for this calculation to make sense, the matrix S must make sense in the first place. This is the reason why the matrix is required to be consistent. An n-by-n matrix is consistent if its elements satisfy the equations $s_{ij} = s_{im}s_{mj}$ for all $i, j, m = 1, 2, \dots, n$. The amount of (in)consistency is measured by the inconsistency index $(\lambda - n)/(n - 1)$, where λ is the largest eigenvalue of S. If the index is smaller than 0.1, the amount of consistency is considered good enough. In the case of a (fully) consistent matrix, it can be shown (Shiraishi, Obata and Daigo, 1998) that $\lambda = n$ and the index is thus zero. Generally, the smaller the index, the better.

If the matrix S has a reasonably high consistency, the weights based on the matrix can be calculated. As has been outlined, such calculations may utilize an expression to be optimized, an optimization criterion O. The optimization occurs when the calculation provides the weights v_i that minimize O, an expression based on differences between v_i/v_j and s_{ij}. Some of these expressions are provided later in the text. Naturally, the resulting weights generally depend on the type of the optimization criterion selected, which raises the question which optimization criterion to choose. One possibility is to employ the principles of goal programming for the set of available optimization criteria – it is possible to adopt optimization criteria $O_1, \dots, O_k$, the optimal values of which are $o_1, \dots, o_k$, respectively, if the criteria are used individually for finding the weights, and then find the weights that minimize $\sum_i (O_i - o_i)^2$. This would take into account all the optimization criteria simultaneously. Such procedure, however, would not be

elementary, as some of the terms in the summation can be expected to be nonlinear and even nonconvex functions of the weights, meaning that a sofware-supported numerical procedure would be required to find only a local minimum of the expression at best, not even the global minimum. It is more convenient to select a single optimization criterion to avoid these mathematical problems. Although this may still result in a non-elementary procedure, the approach will generally be simpler. Of course, the question which optimization criterion to select still remains unanswered.

This paper discusses the problem of selection of an optimization criterion, exploiting the concept of consistency of the matrix of pairwise comparisons *S*, because not only does this concept rationalize the matrix itself, but it also significantly contributes to solving the problem of which optimization criterion to use when finding the customer's weights. The analysis focuses on a specific class of optimization criteria, which contains many popular mathematical expressions used for these purposes, and answers the question to what extent an element of this class plays a role in the whole procedure of finding the weights in the case of full consistency of the matrix *S*.

2 EXACT WEIGHTS

Let us start by analyzing the set of linear equations with *n* unknown weights v_i:

$$\begin{gathered} v_i = s_{ij} v_j, 1 \le i < j \le n, \\ \sum_{i=1}^{n} v_i = 1. \end{gathered} \tag{1}$$

If we wanted a solution to (1) to represent true weights, inequalities should also be attached to (1) – each v_i should be nonnegative. We shall see, however, that a solution to (1), if it exists, automatically meets this condition. Let us also note that a solution to (1) trivially satisfies the equation $v_i = s_{ij} v_j$ for $i = j$, since $s_{ii} = 1$, and given the reciprocity of *S*, $v_i = s_{ij} v_j$ also holds for $i > j$. Thus, if (1) holds, then $v_i = s_{ij} v_j$ holds for *all* the indices $i, j = 1, 2, \dots, n$.

In the matrix form, equations (1) can be expressed as:

$$\underbrace{\begin{pmatrix} 1 & -s_{12} & 0 & .. & 0 & 0 \\ 1 & 0 & -s_{13} & .. & 0 & 0 \\ : & : & : & : & : & : \\ 1 & 0 & 0 & .. & 0 & -s_{1n} \\ 0 & 1 & -s_{23} & .. & 0 & 0 \\ : & : & : & : & : & : \\ 0 & 1 & 0 & .. & 0 & -s_{2n} \\ : & : & : & : & : & : \\ 0 & 0 & 0 & .. & 1 & -s_{n-1,n} \\ 1 & 1 & 1 & .. & 1 & 1 \end{pmatrix}}_{M} \cdot \begin{pmatrix} v_1 \\ v_2 \\ : \\ : \\ : \\ : \\ : \\ : \\ : \\ v_n \end{pmatrix} = \underbrace{\begin{pmatrix} 0 \\ 0 \\ : \\ 0 \\ 0 \\ : \\ 0 \\ : \\ 0 \\ 1 \end{pmatrix}}_{b}. \tag{2}$$

The matrix M has $(n-1)(n-2)\cdot\ldots\cdot 2\cdot 1+1=(n-1)!+1$ rows and n columns, so its rank is at most n. Looking at the second, third, …, n-th column of this matrix, these columns are clearly linearly independent because only the trivial linear combination of these column vectors-the combination involving zero coefficients-yields the null vector (Bican, 2000). Let us see what happens when the first column of *M* is added to the group of the remaining columns. The new group of vectors cannot be linearly dependent because if it was, the first column would be a linear combination of the other $(n-1)$ columns with some coefficients $k_2,\ldots,k_n$. This would mean that:

$$k_2 = 1/-s_{12},\ k_3 = 1/-s_{13},\ldots,\ k_n = 1/-s_{1n}, \tag{3}$$

and so, given the last row of the matrix, $1=(1/-s_{12})+\cdots+(1/-s_{1n})$ would have to hold, which is impossible given that s_{ij}'s are all positive. Therefore, the first column of *M* cannot be a linear combination of its other columns, in other words, the rank of *M* is *exactly* n.

Let us now extend *M* by adding the column vector *b*, and write the matrix equation:

$$b = r_1\begin{pmatrix} 1 \\ 1 \\ : \\ 1 \\ \sim \\ 1 \end{pmatrix} + r_2\begin{pmatrix} -s_{12} \\ 0 \\ : \\ 0 \\ \sim \\ 1 \end{pmatrix} + \ldots + r_n\begin{pmatrix} 0 \\ 0 \\ : \\ -s_{1n} \\ \sim \\ 1 \end{pmatrix}, \tag{4}$$

for some coefficients r_i. The symbol "~" replaces the n-th, n+1-st, …, the second-to-last row of M. Let S be fully consistent: $s_{ij} = s_{im}s_{mj},\ i,j,m = 1,2,\dots,n$. Then, in particular, $s_{i1} = s_{im}s_{m1}, i = 1,\dots,n-1, m > i$, holds. For this reason, by setting up $r_i = s_{i1}(1 + s_{21} + \cdots + s_{n1})^{-1}$, $i = 1,\dots,n$, we get:

$$r_i - r_m s_{im} = 0, i = 1,\dots,n-1, m > i, \tag{5}$$

$$1 = \sum_i r_i, \tag{6}$$

which is the same as (4). In other words, nonzero coefficients r_i were found so that (4) is satisfied, and so the matrix M and the extended matrix (M, b) have the same rank because the last column of the extended matrix, the column b, is linearly dependent on its other columns by (4). By the Frobenius theorem (Bican, 2000), this means that (1) has a solution. The solution will represent "exact weights" v_i in the sense that their ratio (the division is possible-see the discussion below) equals *exactly* the corresponding element from the matrix S. What's more, the dimension of the set of all solutions to the equations $M\mathbf{v} = \mathbf{0}$ is known to be generally n – rank(M) (Bican, 2000), which is zero now. This means that the solution to the equations $M\mathbf{v} = b$ is determined uniquely (Bican, 2000). *The main result of this paragraph is that a fully consistent matrix S implies existence of a unique set of exact weights, or a unique solution to (1).*

The opposite implication is also true, however (Ramík and Perzina, 2008). If (1) has a unique solution, then S is fully or perfectly consistent. Therefore, the standard matrix of pairwise comparisons S, which is reciprocal, contains positive elements only and ones on its main diagonal, is fully or perfectly consistent *if and only if* there exist exact weights satisfying (1). When this happens, the exact weights are determined uniquely.

When it comes to the resulting exact weights, none of the weights is zero. If a weight was zero, then all the weights would have to be zero to satisfy $v_i = s_{ij}v_j$, but then the weights could not sum to one, so (1) would be violated. Further, we also know that all the weights are positive. If they were all negative, they couldn't sum to one again. If some of them were positive and others negative, $v_i = s_{ij}v_j$ couldn't hold. The only solution is thus a set of positive numbers that represent true weights.

To give an example of this situation, let:

$$S = \begin{pmatrix} 1 & 1/6 & 1/2 \\ 6 & 1 & 3 \\ 2 & 1/3 & 1 \end{pmatrix}. \tag{7}$$

The matrix satisfies our assumptions and is consistent-the index of inconsistency is zero, as the largest eigenvalue of the matrix is 3 (EqsQuest, 2017). Regarding

the rank of M and its extension (M,b), we have by elementary transformations (Bican, 2000):

$$M = \begin{pmatrix} 1 & -1/6 & 0 \\ 1 & 0 & -1/2 \\ 0 & 1 & -3 \\ 1 & 1 & 1 \end{pmatrix} \sim \ldots \sim \begin{pmatrix} 1 & -1/6 & 0 \\ 0 & 1/6 & -1/2 \\ 0 & 0 & 0 \\ 0 & 0 & 4.5 \end{pmatrix} \Rightarrow h(M) = 3 \tag{8}$$

$$(M,b)^T = \begin{pmatrix} 1 & 1 & 0 & 1 \\ -1/6 & 0 & 1 & 1 \\ 0 & -1/2 & -3 & 1 \\ 0 & 0 & 0 & 1 \end{pmatrix} \sim \ldots \sim \begin{pmatrix} 1 & 1 & 0 & 1 \\ 0 & 1/6 & 1 & 7/6 \\ 0 & 0 & 0 & 27/6 \\ 0 & 0 & 0 & 1 \end{pmatrix} \Rightarrow h(M,b) = 3 \tag{9}$$

Since the two matrices have the same rank of 3, the exact weights exist uniquely. Their values are $v_1 = 0.\overline{11}$, $v_2 = 0.\overline{66}$, $v_3 = 0.\overline{22}$, and they satisfy $v_i = s_{ij}v_j$, $i,j = 1,2,3$, $v_1 + v_2 + v_3 = 1$, where s_{ij} is the element of S from its i-the row and j-the column.

3 CONSISTENCY AND CRITERIA FOR FINDING WEIGHTS

If S is not fully consistent, the exact weights do not exist, as we have seen. Another possibility then is to seek weights whose ratio is in a sense close to the corresponding elements s_{ij}, which reflect the customer's feelings about the ratios. Different optimization criteria were defined for this purpose-by optimizing these criteria, such an accession of the weights to the elements of S can be carried out. Standard optimization criteria include the expressions:

$$\sum\nolimits_{i,j} (s_{ij} - v_i/v_j)^2, \tag{10}$$

$$\sum\nolimits_{i,j} (\ln(s_{ij}) - \ln(v_i/v_j))^2 \tag{11}$$

and the weights are obtained by minimizing one of these criteria. This way, "the least squares method" (LS) and "the logarithmic least squares method" (LLS) were defined, the latter being also known as the method of geometric average, as the weights minimizing (11) can be expressed explicitly as a normalized geometric mean. From the mathematical point of view, to solve (10) or (11) means to seek the global extreme of the function of the weights (10) or (11) on the set $L = \{\boldsymbol{v}: \sum_i v_i = 1\} \cap \{\boldsymbol{v}: v_i > 0, i = 1, \ldots, n\}$. In the case of a fully consistent matrix S, when the exact weights exist, i.e. $s_{ij} = v_i/v_j$, and the weights are positive, as we have seen, so that the vector of the weights belongs to L, expressions (10) and (11) equal zero at the point represented by these exact weights. The two expressions *cannot* take on a lower value by their design,

which means that the vector of exact weights is the point of global minimum of (10) and (11) on *L*. This is a rather simple but important result, because while minimizing (11) results in an explicit formula for the weights, the normalized geometric mean (Ramík and Tošenovský, 2013):

$$v_i = v_i^* / \sum_{j=1}^{n} v_j^*, v_j^* = \left(s_{j1} s_{j2} \dots s_{jn}\right)^{1/n} \text{ for } j = 1,2, \dots, n \tag{12}$$

minimizing (10), for instance, is much more complicated. Many scholarly texts deal with the complexity of constrained optimization of similar functions (Bonnans et al., 2006; Nocedal and Wright, 2006; Bertsekas, 2016), and there is no complete theory in this respect to this date! Regarding the global minimum of (10) and (11), the same conclusion is clearly valid not only for LS and LLS, but for any criterion of the form $g(v_1, \dots, v_n) = \sum_{i,j}(f(s_{ij}) - f(v_i/v_j))^2$, the minimization of which on *L* is to provide the suitable weights.

Therefore, if the matrix of pairwise comparisons S is fully consistent, the global minimum of any such function g defined on L, with no other conditions imposed on this function, is at the point represented by the vector of exact weights. Since that vector is determined uniquely, the resulting weights, the exact ones, are the same regardless of what optimization criterion g is used for their calculation. In other words, the discussion on which criterion g to choose to find the weights is pointless, as all such criteria will give us the same vector of weights in the case of consistent S!

The idea is portrayed in Fig.1 which describes the case of the optimization criterion $g(v_1,v_2) = g(x,y)$ for a two-weight problem with the function $f(\cdot) = \sin(\cdot)$ and the matrix *S* made up of elements $s_{11} = s_{22} = 1$, $s_{12} = 2$, $s_{21} = 0.5$.

Figure 1 shows that it may not be elementary to find the point of global minimum of the corresponding optimization criterion. When *S* is fully consistent, however, it is possible to resort to a far simpler criteron, such as the one used by LLS, to get the same point of extreme, i.e. the same weights. In this example, LLS yields $v_1 = x = 0.66, v_2 = y = 0.33$.

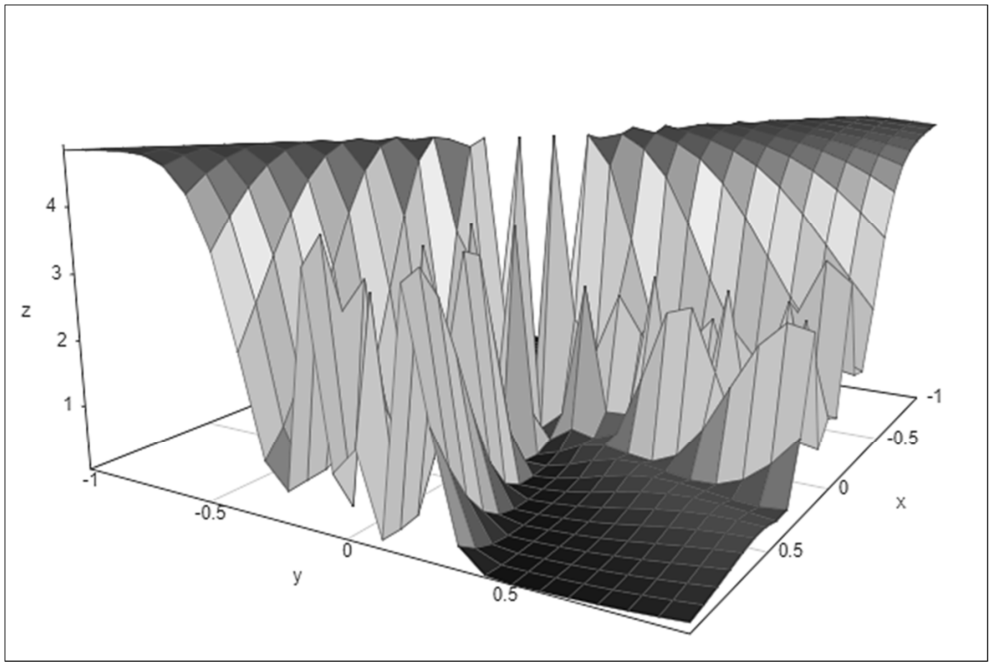


Figure 1 – An Example of a More Complicated Optimization Criterion Z = G(X,Y)

From what has been said so far, it should be clear that before starting to solve an MDM problem, a working matrix of pairwise comparisons *S* with a high degree of consistency should be first constructed. Hardly ever will it happen that the decision-maker, or the customer in this case, will manage to set up a perfectly consistent matrix. Then, one could try to adjust its elements to a *small* extent to make the matrix *fully consistent*. Such a procedure is not going to be simple unless a systematic approach is adopted. And such an approach can be designed. To turn a highly consistent matrix to the fully consistent one, we could try to solve the auxiliary optimization problem:

$$\min_{n_{11},\dots,n_{nn}} \sum_{i,j} n_{ij}^2 \tag{13}$$

subject to:

$$\left(s_{ij} + n_{ij}\right)\left(s_{jk} + n_{jk}\right) = \left(s_{ik} + n_{ik}\right), \qquad i,j,k = 1,\dots,n. \tag{14}$$

Viewing (13), (14), we want to change the elements of the not quite consistent matrix *S* to make it fully consistent, as described by (14), the change being expressed by the terms n_{ij}, but we want that change to be as small as possible, so that the change still reasonably reflects the original intentions of the decision-

maker, or the customer. This procedure is not ideal in its current form, however, as it works with quite a few variables and constraints, and thus becomes cumbersome. Fortunately, it turns out it suffices if the constraints (14) are valid only for the indices $i < j < k$, i.e. for the elements above the main diagonal of the matrix S. If the problem (13), (14) is solved for these indices only, and the elements on the main diagonal of S are left to be equal to one, while the elements below the main diagonal are automatically changed to be reciprocal to the elements that solved (13), (14), the changed matrix will be fully consistent as is shown below. Moreover, small enough changes to the elements above the main diagonal will lead to small changes in the elements below the main diagonal because of the continuity of the reciprocal function. Thus one can focus only on altering as little as possible the elements above the main diagonal of S to secure its full consistency.

To see this, if constraints (14) are satisfied for the indices $i < j < k$, i.e. the changed matrix is consistent in the elements above its main diagonal, then obviously:

$$s_{kj}s_{ji} = \left(\frac{1}{s_{jk}}\right)\left(\frac{1}{s_{ij}}\right) = \frac{1}{s_{ik}} = s_{ki}, \tag{15}$$

and so the changed matrix is consistent also in the elements below its main diagonal. If $i < j > k$, then we have, for the case $i < k < j$:

$$s_{ij}s_{jk} = \frac{s_{ij}}{s_{kj}} = \frac{s_{ij}s_{ik}}{s_{kj}s_{ik}} = \frac{s_{ij}s_{ik}}{s_{ij}} = s_{ik}, \tag{16}$$

and, for the case $k < i < j$:

$$s_{ij}s_{jk} = \frac{s_{ij}s_{ki}}{s_{kj}s_{ki}} = \frac{s_{kj}}{s_{kj}s_{ki}} = s_{ik}, \tag{17}$$

so the changed matrix is also consistent if the property is checked with the elements both from above and below its main diagonal. Finally, to check this property with the elements from its main diagonal participating – the property is obviously valid if both the elements are from the main diagonal, i.e. they are both equal to one. If only one of them equals one, the result is also straightforward:

$$\begin{gathered} s_{ij}s_{jk} = s_{ii}s_{ik} = s_{ik} \\ \text{or} \\ s_{ij}s_{jk} = s_{ij}s_{jj} = s_{ij} = s_{ik}. \end{gathered} \tag{18}$$

To give an example of the procedure, we use the following matrix of pairwise comparisons with the amount of incosistency equal to 0.005.

$$S = \begin{pmatrix} 1 & 4 & 8 & 3 \\ 1/4 & 1 & 2 & 1/2 \\ 1/8 & 1/2 & 1 & 1/4 \\ 1/3 & 2 & 4 & 1 \end{pmatrix} \tag{19}$$

Solving (13), (14) in Matlab for the elements above the diagonal of *S*, we obtain:

$$\begin{aligned} n_{12} = 0.03, n_{13} = -0.03, n_{14} = -0.03, \\ n_{23} = -0.02, n_{24} = 0.24, n_{34} = 0.12. \end{aligned} \tag{20}$$

Thus, the adjusted matrix of pairwise comparisons is, after some diminutive rounding:

$$S^* = \begin{pmatrix} 1 & 4.03 & 7.97 & 2.97 \\ 0.2481 & 1 & 1.98 & 0.74 \\ 0.12547 & 0.50505 & 1 & 0.37 \\ 0.3367 & 1.35135 & 2.7027 & 1 \end{pmatrix}. \tag{21}$$

The highest eigenvalue of S^* is four, therefore the matrix is fully consistent. Still, it hasn't changed much compared to the matrix *S*.

4 CONCLUSION

This paper analyzed relations between the consistency of the matrix of pairwise comparisons and the mathematical form of an optimization criterion which, using the comparisons, determines the weights or preferences provided by the customer before the overall product value, as perceived by the customer, is calculated. The impulse for the analysis was the fact that the resulting weights depend on the optimization criterion selected if the matrix of pairwised comparisons, used for the optimization, is not fully consistent. The conclusion of the analysis is such that within a general class of optimization criteria, it does not matter which criterion is selected for the calculation of the weights as long as the utilized matrix of pairwise comparisons is fully consistent. Since the optimization criteria result in the same set of weights in such cases, it makes sense to define the pairwise comparisons consistently, so that subsequently, any optimization criterion, and preferably the one that simplifies the calculations, can be selected to calculate the weights. Since it will be almost always difficult for the customer to define the pairwise comparisons in a fully consistent way immediately, the paper incorporated a procedure that will help the customer convert the provided pairwise comparisons to fully consistent ones. The procedure is most easily implemented with a suitable software incorporating optimization algorithms.

ACKNOWLEDGEMENTS

This paper was prepared under specific research project No. SP2020/51 of the Faculty of Materials Science and Technology, VŠB-TU Ostrava, with support from the Ministry of Education of the Czech Republic.

REFERENCES

Bertsekas, D., 2016. *Nonlinear Programming*. 3rd Edition. Massachusetts: Athenas Scientific.

Bican, L., 2000. *Lineární algebra a geometrie*. Prague: Academia.

Bonnans, J.F., Gilbert, J.C., Lemarechal., C. and Sagastizábal, C.A., 2006. *Numerical Optimization*. Berlin: Springer International Publishing.

EqsQuest, 2017. *Symbolab*. [online] Available at: <https://www.symbolab.com/solver/matrix-eigenvalues-calculator> [Accessed 13 March 2020].

Ishizaka, A. and Nemery, P. 2013. *Multi-criteria Decision Analysis*: *Methods an Software*. Chichester: John Wiley and Sons.

Levy, H., 2015. *Stochastic Dominance: Investment Decision Making under Uncertainty.* Springer International Publishing.

Nocedal, J. and Wright, S., 2006. *Numerical Optimization*. New York: Springer International Publishing.

Park, D.G., Kwun, Y.Ch, Park, J.H. and Park, I.Y., 2009. Correlation Coefficient of Interval-Valued Intuitionistic Fuzzy Sets and Its Application to Multiple Attribute Group Decision-Making Problems. *Mathematical and Computer Modelling* [e-journal], 50(9-10), pp.1279-1293. doi: 10.1016/j.mcm.2009.06.010.

Ramík, J. and Perzina, R., 2008. *Moderní metody hodnocení a rozhodování.* Karviná: Silesian University in Opava.

Ramík, J. and Tošenovský, F., 2013. *Rozhodovací analýza pro manažery.* Karviná: Silesian University in Opava.

Saaty, T.L., 2005. *Theory and Applications of the Analytic Network Process*: *Decision Making with Benefits, Opportunities, Costs, and Risks.* Pittsburgh: RWS Publications.

Shiraishi, S., Obata, T. and Daigo, M., 1998. Properties of a Positive Reciprocal Matrix and Their Application to AHP. *Journal of the Operations Research* [e-journal], 41(3), pp.404-414. doi: 10.15807/jorsj.41.404.

Wang, Z., Li, K. and Wang, W., 2009. An Approach to Multiattribute Decision Making with Interval-Valued Intuitionistic Fuzzy Assessments and Incomplete Weights. *Information Sciences* [e-journal], 179(17), pp.3026-3040. doi: 10.1016/j.ins.2009.05.001.

Ye, J., 2010. Multicriteria Fuzzy Decision-Making Method Using Entropy Weights-Based Correlation Coefficients of Interval-Valued Intuitionistic Fuzzy Sets. *Applied Mathematical Modelling* [e-journal], 34(12), pp.3864-3870. doi: 10.1109/IHMSC.2009.23.

Zgodavova, K. and Slimak, I., 2008. Advanced Improvement of Quality. In: B. Katalinc, ed. *Annals of DAAAM for 2008 & Proceedings of the 19th International DAAAM Symposium: Intelligent Manufacturing & Automation: Focus on Next Generation of Intelligent Systems and Solutions*. Trnava, Slovakia, 22-25 October 2008. Wien: DAAM.

ABOUT THE AUTHOR

Filip Tošenovský – VSB-Technical University of Ostrava, Faculty of Materials Science and Technology, Ostrava, Czech Republic, Department of Quality Management, Assist. Prof., e-mail: filip.tosenovsky@vsb.cz, Author's ORCID: 0000-0003-3946-7815.

CONFLICTS OF INTEREST

The author declares no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

The Link Between Asset Risk Management and Maintenance Performance: A Study of Industrial Manufacturing Companies

DOI: 10.12776/QIP.V24I3.1477

Damjan Maletič, Hana Pačaiová, Anna Nagyová, Matjaž Maletič

Received: 2020-08-24 Accepted: 2020-09-29 Published: 2020-11-30

ABSTRACT

Purpose: The purpose of this paper is to examine risk management practices and their impact on performance. Specifically, the study aimed to examine risk management practices as part of physical asset management and their impact on maintenance management and its performance.

Methodology/Approach: The empirical data were obtained from 76 manufacturing companies. Partial Least Squares Path Modeling (PLS-PM) was applied to evaluate the measurement and structural model.

Findings: The results emphasized the importance of integrating risk management practices into asset management processes in order to improve performance outcomes.

Research Limitation/Implication: This study contributes to a better understanding of how companies could achieve higher performance results by implementing risk management practices. The results of this study can help managers identify key asset risk management practices. Despite the important implications that can be derived from this study, further research that would extend the model to include additional performance measures and/or asset management dimensions would be of great importance.

Originality/Value of paper: By analyzing the interrelationships between asset risk management practices and their direct and indirect effects on maintenance performance, the study provides important insights for the development of strategies to promote the novel and important discipline of asset management.

Category: Research paper

Keywords: risk management; maintenance performance; physical assets; ISO 31000

1 INTRODUCTION

Today's global marketplace puts tremendous pressure on manufacturers to continually adapt proactive, innovative strategies to improve their manufacturing capabilities (Ahuja and Khamba, 2008). While asset availability and reliability are becoming critical issues in capital-intensive operations, the strategic importance of maintenance in such companies should be recognized (Tsang, 2002). With physical asset management that is even more profound than traditional maintenance management, companies should be able to realize their full potential and effectively achieve their business objectives. Consequently, effective management of physical assets is playing an increasingly important role in optimizing the business profitability (Maletič et al., 2018; Schuman and Brent, 2005). As a result, asset managers today face many challenges, such as the need to achieve social and environmental objectives in addition to more traditional technical and economic goals, the importance of risk management, and the need to use the best available technology in the asset management process (Thorpe, 2010). As Woodhouse (2007) noted, physical asset management represents the best sustainable mix of asset care (i.e., maintenance and risk management) and asset utilization (i.e., using the asset to achieve a business objective or performance advantage). Efficient management of existing and emerging risks of industrial technologies is therefore critical for companies (Pačaiová, Sinay and Nagyová, 2017) that want to meet the requirements of various areas of organizational management (e.g., occupational health and safety, accident prevention, critical infrastructure, transportation of hazardous materials, environmental or financial requirements) (Pačaiová, 2018). This means that risk management is an important element of any asset management system. To realize value, asset management, therefore, involves balancing the costs, opportunities and risks against the desired performance of assets to achieve organizational objectives (ISO, 2014).

Most of the earlier studies on risk management focused on Enterprise Risk Management (ERM), with the researchers'primary aim being to investigate the role of ERM in supply chain management (Olson and Wu, 2010; Wu and Olson, 2010). Another group of studies has tried to address the Risk-based thinking (RBT) in an ISO standards-compliant way (Chiarini, 2017; Pačaiová, Sinay and Nagyová, 2017). Recently, considerable efforts have been made to develop a risk-based approach to safety analysis within maintenance processes, especially in specific environments such as offshore pipeline maintenance (Li et al., 2019) or technical maintenance system optimization (Gill, 2017). Although previous studies have examined the relationship between risk management and performance implications (Callahan and Soileau, 2017; Zhang et al., 2018), several research gaps remain unexamined. Accordingly, the literature has not paid sufficient attention to the impact of risk management practices on various aspects of organizational performance (e.g., maintenance performance directly related to physical assets). The rationale for conducting this research is the need to examine the relationships between asset risk management practices and

maintenance performance. Using empirical data collected from industrial companies, this study attempts to fill this gap. There is therefore a lack of understanding of the mechanisms that might explain how key elements of risk management are related to maintenance performance. Our study builds on findings from previous research investigating the relationship between risk management and performance outcomes (e.g. Callahan and Soileau, 2017), in particular by bridging the risk with maintenance management (Pačaiová and Ižaríková, 2019). We thus add a novel perspective by conceptualizing and operationalizing risk management and linking core elements of risk management to maintenance performance.

The structure of the paper is as follows: Section 2 provides an overview of the relevant literature on risk and maintenance management. Section 3 aims to illustrate a methodological framework for this study. Section 4 aims to present the data analysis, while section 5 concludes with a summary of the main findings, in particular by highlighting them from a theoretical and practical point of view and by outlining limitations and future research directions.

2 LITERATURE REVIEW

2.1 Risk Management

In the past, much has been written about risk management. Many scholars have studied ERM in companies (e.g. Hoyt and Liebenberg, 2011). This literature covers a number of approaches, including some frameworks, risk categorization, processes and mitigation strategies. In addition, International Organization for Standardization (ISO) has published ISO 31000:2009 Risk Management Principles to provide guidance on ERM implementation. A new version was recently published. ISO 31000:2018 provides more strategic guidance than ISO 31000:2009 and places more emphasis on both senior management involvement and the integration of risk management in the organization.

There are many definitions of risk and risk management. The ISO defines risk as the “impact of uncertainty on objectives”. The ISO 31000:2009 definition of risk shifts the focus from the previous preoccupation with the possibility of an event (something happening) to the possibility of an effect and especially an impact on objectives (Purdy, 2010). As noted by Wu and Olson (2010), risk can include a variety of factors with potential impacts on the activities, processes and resources of any organization. The authors explained that external factors can result from economic changes, financial market developments, and threats that occur in political, legal, technological, and demographic environments. One of the recurring themes in IS0 31000 for effectiveness is that risk management must be integrated into a company’s decision-making processes (Purdy, 2010). For manufacturing companies, risk management can be described as a fundamental and unchanging process and represents an iterative approach (ALARP-As Low As Reasonably Practicable) that the designer or developing engineer must

consider when designing the physical asset (i.e. the machine and equipment), but also the user when managing workplace safety (Pačaiová, Markulik and Nagyová, 2016).

2.2 Maintenance Management

Maintenance management in the form of a Management System is currently not subject to any specific standard. Normally, Maintenance Management System (MMS) is associated with the software application of maintenance management (Grubb and Takang, 2003; Starr et al., 2010). The European standard for maintenance management of physical assets (European standards, 2014) describes the interaction between the requirements of the company, the physical assets and the management of its maintenance. It is based on the four main areas of the company's requirements, which are transferred to the management of physical assets through strategic analysis based on risk assessment (RBT). These four requirement areas are divided into the organizational goals, market requirements, stakeholder requirements (e.g. society, requirements of government legislation) and technologies in terms of their structure, inherent reliability, flexibility, know-how and, of course, their maintenance. The standard describes how these requirements are manifested through strategic management in the policy and objectives of physical asset management. The asset management plan must be translated into the maintenance management plan and strategies. Understanding the relationship between the organization's asset management objectives and maintenance management objectives is considered a gap in the understanding of how the maintenance management system works.

It is obvious that the decision process in maintenance applies a suitable strategy (preventive, predictive or corrective) (Al-Najjar, 2007; Bevilacqua and Braglia, 2000; Flores-Colen and de Brito, 2010). Indeed, effective and efficient maintenance processes and activities should be based on risk management (Arunraj and Maiti, 2007; Khan and Haddara, 2003). In general, there are two approaches to integrating risks into maintenance processes:

1. Maintenance planning and activities are based on unconscious decisions of maintenance personnel with high qualification and responsibility and taking into account the equipment risk (Gill, 2017; Sakai, 2010).
2. Maintenance management is based on specific concepts such as Total Productive Maintenance (TPM), Reliability Centred Maintenance (RCM) or risk-based inspection (RBI), which include risk management principles and tools (Ahuja and Khamba, 2008; Sakai, 2010).

With regard to the first approach, it should be noted that the skills are usually oriented towards quality management tools that are generally used for process assessment. For example, Failure Mode and Effects Analysis (Process FMEA: P-FMEA) aims to identify potential non-conformities and their sources (Teng and Ho, 1996). It can also be used for maintenance processes, applied to equipment (physical asset) as a process element, whose functional failure affects product

quality or causes unacceptable downtime. After the analysis, Pareto analysis (the 80/20 rule) can be used for decision making in maintenance, for example, for strategy optimization, to assess which equipment with the highest risk (risk priority number RPN specification) and its failures are involved in 80% of the problems. It is a similar approach to RCM. In small companies, the maintenance personnel only decide on empirical skills that result from many years of experience and the documentation of the device manufacturer (Teng and Ho, 1996). In general, the state authority, e.g. the labor inspectorate, checks whether a documented maintenance plan exists as an accident prevention measure.

The second approach is more sophisticated and is usually based on consideration of the acceptable level of loss in an entity when a default occurs on a particular asset. In the automotive industry, there is a strong emphasis on quality (product, delivery time). Accordingly, quality management standards (e.g. IATF, 2016) are strictly required. These standards are aligned with TPM. This Japanese concept (from the 70th of the last century) is based on principles described by TPM eight pillars (Chlebus et al., 2015) and uses tools whose application minimizes the probability of failure (5S methodology). TPM prevents problems (losses) related to safety, environment, quality, ineffective management procedures, operating errors and poorly performed maintenance. This maintenance management system prevents any hazards/risks in the company that affect business objectives.

The origin of the RCM methodology is the aircraft industry in the USA. RCM is typically applied in the petrochemical, nuclear power, gas, steel and other "heavy"industries (Srikrishna, Yadava and Rao, 1996). The need for high reliability is a typical aspect of the technology, and failure of the technology has a significant impact on the activities of companies and on society and the environment. RCM uses Critical Equipment Analysis – a methodology that helps to identify usually three categories of high-risk equipment: A – high risk (prevention strategy focused on reliability and safety), B – medium risk (high availability requirement) and C – low risk (cost optimization strategy) (Hansson, Backlund and Lycke, 2003). The next step of the RCM is the implementation of FMEA for risky equipment – the priority is applied to category A and after B the optimization of the maintenance plan and strategies is considered.

RBI is a very specific concept that mainly uses quantitative risk management tools. Inspections of pressure vessels, pipelines, cranes and electrical equipment are under legal control in most European countries because the consequences of their failure have an impact on the health and/or life of people. Containers and pipelines containing dangerous goods are hazardous technologies and their risk depends on the probability of failure and scenarios (e.g. fire, explosion, toxicity) resulting from loss of containment due to specific conditions and the impact on property, society and the environment. In this case, maintenance management is the preventive approach to how the probability of failure can be minimized by an effective and efficient predictive maintenance strategy. The inspection interval is based on a quantitative risk assessment (e.g. combination of fault tree FTA and event ETA tree analysis or layer of protection analysis LOPA) and the level of

risk depends on equipment condition monitoring and failure prediction (Pačaiová, Sinay and Nagyová, 2017).

These concepts and methodologies in maintenance management can be modified in practical application through optimization and cost minimization. Why is it important to improve maintenance performance based on risk assessment? In the past TPM, Overall Equipment Effectiveness – OEE (Hedman, Subramaniyan and Almström, 2016) was used as a performance indicator, but in other concepts (also in TPM) companies now use other indicators derived from reliability management, such as MTBF (Mean Time Between Failure), MTTR (Mean Time to Recovery), MDT (Mean Down Time). The European Standard (2007) provides three main groups of Key Performance Indicators in maintenance (organizational, technical and economic), but the complexity of using performance indicators in risk management usually depends on the maintenance maturity of the organization (Tubis and Werbińska-Wojciechowska, 2017).

2.3 Risk Management and Performance

Several authors (e.g. Gordon, Loeb and Tseng, 2009; Ritchie and Brindley, 2007) have addressed the relationship between risk and performance. These studies have looked at risk mainly from a supply chain perspective. However, risk has also been a key issue for researchers in the field of maintenance and physical asset management. According to Parida and Kumar (2006), maintenance provides critical support to heavy and capital-intensive industries by keeping machinery and equipment in a safe operating condition. It is widely recognized that maintenance is a key function in maintaining the long-term viability of an organization (e.g. Al-Najjar, 2007; Maletič et al., 2014). It is argued that maintenance performance is a result of complex activities. More significantly, it is necessary to apply risk management methods when making decisions and controlling maintenance activities (Pačaiová, Glatz and Kacvinský, 2012). In addition, previous studies have also looked at risk management as part of the management of physical assets (e.g. Maletič et al., 2018; Pačaiová and Grenčík, 2014). It could also be argued that asset, risk and maintenance management are strongly interrelated. The latter implies that performance and risk are related.

3 METHODOLOGY

3.1 Data Collection Procedure

This empirical study is based on a questionnaire survey. To ensure the face validity of the questionnaire, all measured variables were reviewed by academics and experts from industry. Accordingly, a pilot study was carried out in Slovakia, taking into account a sample of 19 Slovakian enterprises from the manufacturing sector. The final survey was conducted among Slovenian manufacturing enterprises. The questionnaire with the cover letter indicating the purpose of the

study was sent to the target persons by e-mail. It was asked to address the questionnaire to employees who hold a managerial position in relation to maintenance and operational decision-making processes. The questionnaire was sent to 300 Slovenian companies in the manufacturing industry. A total of 76 usable answers were collected within the given time frame, which corresponds to a response rate of 25.3 percent. The population for this study is composed of micro (8%), small (12%), medium-sized (45.3%) and large (34.7%) enterprises.

3.2 Research Model

A research model has been developed that shows the connections between the core elements of asset risk management and maintenance performance. First, a thorough literature review was conducted, which included relevant scientific publications and international standards. In the following steps, theoretical constructs were identified. This conceptual background forms the basis for outlining the proposed research model. In accordance with the literature and relevant standards (such as ISO, 2018), four constructs of asset risk management were conceptualized and operationalized. Asset risk management measures were developed on the basis of ISO (2018), which define the "Risk Context (LV1)" in connection with organizational activities, the "Risk Identification (LV2)" (source of hazard/threat), the "Risk Analysis and Evaluation (LV3)" (steps for risk assessment) and the "Risk Treatment (LV4)". With reference to previous measurements (Maletič, Maletič and Gomišcek, 2012), the study measures maintenance performance as the unidimensional latent variable. The corresponding items for measuring asset risk management and maintenance performance are shown in Table 1. The questionnaire items for risk management were operationalised using 5-point Likert scales, where 1 means that respondents strongly disagree and 5 that they strongly agree. With regard to maintenance performance measures, respondents were asked to estimate performance aspects in line with the industry average over the last three years using a 5-point Likert scale.

We have applied Partial Least Squares Path Modeling (PLS-PM) using the R-package plspm to assess the measurement and the structural model (Sanchez, 2013). Previous studies have argued that PLS-PM is particularly suitable for small sample sizes (Chin and Newsted, 1999).

4 ANALYSIS AND RESULTS

To evaluate the PLS-PM measurement model (outer model) (Sanchez, 2013), loadings and communalities were examined. As suggested by Sanchez (2013), loadings should be above the value of 0.7. The results of the evaluation of the outer model (loadings, weights and communalities) for studied constructs are presented in Appendix. As the results show, the majority of the values exceed the loading threshold criterion of 0.7. The loadings for 4 items are between 0.6 and 0.7; however, the items have been retained in the model due to the content

validity. In addition, cross-loadings were also checked with regard to the validity of the measurement model.

The following indices were used to assess the block unidimensionality: Cronbach's Alpha, Dillon-Goldstein's Rho and eigenvalues (see Table 1). The results show that Cronbach's alpha values for LV1, LV3, LV4 and LV5 were above the recommended value of 0.70 (Hair et al., 2010; Sanchez, 2013). The results show that the Cronbach alpha value for LV2 is below the recommended value, but the corresponding composite reliability is above the recommended value. The composite reliability was assessed by Dillon-Goldstein's rho. In the literature (Sanchez, 2013) the cut-off value of 0.7 is suggested to consider the corresponding block as unidimensional. The results show that the Dillon-Goldstein's rho value exceeds the cut-off point of 0.7 for all constructs. Additionally, the block is considered unidimensional if the first eigenvalue is greater than one. It appears that all indicator blocks fulfill this criterion.

Table 1 – Summary of the Results Regarding the Outer Model Assessment

	Mode	*MVs*	*Cronbach's alpha*	*Dillon-Goldstein's rho*	*AVE*	*eig.1st*	*eig.2nd*
Risk Context (LV1)	A	3	0.712	0.840	0.637	1.91	0.685
Risk Identification (LV2)	A	3	0.602	0.792	0.562	1.69	0.860
Risk Analysis and Evaluation (LV3)	A	3	0.773	0.869	0.687	2.07	0.549
Risk Treatment (LV4)	A	3	0.752	0.858	0.669	2.01	0.555
Maintenance Performance (LV5)	A	5	0.738	0.827	0.488	2.45	0.832

Notes: MVs – manifest variables (no. of items); A – reflective mode.

Furthermore, for the purpose of assessing convergent validity (Sanchez, 2013), the average variance extracted (AVE) was used to measure the amount of variance that a latent variable captures from its indicators (Sanchez, 2013). The results show that the AVE values for LV1 to LV4 are above the conventional threshold of 0.5 (Sanchez, 2013). As the AVE value for LV5 is just below the recommended value, it is also considered acceptable.

The results regarding the evaluation of the structural (inner) model are presented in Table 2. According to the results of the coefficients of determination (R^2),

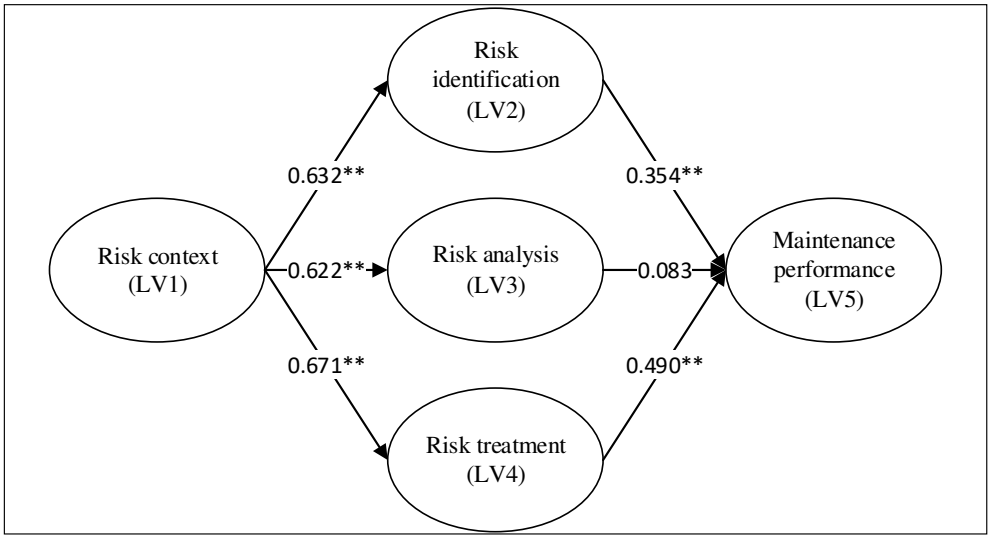
50.5% of the variance of the "Maintenance Performance (LV5)" is explained by corresponding prediction variables (e.g. LV2-LV4). Furthermore, the average communality values represent the average of all squared correlations between each manifest variable and the corresponding latent variable scores in the model. As the results show, the highest value corresponds to "Risk Analysis and Evaluation (LV3)", while the lowest value corresponds to "Maintenance Performance (LV5)". The mean redundancy illustrates the percentage of variance in the endogenous block predicted from the independent latent variables. A high redundancy emphasises the ability to predict. Therefore, prediction by means of redundancy could be outlined for "Risk Treatment (LV4)". It could be interpreted that 30.1% of the variability of block LV4 is predicted by "Risk Context (LV1)".

Table 2 – Summary of the Results Regarding the Inner Model Assessment

	Type	R^2	*Block Communality*	*Mean Redundancy*
Risk Context (LV1)	Exogenous	0.000	0.637	0.000
Risk Identification (LV2)	Endogenous	0.399	0.562	0.224
Risk Analysis and Evaluation (LV3)	Endogenous	0.387	0.687	0.266
Risk Treatment (LV4)	Endogenous	0.450	0.669	0.301
Maintenance Performance (LV5)	Endogenous	0.505	0.488	0.247

Notes: AVE – Average Variance Extracted.

The path analysis was further performed to test the relationships between the latent variables. The results concerning the inner model are shown in Figure 1. The path coefficients represent the strength and direction of the relationships between the latent variables (Sanchez, 2013). According to the results, the "Risk Context (LV1)" has a strong direct influence on the variables LV2 to LV4 (0.632; 0.622; 0.671 and $p < 0.01$). As regards the effect on "Maintenance Performance (LV5)", "Risk Treatment (LV4)" seems to be the dominant variable (0.490, $t= 3.76$, $p < 0.01$). Regarding the indirect effect, it can be outlined that "Risk Context (LV1)" indirectly (0.500) influences "Maintenance Performance (LV5)" through "Risk Identification (LV2)", "Risk Analysis and Evaluation (LV3)" and "Risk Treatment (LV4)" influences the "Maintenance Performance (LV5)".



Notes: **statistically significant at the 0.01 level.

Figure 1 – Structural (inner) Model with Path Coefficients

5 DISCUSSION AND CONCLUSIONS

The potential links between risk management and performance outcomes have attracted considerable attention in recent years, as risk management issues have become one of the main concerns of a wide range of stakeholders in organizations. However, there are still few papers in the academic literature on asset management that specifically address the relationship between risk management and performance outcomes. Therefore, this study determines the importance of risk management and its impact on business results, particularly maintenance performance. From the perspective of theoretical explanation and empirical evaluation, this study therefore contributes to a greater clarity and understanding of the relationship between risk management practices and maintenance management. Our results support the idea of conceptualizing and operationalizing risk management within the framework of standard ISO (2018). The results of this study are consistent with theoretical arguments in the literature, which considers risk management as an important elementary form of performance measurement in maintenance (Söderholm and Norrbin, 2013). Thus, our results strengthen credence to the growing importance of integrating risk management into the asset management framework (Trindade et al., 2019). Our findings are consistent with previous findings that suggest that organizational context definition, opportunity and risk identification, monitoring and analysis are among the most important factors supporting the realization of value from physical assets (Maletič et al., 2017; Maletič et al., 2018, Maletič et al., 2019; Trindade et al., 2019).

Furthermore, as the results show, it could be argued that the most important predictors of maintenance performance are risk identification and risk treatment. Our results reinforce the belief in the growing importance of linking risk management to performance measurement (Arena and Arnaboldi, 2014). In addition, as shown in previous research (Callahan and Soileau, 2017), operational performance could be improved by a commitment to company-wide risk assessment and management. As evidenced by the results, our study revealed no direct impact of risk analysis on maintenance performance. Several plausible explanations could be delivered in this regard. The results of the risk analysis include, for example, the identified hazards and risk factors that have the potential to cause harm. These results are then incorporated into action plans (which are part of risk treatment) that bear a positive association with maintenance performance. As mentioned earlier, Risk Treatment (LV4) is the strongest predictor of maintenance performance in our model ($\beta = 0.490$, $t= 3.76$, $p < 0.01$). Therefore, although no direct effects of Risk Analysis and Evaluation (LV3)were found, possible indirect effects on maintenance performance through Risk Treatment (LV4) can be indicated.

We build on previous research and distinguish our study from the work previously published in the risk management literature in the following ways First, unlike previous studies, our study focuses on risk management in the context of asset management. Second, by looking at the importance of assessing the maintenance performance of companies (Liyanage, 2007), we examined whether and to what extent risk management activities contribute to maintenance performance (because risk mitigation, probability of failure) in asset management mainly depends on a proactive maintenance strategy). Accordingly, this study adds risk and asset management perspectives to the existing research on maintenance performance. Previous studies have mainly focused on the development of maintenance performance measurement systems (Parida et al., 2015). Finally, also in a departure from previous research that addressed risk in maintenance activities (e.g. Wijeratne, Perera and De Silva, 2014), our study proposes the empirically validated structural model, thereby expanding the literature on the benefits of integrating risk management into maintenance and asset management activities. Since asset management has become an attractive area of research, many researchers have worked in a variety of areas, such as exploring the applicability of advanced decision support techniques in different maintenance and asset management business processes (De la Fuente et al., 2018), developing the theoretical framework for physical asset management (Alhazmi, 2018), studying the performance implications of physical asset management practices (Maletič et al., 2018), developing a risk-based approach to maintenance (e.g. Arunraj and Maiti, 2007; Li et al., 2019; Pačaiová, Sinay and Nagyová, 2017) The biggest gap in this area results from neglecting the potential of integrating risk management into the physical asset management framework. The present study aims to contribute to the existing research gap by bridging the risk and asset management, especially from the performance results perspective.

The results of this study may provide additional management insights that have the potential to support the decision making process regarding the management of physical assets and maintenance. One important aspect of physical asset management is therefore to achieve the right balance between performance, costs and associated risks in pursuing business objectives. Indeed, managers should integrate risk management into the asset management plan to proactively and holistically address the underlying issues. Managers in management and operations (M&O) are advised to follow well-established frameworks (such as EFNMS-EAMC, 2012; GFMAM, 2014; IAM, 2015) and relevant European and international standards that recognize the integration of risk management into maintenance and asset management activities.

For future research we propose a combination of qualitative and quantitative studies to further investigate the proposed model. Furthermore, the proposed model may be extended to include additional performance measures and/or asset management dimensions. Future studies could also take into account some other limitations of this study. For example, given the relatively small number of companies surveyed, potential control variables could not be included without compromising statistical power. It is therefore recommended that future studies include relevant control variables and test the model with a larger sample of organizational units.

ACKNOWLEDGEMENTS

This contribution is the result of the implementation of KEGA project No. 015TUKE-4/2019 Audit management using software application according to standard ISO 9001:2015, KEGA project No. 004TUKE-4/2019 Scientific and educational centre for remote sensing with the focus on the application of e-learning approaches in education and also of the project No. APVV-19-0367 Integrated Process Safety Management Approach Framework for the Smart Enterprise.

REFERENCES

Ahuja, I.P.S. and Khamba, J.S., 2008. An evaluation of TPM initiatives in Indian industry for enhanced manufacturing performance. *International Journal of Quality & Reliability Management* [e-journal], 25(2), pp.147-172. doi: 10.1108/02656710810846925.

Alhazmi, N., 2018. A theoretical framework for physical asset management practices. *Facilities* [e-journal], 36(3/4), pp.135-150. doi: 10.1108/F-02-2016-0025.

Al-Najjar, B., 2007. The lack of maintenance and not maintenance which costs: A model to describe and quantify the impact of vibration-based maintenance on company's business. *International Journal of Production Economics* [e-journal], 107(1), pp.260-273. doi: 10.1016/j.ijpe.2006.09.005.

Arena, M. and Arnaboldi, M., 2014. Risk and performance management: are they easy partners? *Management Research Review* [e-journal], 37(2), pp.152-166. doi: 10.1108/MRR-08-2012-0180.

Arunraj, N.S. and Maiti, J., 2007. Risk-based maintenance—Techniques and applications. *Journal of hazardous materials* [e-journal], 142(3), pp.653-661. doi: 10.1016/j.jhazmat.2006.06.069.

Bevilacqua, M. and Braglia, M., 2000. The analytic hierarchy process applied to maintenance strategy selection. *Reliability Engineering & System Safety* [e-journal], 70(1), pp.71-83. doi: 10.1016/S0951-8320(00)00047-8.

Callahan, C. and Soileau, J., 2017. Does enterprise risk management enhance operating performance? *Advances in accounting* [e-journal], 37, pp.122-139. doi: 10.1016/j.adiac.2017.01.001.

Chiarini, A., 2017. Risk-based thinking according to ISO 9001:2015 standard and the risk sources European manufacturing SMEs intend to manage. *The TQM Journal* [e-journal], 29(2), pp.310-323. doi: 10.1108/TQM-04-2016-0038.

Chin, W.W. and Newsted, P.R., 1999. Structural equation modeling analysis with small samples using partial least squares. *Statistical strategies for small sample research*, 1(1), pp.307-341.

Chlebus, E., Helman, J., Olejarczyk, M. and Rosienkiewicz, M., 2015. A new approach on implementing TPM in a mine–A case study. *Archives of Civil and Mechanical Engineering* [e-journal], 15(4), pp.873-884. doi: 10.1016/j.acme.2015.07.002.

De la Fuente, A., González-Prida, V., Crespo, A., Gómez, J.F. and Guillén, A., 2018. Advanced Techniques for Assets Maintenance Management. *IFAC-PapersOnLine* [e-journal], 51(11), pp.205-210. doi: 10.1016/j.ifacol.2018.08.260.

EFNMS-EAMC (European Federation of National Maintenance Societies-European Asset Management Committee), 2012. *How organizations manage their physical assets in practice*. Brussel: EFNMS Asset Management Survey.

European Standards, 2007. *EN 15341:2007: Maintenance - Maintenance Key Performance Indicators*. Brussel: Management Centre.

European Standards, 2014. *EN 16646:2014: Maintenance within Physical Assets Management*. BSI Standards Limited.

Flores-Colen, I. and de Brito, J., 2010. A systematic approach for maintenance budgeting of buildings façades based on predictive and preventive strategies. *Construction and Building Materials* [e-journal], 24(9), pp.1718-1729. doi: 10.1016/j.conbuildmat.2010.02.017.

GFMAM (The Global Forum on Maintenance and Asset Management), 2014. *The asset management landscap*. 2nd Edition. Global Forum.

Gill, A., 2017. Optimisation of the technical object maintenance system taking account of risk analysis results. *Eksploatacja i Niezawodność– Maintenance and Reliability* [e-journal], 19(3), pp.420-431. doi: 10.17531/ein.2017.3.13.

Gordon, L.A., Loeb, M.P. and Tseng, C.Y., 2009. Enterprise risk management and firm performance: A contingency perspective. *Journal of accounting and public policy* [e-journal], 28(4), pp.301-327. doi: 10.1016/j.jaccpubpol.2009.06.006.

Grubb, P. and Takang, A., 2003. *Software maintenance: concepts and practice*. New Jersey: World Scientific.

Hair, J.F., Black, B., Babin, B. and Anderson, R.E., 2010. *Multivariate Data Analysis*. 7th Edition. Upper Saddle River, NJ: Pearson Prentice Hall.

Hansson, J., Backlund, F. and Lycke, L., 2003. Managing commitment: increasing the odds for successful implementation of TQM, TPM or RCM. *International Journal of Quality & Reliability Management* [e-journal], 20(9), pp.993-1008. doi: 10.1108/02656710310500815.

Hedman, R., Subramaniyan, M. and Almström, P., 2016. Analysis of critical factors for automatic measurement of OEE. *Procedia Cirp* [e-journal], 57, pp.128-133. doi: 10.1016/j.procir.2016.11.023.

Hoyt, R.E. and Liebenberg, A.P., 2011. The value of enterprise risk management. *Journal of risk and insurance* [e-journal], 78(4), pp.795-822. doi: 10.1111/j.1539-6975.2011.01413.x.

IATF (International Automotive Task Force), 2016. *16949:2016 - Quality management system requirements for automotive production and relevant service parts organizations*. The Automotive Industry Action Group.

Institute of Asset Management, 2015. *Asset Management-An anatomy.* London: Institute of Asset Management.

ISO (International Standards Organization), 2009. *ISO 31000:2009. Risk management - Principles and guidelines.* Geneva: ISO.

ISO (International Standards Organization), 2014. *ISO 55000: 2014. Asset management: Overview, principles and terminology.* Geneva: ISO.

ISO (International Standards Organization), 2018. *ISO 31000:2018. Risk management – Guidelines*. Geneva: ISO.

Khan, F.I. and Haddara, M.M., 2003. Risk-based maintenance (RBM): a quantitative approach for maintenance/inspection scheduling and planning. *Journal of loss prevention in the process industries* [e-journal], 16(6), pp.561-573. doi: 10.1016/j.jlp.2003.08.011.

Li, X., Chen, G., Chang, Y. and Xu, C., 2019. Risk-based operation safety analysis during maintenance activities of subsea pipelines. *Process Safety and Environmental Protection* [e-journal], 122, pp.247-262. doi: 10.1016/j.psep.2018.12.006.

Liyanage, J.P., 2007. Operations and maintenance performance in production and manufacturing assets. *Journal of Manufacturing Technology Management* [e-journal], 18(3), pp.304-314. doi: 10.1108/17410380710730639.

Maletič, D., Maletič, M. and Gomišček, B., 2012. The relationship between continuous improvement and maintenance performance. *Journal of Quality in Maintenance Engineering* [e-journal], 18(1), pp.30-41. doi: 10.1108/13552511211226175.

Maletič, D., Maletič, M., Al-Najjar, B. and Gomišček, B., 2014. The role of maintenance in improving company's competitiveness and profitability: a case study in a textile company. *Journal of Manufacturing Technology Management* [e-journal], 25(4), pp.441-456. doi: 10.1108/JMTM-04-2013-0033.

Maletič, D., Maletič, M., Al-Najjar, B. and Gomišček, B., 2018. Development of a model linking physical asset management to sustainability performance: An empirical research. *Sustainability* [e-journal], 10(12), pp.4759. doi: 10.3390/su10124759.

Maletič, D., Maletič, M., Al-Najjar, B. and Gomišček, B., 2019. Examination of the Mediating Effects of Physical Asset Management on the Relationship Between Sustainability and Operational Performance. In: A. Hamrol, M. Grabowska, D. Maletič and R. Woll, *6th International Scientific-Technical Conference MANUFACTURING 2019*. Ponan, Poland, 19-22 May 2019. Cham: Springer. pp.33-43. doi: 10.1007/978-3-030-17269-5_3.

Maletič, D., Maletič, M., Al-Najjar, B., Gotzamani, K., Gianni, M., Kalinowski, T.B. and Gomišček, B., 2017. Contingency factors influencing implementation of physical asset management practices. *Organizacija* [e-journal], 50(1), pp.3-16. doi: 10.1515/orga-2017-0003.

Olson, D.L. and Wu, D.D., 2010. A review of enterprise risk management in supply chain. *Kybernetes* [e-journal], 39(*5*), pp.694-706. doi: 10.1108/03684921011043198.

Pačaiová, H. and Grenčík, J., 2014. Risk management as an integrated part of the Asset Management. In: Euro Maintenance, *22nd European Congress and Expo on Maintenance and Asset Management*. Helsinki, Finland, 05-07 May 2014. Helsinki: EFNMS. pp.334-339.

Pačaiová, H. and Ižaríková, G., 2019. Base Principles and Practices for Implementation of Total Productive Maintenance in Automotive Industry. *Quality Innovation Prosperity* [e-journal], 23(1), pp.45-59. doi: 10.12776/qip.v23i1.1203.

Pačaiová, H., 2018. Machinery Safety Requirements as an Effective Tools for Operational Safety Management. In: V. Svalova, ed. 2018. *Risk Assessment*. Rijeka: InTech. Chapter 6.

Pačaiova, H., Glatz, J. and Kacvinský, S., 2012. Positive and negative aspect in application of maintenance management philosophy. *Journal of Applied Engineering Science* [e-journal], 10(2), pp.99-105. doi: 10.5937/jaes10-2131.

Pačaiová, H., Markulik, Š. and Nagyová, A., 2016. *The importance of risk in management systems.* Košice: BEKI Design.

Pačaiová, H., Sinay, J. and Nagyová, A., 2017. Development of GRAM−A risk measurement tool using risk based thinking principles. *Measurement* [e-journal], 100, pp.288-296. doi: 10.1016/j.measurement.2017.01.004.

Parida, A. and Kumar, U., 2006. Maintenance performance measurement (MPM): issues and challenges. *Journal of Quality in Maintenance Engineering* [e-journal], 12(3), pp.239-251. doi: 10.1108/13552510610685084.

Parida, A., Kumar, U., Galar, D. and Stenström, C., 2015. Performance measurement and management for maintenance: a literature review. *Journal of Quality in Maintenance Engineering* [e-journal], 21(1), pp.2-33. doi: 10.1108/JQME-10-2013-0067.

Purdy, G., 2010. ISO 31000: 2009—setting a new standard for risk management. *Risk Analysis: An International Journal* [e-journal], 30(6), pp.881-886. doi: 10.1111/j.1539-6924.2010.01442.x.

Ritchie, B. and Brindley, C., 2007. Supply chain risk management and performance. *International Journal of Operations & Production Management* [e-journal], 27(3), pp.303-322. doi: 10.1108/01443570710725563.

Sakai, S., 2010. Risk-based maintenance. *JR East Technical Review*, 17, pp.1-4.

Sanchez, G., 2013. *PLS path modeling with R*. Berkeley: Trowchez Editions.

Schuman, C.A. and Brent, A.C., 2005. Asset life cycle management: towards improving physical asset performance in the process industry. *International Journal of Operations & Production Management* [e-journal] 25(6), pp.566-579. doi: 10.1108/01443570510599728.

Söderholm, P. and Norrbin, P., 2013. Risk-based dependability approach to maintenance performance measurement. *Journal of Quality in Maintenance Engineering* [e-journal], 19(3), pp.316-329. doi: 10.1108/JQME-05-2013-0023.

Srikrishna, S., Yadava, G.S. and Rao, P.N., 1996. Reliabilitycentred maintenance applied to power plant auxiliaries. *Journal of Quality in Maintenance Engineering* [e-journal], 2(1), pp.3-14. doi: 10.1108/13552519610113809.

Starr, A., Al-Najjar, B., Holmberg, K., Jantunen, E., Bellew, J. and Albarbar, A., 2010. Maintenance today and future trends. In: K. Holmberg, A. Adgar, A. Arnaiz, E. Jantunen, J. Mascolo, S. Mekid, eds. 2010. *E-maintenance*. London: Springer. Chaper 2. doi: 10.1007/978-1-84996-205-6_2.

Teng, S.H.G. and Ho, S.Y.M., 1996. Failure mode and effects analysis. *International journal of quality & reliability management* [e-journal], 13(5), pp.8-26. doi: 10.1108/02656719610118151.

Thorpe, D., 2010. The development of strategic asset management leaders through postgraduate education. In: J.E. Amadi-Echendu, K. Brown, R. Willett, J. Mathew, eds. 2010. *Definitions, Concepts and Scope of Engineering Asset Management.* London: Springer. pp.357-380. doi: 10.1007/978-1-84996-178-3_19.

Trindade, M., Almeida, N., Finger, M. and Ferreira, D., 2019. Design and development of a value-based decision making process for asset intensive organizations. In: J. Mathew, C. Lim, L. Ma, D. Sands, M. Cholette and P. Borghesani, eds. 2019. *Asset intelligence through integration and interoperability and contemporary vibration engineering technologies.* Cham: Springer. pp.605-623. doi: 10.1007/978-3-319-95711-1_60.

Tsang, A.H., 2002. Strategic dimensions of maintenance management. *Journal of Quality in maintenance Engineering* [e-journal], 8(1), pp.7-39. doi: 10.1108/13552510210420577.

Tubis, A. and Werbińska-Wojciechowska, S., 2017. Risk assessment issues in the process of freight transport performance. *Journal of KONBiN* [e-journal], 42(1), pp.235-253. doi: 10.1515/jok-2017-0027.

Wijeratne, W.M.P.U., Perera, B.A.K.S. and De Silva, L., 2014. Identification and assessment risks in maintenance operations. *Built Environment Project and Asset Management* [e-journal], 4(4), pp.384-405. doi: 10.1108/BEPAM-09-2013-0041.

Woodhouse, J., 2007. Joining the jigsaw puzzle—PAS 55 standards for the integrated management of assets. *Maintenance and Asset Management*, 12(1), pp.12-16.

Wu, D.D. and Olson, D., 2010. Enterprise risk management: a DEA VaR approach in vendor selection. *International Journal of Production Research* [e-journal], 48(16), pp.4919-4932. doi: 10.1080/00207540903051684.

Zhang, Y., Liu, S., Tan, J., Jiang, G. and Zhu, Q., 2018. Effects of risks on the performance of business process outsourcing projects: The moderating roles of knowledge management capabilities. *International journal of project management* [e-journal], 36(4), pp.627-639. doi: 10.1016/j.ijproman.2018.02.002.

ABOUT AUTHORS

Damjan Maletič – (D.M.) University of Maribor, Faculty of Organizational Sciences, Slovenia, Assist. Prof., e-mail: damjan.maletic@um.si, Author's ORCID: 0000-0002-6871-2720.

Hana Pačaiová, PhD. – (H.P.) Technical University of Košice, Faculty of Mechanical Engineering, Košice, Slovakia, Prof., Department of Safety and Quality, e-mail: hana.pacaiova@tuke.sk, Author's ORCID: 0000-0002-0308-1980.

Anna Nagyová, PhD. – (A.N.) Technical University of Košice, Faculty of Mechanical Engineering, Košice, Slovakia, Prof., Senior Lecturer, e-mail: anna.nagyova@tuke.sk, Author's ORCID: 0000-0003-3936-4517.

Matjaž Maletič – (M.M.) University of Maribor, Faculty of Organizational Sciences, Slovenia, Assist. Prof., e-mail: matjaz.maletic@um.si, Author's ORCID: 0000-0002-3845-744X.

AUTHOR CONTRIBUTIONS

H.P. – supervision; H.P., D.M. – methodology; M.M., H.P. – validation; H.P., A.N. – formal analysis, review and editing; D.M., M.M. – data curation,; D.M., M.M., H.P. – conceptualization, original draft preparation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

APPENDIX

Table A1 – Questionnaire Items and Outer Model Assessment Statistics for Asset Risk Management and Maintenance Performance

	Weight	*Loading*	*Communality*	*Redundancy*
Risk context (LV1)				
Risk management approach is established in our organization.	0.410	0.822	0.676	0.000
Risk management is integral part of our physical asset management strategy.	0.454	0.850	0.7	0.000
We have a sufficient level of resources to be allocated to risk management activities.	0.387	0.716	0.512	0.000
Risk identification (LV2)				
We are using teamwork during all phases of risk identification process.	0.454	0.837	0.700	0.279
We have clearly established roles and responsibilities in relation to asset risk management activities.	0.428	0.669	0.447	0.178
We are using advanced techniques (e.g. condition monitoring) for asset risk identification.	0.455	0.733	0.538	0.214
Risk analysis and evaluation (LV3)				
We are applying risk assessment analysis for managing our physical assets.	0.384	0.786	0.618	0.239
We are using tools and techniques (e.g. FMEA) within risk assessment analysis.	0.471	0.861	0.741	0.287
We have established a process for risk evaluation (e.g. risk prioritization) of our physical assets.	0.350	0.837	0.700	0.271

	Weight	*Loading*	*Communality*	*Redundancy*
Risk treatment (LV4)				
We are applying the principles of cost/benefit analysis in developing risk actions for physical assets.	0.429	0.824	0.679	0.306
We are developing and executing the risk action plan.	0.392	0.791	0.625	0.281
We are using risk monitoring to better manage the risk action plan.	0.401	0.838	0.702	0.316
Maintenance performance (LV5)				
Efficiency of maintenance processes has increased during the last three years.	0.217	0.612	0.374	0.189
Overall Equipment Effectiveness (OEE) has increased during the last three years.	0.256	0.664	0.441	0.223
Availability of physical assets has improved during the last three years.	0.297	0.730	0.533	0.269
Mean times between failures (MTBF) have improved during the last three years.	0.339	0.786	0.617	0.312
Total maintenance costs have decreased during the last three years.	0.310	0.690	0.477	0.241

Strategic Innovation and Competitive Advantage of Manufacturing SMEs: The Mediating Role of Human Capital

DOI: 10.12776/QIP.V24I3.1493

Nagwan A. AlQershi, Mohd L.B.M. Diah, Aryani B.A. Latiffi, Wan N.K.W. Ahmad

Received: 2020-08-19 Accepted: 2020-10-22 Published: 2020-11-30

ABSTRACT

Purpose: The purpose of this paper is to examine the mediating effect of human capital on the relation between the strategic innovation and competitive advantage of SMEs in Yemen.

Methodology/Approach: The PLS-SEM analysis is performed to test the hypotheses by using data collected from 238 SMEs in Yemen. The results support the hypotheses.

Findings: The results of the PLS-SEM analysis are as follows: strategic innovation had a significant effects on SMEs' competitive advantage; also human capital had a significant effects on SMEs' competitive advantage; human capital mediated the effect of strategic innovation on competitive advantage; and strategic innovation had a positive and significant effect on human capital.

Research Limitation/Implication: The population of the study was limited to manufacturing SMEs, so the results cannot be generalized to other types of industry such as services, whose structure and vision differ from those of manufacturing companies.

Originality/Value of paper: The paper is one of the first to highlight human capital as a mediator between strategic innovation and competitive advantage of manufacturing SMEs in Yemen and the Middle East, describing a single study applied in the context of a developing country.

Category: Research paper

Keywords: competitive advantage; strategic innovation; human capital

1 INTRODUCTION

In today's rapidly changing business environment, firms need to be innovative in order to remain competitive (Edeh, Obodoechi and Ramos-Hidalgo, 2020; Sabahi and Parast, 2020; Popa, Soto-Acosta and Martinez-Conesa, 2017). It has been posited that innovation goes beyond the development and introduction of new technologies into new services or products. In addition, the application of new evidence-based and result-oriented business models can effectively and efficiently manage changes in the business environment (Genc, Dayan and Genc, 2019; Afuah, 2009). According to Sisodia, Wolfe and Sheth (2003), organizations must struggle to survive in a capitalistic society and generate some tangible profit. They added that companies must have some competitive edge over their counterparts to enjoy high profits. Due to rapid globalization, intense competition and the implementation of new technologies, the business environment has become more complex with the passage of time (Soosay et al., 2016).

In line with the above, such a complex situation has pushed organizations to create efficient and effective competitive advantage (Stajkovic and Sergent, 2019). By having a competitive edge, organizations can achieve a unique position in the global market. Moreover, firms with a competitive edge in the market can sustain and maintain their position in the market for longer (Kotabe and Kothari, 2016). For example, Nestlé, which yields substantial returns for its investors, does this by capitalizing on its competitive advantage (Dyer and Singh, 1998).

Against this background, the role of achieving competitive advantage has been extensively examined in the literature (Quaye and Mensah, 2019; Lee et al., 2016; Eniola and Ektebang, 2014; Simpson, Taylor and Barker, 2004). In this regard, Herrera (2015), contended that firms should have transitioned from a technology-focused view to a more innovative one. According to Johnson and Lafley (2010), the benefits of business model innovation are that it transforms the creation, delivery and extraction of customer value and that it is the key by which new entrants can create a niche for themselves through competitive advantage. Therefore, strategic innovation is the need to address strategic management in an innovative way, to think not only about the current strategy but also about tomorrow's (Hjalager, 2018). Strategic innovation is based on fostering creative thinking within the organization; it is not just interpreting it as better technology and product-based markets, but involves constantly developing concepts and business models (Dogan, 2017; Drejer, 2006).

In this scenario, strategic innovation is regarded as the most important factor that can have a relative impact on a firm's sustainable competitive advantage (Yang, 2014). Firms should depend on featured and innovative ideas to survive and compete in the rapidly changing and aggressive markets (Giachetti and Lanzolla, 2016). According to Verbano and Crema (2016), many sectors in developed countries must depend on innovation to survive and compete. However,

manufacturing industry in Yemen is still engaged in very few innovation activities compared to other countries (Sky-News, 2012). Furthermore, many manufacturers are also facing a number of typical problems with regards to their innovation processes. In other words, they are suffering from lack of innovation and the implementation of new ideas in their attempts to create value products. Therefore, it is necessary to address customers' expectations of new standards in order to satisfy them (AlQershi, Abas and Mokhtar, 2020a). Innovation is something that all companies should focus on, regardless of their size and sector.

The suggestion that firms must implement dynamic and innovative strategies does not take into account whether the firm has the ability to enhance its activities in pursuit of more complex and advantageous strategies. Hence, even small and medium manufacturing industries must respond by adopting more innovation to establish or sustain competitive advantage in the marketplace (Abd Aziz and Samad, 2016). Strategic innovation directly affects the ability of firms to develop their products in order to meet the wide range of customer and market needs. However, Yemeni firms are faced with a lack of advanced technology (AlQershi, Abas and Mokhtar, 2020b), in fact, according to the Global Innovation Index (2014, 2015, 2016, 2017), Yemen was ranked 141, 137, 128 and 127 in successive years, indicating very little innovation activity.

Therefore, firms must create a distinction between themselves and their rivals through unique strategies. Most commonly, leading organizations implement strategic innovation to create competitive edge. These organizations even follow through with innovation in warehouse management to reduce inventory. Making innovative and strategic changes in the organization helps them to respond to market changes in a timely manner. However, most of the literature does not really explain the role of strategic innovation on human capital, with the exception of the study by AlQershi, Abas and Mokhtar (2019b), which does not examine competitive advantage.

Strategic innovation in this study has been subdivided into twelve dimensions, to strengthen the results of tests on the effect of strategic innovation and human capital on competitive advantage. Three questions are raised: (1) Can strategic innovation maintain an active role in creating competitive advantage? (2) Does strategic innovation significantly contribute to a human capital? And (3) does human capital play a mediating role in the causal relationships between strategic innovation and competitive advantage?

In this context, manufacturing industry could be an important contributor to Yemen's economic growth, as human capital and strategic innovation are vital if it is to move up the high-value chain. To do so, industry needs a systematic approach to strategic innovation with the benefits of human capital that would accelerate competitive advantage. As highlighted by Sky-News (2012), manufacturing industry has the potential to be at the heart of Yemen's economic growth.

2 LITERATURE REVIEW

2.1 Strategic Innovation and Human Capital

Strategic innovation refers to the basic re-conceptualization of business models and the reformation of current markets through rule breaking and changing competition (AlQershi, Abas and Mokhtar, 2019c; Schlegelmilch, Diamantopoulos and Kreuz, 2003). According to Markides (1997), strategic innovation determines whether a firm succeeds in attacking an established industry leader and creating a competitive advantage.

Strategic innovation occurs when a company identifies gaps in the industry positioning map, decides to fill them, and the gaps grow to become the new mass market (AlQershi, Abas and Mokhtar, 2020a; Derrick and Soren, 2007). So, the investigation of these concepts could fill the conceptual (and empirical) gap in extant strategic innovation research. Largely coming from a managerial research perspective, most of the contributions to strategic innovation lack rigorous scientific analysis, despite having promising ideas and measures (Kodama, 2018). According to the literature on strategic innovation and other managerial concepts associated with it, such as strategic renewal, innovation is more closely related to the current requirements and needs of organizations and their customers (Anderson and Tushman, 2004). In fact, it should focus on the future requirements and needs of organizations and customers.

Previous studies have investigated the relationship between strategic innovation and human capital. For example, AlQershi, Abas and Mokhtar (2019b), investigated this relationship among manufacturing SMEs in Yemen and found a significant association. Verbano and Crema (2016), investigated the relationship between innovation and human capital among manufacturing SMEs and found a significant relationship in the study population. Zerenler, Hasiloglu and Sezgin (2008), investigated this relationship in automotive suppliers in Turkey and found a significant positive association. Kianto, Saenz and Aramburu (2017), also found a significant association.

Traditionally, the primary foci have been on strategic innovation, globalization and the effect of information and communications technologies on value-adding activities (AlQershi, 2020; Afuah, 2009). Such issues are primarily related to the way organizations can obtain a competitive edge via strategic innovation through the application of new game strategies, and how to guarantee that they stand out in a market that is dynamic and in a world rife with technological change and globalization (Giachetti and Lanzolla, 2016). Taking into account the arguments presented, this study constructs the following hypothesis:

H1. Strategic innovation has a positive effect on human capital.

2.2 Strategic Innovation and Competitive Advantage

An organization's resources become inimitable if they develop as a result of unique historical conditions and if the link between the resource and competitive advantage is causally ambiguous and socially complex (Chowhan, 2016). Nowadays, many organizations depend on innovation for their products, patents, copyrights and other appropriate barriers but these are rarely strong enough to fully protect an innovator from competitive entry (Liu and Atuahene-Gima, 2018).

Previous studies have focused on the entire set of new or modified products and processes adopted by a firm and its competitors. An argument may be made of an even stronger relationship between innovations that are industry firsts (true innovations) and the emergence of performance (Spring et al., 2017). Even if the performance benefits associated with short-term monopoly positions are not evident, the propensity to move into new initiatives may enhance a firm's overall competitive position. The issue is whether to expect first-mover advantages at the level of the specific strategic attribute (Ma, Hou and Xin, 2017). Strategic innovation helps to ensure that firms do not fall into the trap of blindly following "best practices" and management fads, which cannot in any case afford competitive advantage because all their competitors are doing similar things (AlQershi, Abas and Mokhtar, 2018).

Furthermore, according to Hinterhuber and Liozu (2014), the previous studies on innovation generally suppose that the implementation of innovation strategies will improve a firm's competitive advantage. Davey and Sanders (2012), for example, showed that strategic innovation has a significant effect on the competitive advantage of enterprises. Technology is a key factor which influences SMEs and leads to superiority over competitors. To improve performance, enterprises should pay attention to innovation activities.

Therefore, effective and efficient creation to design new products are crucial to the organization (Kahn, 2018). Rajapathirana and Hui (2018), stated that the selection, storage and spread process of innovation capabilities can significantly influence the implementation of a competitive advantage. Other scholars have argued that an enterprise should develop the capability of innovation storage to increase the firm's market share and enhance its competitive advantage (Lin and Chen, 2017). Hence, this study examines the effect of strategic innovation on competitive advantage in the Yemeni manufacturing sector, and hypothesizes:

H2. Strategic innovation has a positive effect on competitive advantage.

2.3 Human Capital

Although human capital is considered one of the critical elements in gaining a competitive advantage (AlQershi, Abas and Mokhtar, 2019c; Delery and Roumpi, 2017), the literature provides numerous definitions of the term. For example, Roos and Roos (1997), defined human capital as the hidden assets of

the company not fully captured on the balance sheet, including both what is in the heads of the organization's members and what is left in the company when they leave. Ramezan (2011), defined it as the set of attitudes, values and aptitude of employees that result in competitive advantage and the creation of organizational value. In other words, it is the employees' experience, know-how and talent in the organization (Bontis, 1998). It refers to the individual's capability, skills, knowledge and experience (Sharabati, Jawad and Bontis, 2010; Hitt et al., 2001).

Human capital thus represents the human factor in the organization, the skills combining intelligence and expertise that employees take with them when they leave and which give the company its distinctive character (Vidotto et al., 2017). In this study we define human capital as possession of knowledge, applied experience, organizational technology and professional skills that provide the firm with the required competitive advantage over its market rivals.

The relationship between human capital and competitive advantage has awakened interest among practitioners and academics who understand human capital as a factor that will contribute to the creation of competitive advantage for firms and new positions for business management (Delery and Roumpi, 2017). From this perspective, firms are aware that human capital encouraging innovation will be the key to ensuring a unique outcome which will last and continue to contribute to substantial increases in market share (Kianto, Sáenz and Aramburu, 2017). At the same time, firms which try to develop their human capital can respond to alterations in their environment efficiently by improving their capability, enabling them to improve their competitive advantage (Huo et al., 2016).

Several studies have obtained specific results from examining how human capital contributes to competitive advantage (Delery and Roumpi, 2017; Hsu and Chen, 2019) and have found a significant relationship between the two variables (Yaseen, Dajani and Hasan, 2016). AlQershi, Abas and Mokhtar (2019b), conclude from a literature review that the studies published to date suggest that firms which invest in human capital are on average more profitable than firms not characterized by human capital. A meta-analysis by Kamukama and Sulait (2017), shows that human capital affects a firm's competitive advantage directly through its impact on the market; this relationship is particularly significant in manufacturing firms. Based on these arguments, we propose the following hypothesis:

H3. Human capital has a positive effect on competitive advantage.

Additionally, a firm aiming to achieve competitive advantage often requires fundamental investment in its human capital. Innovation is not an easy process, and one of its most central components is a high level of skills (Spring et al., 2017; Verbano and Crema, 2016). Human capital can support firms in creating efficient processes to achieve the firm's vision (Vidotto et al., 2017).

Human capital is the key to introducing innovation, creating efficiency in performance and developing new products, thus increasing the firm's revenue (Kianto, Sáenz and Aramburu, 2017). Human capital can also generate advantage that is not easy for competitors to follow, if the human wealth associated with these innovations is exclusive and firm specific.

The human skills and capabilities that firms possess enables them to design efficient products, finding a wider market place. The effect of human capital on organizations is undeniable, and the literature describe the significant influence of this variable on innovation and competitive advantage (Vidotto et al., 2017; Huo et al., 2016). Therefore, we propose the following hypothesis:

H4. Human capital mediates the relationship between strategic innovation and competitive advantage.

3 METHODOLOGY

3.1 Sample and Measurements

This study adopts a survey to collect data which, according to Fowler (2013), furnishes the quantitative/numeric characteristics of the sample. The study's population frame is taken from the 2017 Directory of Small and Medium Manufacturing Companies (MYIT, 2017) that currently lists 1,441 manufacturers.

From the total of 1,441 SMEs, the sample size table of Krejcie and Morgan (1970) was applied; as the population increases, the sample size increases at a diminishing rate, remaining constant at 307 when the population is between 1,400 and 1,500. For this study, to ensure the minimum response of 307 cases, and taking into account that the survey method has a poor response rate, a total of 550 questionnaires was distributed to SME owners. This took into consideration that the larger the study sample, the more the results can be generalized to the target population.

The study employed a stratified random sampling design, where the population was divided into sub-groups/strata prior to obtaining random samples from each stratum proportional to the population. The complete list of SMEs was entered in SPSS and a random number list generated which was finally used for administering the questionnaires. Three research variables are measured: strategic innovation uses 12 items from Yang (2014), human capital indicators are adopted from Sharabati, Jawad and Bontis (2010), measuring items such as skills, knowledge and expertise, attitude and intellectual agility; and competitive advantage indicators are adopted from Porter (1985) and Sharma (2005).

Finally, the software utilized for the PLS-SEM analysis in this research is Smart-PLS (Hair et al., 2017). The analysis was performed in two stages: assessment of the measurement model and of the structural model. The measurement model

determines the association between the latent variable and their respective items to measure reliability and validity. The structural model determines the relationship between the independent variables and the dependent variable to measure the path coefficients, effect sizes, significance of the relationship and the amount of variance in the dependent variable (R^2) explained by the independent variables.

4 ANALYSIS AND RESULTS

4.1 Data Screening

Data preparation and screening is the first stage in analysing data for research using multivariate analysis. This is important in order to check the correctness and suitability of the data for the final analysis. Data cleaning and screening made sure that the data does not violate any of the assumptions of SEM (Hair et al., 2016). They also give the researcher a detailed understanding of the distribution of the data, and indicate if there are missing data (Pallant, 2013).

4.2 Outlier

The Mahalanobis distance (D2) measure can be used to determine and rectify the outlier problem. In the present study it was employed to check multivariate outliers; on the basis of the four variables of the study, the suggested chi-square threshold is 71.43, with (p = 0.001), and the highest D2 value using SPSS is 58.60. Therefore, no multivariate outlier was detected, prompting the researcher to include all 238 cases in multivariate analysis.

The next step was to test the hypothesis results by PLS-SEM analysis. Hypotheses are significant when the p-value is 0.05. Based on Table 2 and Figure 1, the structural model's full estimates are presented as follows: (1) the effect of strategic innovation (SI) on human capital (HC) shows structural coefficient of 0.295 and p-value of 0.002; p-value < 0.05 and positive coefficient indicate that there is a significant and positive relation between SI and HC. The higher SI, the higher is HC. (2) The effect of SI on competitive advantage (CA) shows a structural coefficient of 0.397 and p-value of 0.004. p-value < 0.05 and the positive coefficient indicate that there is a significant and positive relation between SI and CA. The higher SI, the higher is CA. (3) The effect of HC on CA shows a structural coefficient of 0.382 and p-value of 0.003. p-value < 0.05 and positive coefficient indicate a significant and positive relation between HC and CA. The higher HC, the higher is CA. Finally, this study proposed that HC mediates the relationship between IS and CA. Table 1 and Figure 1 present the results of mediation using the Sobel test, which show that the coefficient of indirect influence is 0.173 and p-value 0.041 < 0.05, indicating that HC mediated the effect of SI on CA. The positive coefficient indicates that higher SI will lead to greater CA if mediated by higher HC.

Table 1 – Result of SEM Structural Model

No.	*Relations*	*Coefficient*	*p-values*	*Decision*
1	SI → HC	0.295	0.002	Supported
2	SI → CA	0.397	0.004	Supported
3	HC → CA	0.382	0.003	Supported
4	SI → HC → CA	0.173	0.041	Supported

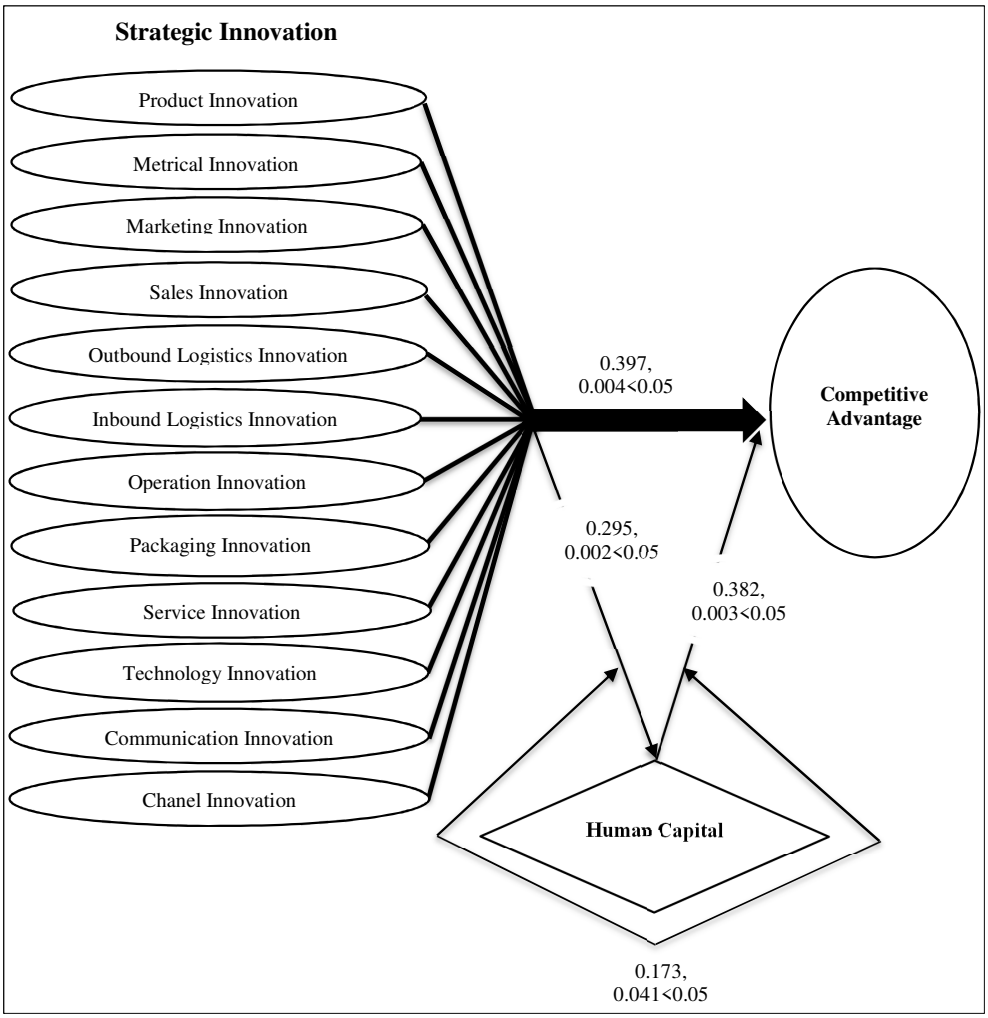


Figure 1 – Results of SEM Structural Model

5 DISCUSSION AND CONCLUSIONS

Manufacturing firms seek to enhance their competitive position by improving their responsiveness to market changes and competitors; it is therefore essential to ensure that they have new technology and respond to the needs of their customers. More importantly, human capital forms the heart of knowledge, applied experience, technology and customer relationships in the organization, where specific professional skills furnish the required competitive advantage. Furthermore, it is the core of organizations in enhancing a market niche, and thus this study contributes by empirically examining its mediating effect. Specifically, the mediating role of human capital in the relationship between strategic innovation and competitive advantage in Yemen and the Middle East is this paper's main contribution to the literature. In fact, this study corroborates for the first time, as far as we know, the influence of HC on SI and CA.

Our findings have implications for owners and managers involved in the manufacturing sector, in line with results reported in the literature. The most important result of our study is the significant positive effect of strategic innovation on SMEs' competitive advantage, in line with a series of high profile studies (Lilly and Juma, 2014; Lynn and Kalay, 2015). This result shows that if manufacturing SMEs invest in obtaining innovation technologies they can achieve better performance and a competitive position in the market. This finding is in line with those of Yang (2014) and AlQershi, Abas and Mokhtar (2019b), who argued that companies that seek to be proactive in acquiring innovation tools and human skills will gain market share, profit margins and competitive advantages.

Our study has also found that investing in human capital will positively influence competitive advantage in the manufacturing sector. In other words, the role of human capital is to explore and improve the skills and knowledge of employees, leading to high performance in terms of profitability and market share. Our finding generally agrees with that of Jin, Hopkins and Wittmer (2010), who found the same positive relationship.

Finally, the relationship between competitive advantage and strategic innovation is fully mediated by human capital. And already explained, strategic innovation had a direct impact on human capital and competitive advantage, before the introduction of human capital in the model. Given the findings in the literature, this is unsurprising and interesting. Human capital is the backbone and hidden wealth of firms (Ahmed and Brennan, 2019; AlQershi, Abas and Mokhtar, 2018), so it is not surprising that strategic innovation, the firm's collection of new technologies, would affect competitive advantage through human capital. Our study highlights the value of the power of human capabilities at the levels of individuals or the firm; all knowledge, which may fall by the wayside in SMEs, depends on the skills and professionalism of employees in creating new ideas (Sharabati, Jawad and Bontis, 2010), enabled by the creation and development of human capital.

6 THEORETICAL IMPLICATIONS

The framework developed here was derived from existing theories and studies. The resource based view and innovation theories (Barney, 1991, 2001; Acemoglu and Linn, 2004; Mytelka and Smith, 2002) present a succinct view for understanding the influence of strategic innovation on human capital and manufacturing SMEs' competitive advantage in Yemen. The results corroborate previous studies and fill the gaps by demonstrating that both strategic innovation and human capital are important for competitive advantage.

There are also direct influences in the relationship between strategic innovation and human capital. The results of this study indicate that strategic innovation has significant effect on manufacturing SMEs' competitive advantage. Human capital is not only directly associated with their competitive advantage, but also mediates in the relationship between strategic innovation and competitive advantage. Thus, human capital is essential in creating a greater competitive advantage in manufacturing SMEs.

The findings also open avenues to examine SMEs' competitive advantage, as previous studies only focused on the direct innovation-competitive advantage relationship but not on strategic innovation. This is also the first study to examine the direct strategic innovation-SMEs' competitive advantage relationship in a Middle Eastern country, Yemen. It provided insight into the strategic innovation types (e.g. marketing, product, sales, material and design innovation). This is pertinent as strategic innovation is presently seen as a tool to improve competitive advantage among manufacturing firms around the globe, and yet its impact on Yemeni SMEs has been overlooked. This study reduced this gap in the literature. In addition, given the strategic role of the manufacturing sector in national economic development, there is an obvious need for studies on the sector. This study contributes to this gap in the literature. The focus on human capital as medietor is also a good contribution to the literature.

Lastly, the majority of studies concerning the competitive advantage of manufacturing SMEs were conducted in Europe, South Asia, Australia and the Americas, leaving out the Middle East and Arab countries. Again, the study context contributes towards filling this gap.

7 MANAGERIAL IMPLICATIONS

The study contributes to the general body of knowledge by integrating strategic innovation and human capital and manufuctering SME performance in one study in order to see their relationship and how these variables contribute to development and growth of not only the Yemeni SMEs but also the economy as a whole. However, no study has previously used the framework developed in this study.

The developed framework can be of benefit to owners and managers in the manufacturing sector in assessing innovations and their competitive advantage. Starting with a situations analysis of the firm's processes and its strategic vision and goals, relevant innovation, human capital and competitive advantage indicators can be identified. The strategic innovation mould indicates the balance between the firm's selection of innovation strategies and the competitive advantage aimed for. The study framework with the process model enables managers to concentrate on particular processes which need to advance, taking the following steps: a) Identification of the firm's strategies, missions and vision. b) Identification of innovation and human capital factors and indicators to support firms in increasing their market share and competitive advantage. c) Access to innovation technologies. d) Obtaining, training and developing human capital. e) Identification of procedures affecting competitive advantage and innovation.

8 LIMITATIONS AND FUTURE RESEARCHES

This study has several limitations. It addressed strategic innovation functionality by adopting a scale developed by Yang (2014), concentrating on twelve main dimensions. However, strategic innovation practice may contain more than twelve dimensions. Nevertheless, the measurements used in this study are appropriate, valid and reliable (AlQershi, Abas and Mokhtar, 2019b). Future studies could expand the number of dimensions and investigate any others which might contribute to the topic. Another limitation of this study is that the sample was limited to manufacturing SMEs. Other sectors of the Yemeni economy could therefore be investigated, for example, food industries, cement, etc. Similarly, the results cannot be generalized to other sectors such as services, whose structure and vision differ from those of manufacturing SMEs. While the current results may be appropriate for SMEs in developing countries, the researcher believes they cannot be appropriate in advanced countries, with different economies, financial structures, and employee and management cultures. Finally, although our findings and results are specific to Yemenis, we they will serve as the basis for sharpening understanding of the relationship between strategic innovation, human capital, and competitive advantage in others emerging economies.

ACKNOWLEDGEMENTS

The authors would like to thank University Tun Hussein Onn Malaysia (UTHM) for funding this research (under research fund E15501, Research Management Center, UTHM). The support given by Research Center, UTHM for providing the facilities to perform this research is highly appreciated.

REFERENCES

Abd Aziz, N.N. and Samad, S., 2016. Innovation and competitive advantage: Moderating effects of firm age in foods manufacturing SMEs in Malaysia. *Procedia Economics and Finance* [e-journal], 35, pp.256-266. doi: 10.1016/S2212-5671(16)00032-0.

Acemoglu, D. and Linn, J., 2004. Market size in innovation: theory and evidence from the pharmaceutical industry. *The Quarterly journal of economics* [e-journal], 119(3), pp.1049-1090. doi: 10.1162/0033553041502144.

Afuah, A., 2009. *Strategic innovation: new game strategies for competitive advantage*. Routledge.

Ahmed, F.U. and Brennan, L., 2019. The impact of Founder's human capital on firms' extent of early internationalisation: Evidence from a least-developed country. *Asia Pacific Journal of Management* [e-journal], 36(3), pp.615-659. doi: 10.1007/s10490-019-09646-4.

AlQershi, N.A., 2020. Strategic thinking, strategic planning, strategic innovation and the performance of SMEs: The mediating role of human capital. *Management Science Letters* [e-journal], 11(1), pp.1003-1012. doi: 10.5267/j.msl.2020.9.042.

AlQershi, N.A, Abas, Z.B. and Mokhtar, S.S.M., 2018. Strategic innovation as driver for SME performance in Yemen. *Journal of Technology and Operations Management* [e-journal], 13(1), pp. 30-41. doi: 10.32890/jtom2018.13.1.9420.

AlQershi, N.A, Abas, Z.B. and Mokhtar, S.S.M., 2019a. Prospecting for structure capital: Proactive strategic innovation and the performance of manufacturing SMEs in Yemen. *International Journal of Entrepreneurship*, 23(3), pp.1-19.

AlQershi, N.A, Abas, Z.B. and Mokhtar, S.S.M., 2019b. The Mediating Effect of Human Capital on the Relationship between Strategic Innovation and the Performance of Manufacturing SMEs in Yemen. *Organizations and Markets in Emerging Economies* [e-journal], 10(1), pp.57-77. doi: 10.15388/omee.2019.10.00003.

AlQershi, N.A, Abas, Z.B. and Mokhtar, S.S.M., 2019c. Investment in the Hidden Wealth of Intellectual Capital and Its Effect on Competitive Advantage. *Anwesh*, 4(1), pp.17-22.

AlQershi, N.A, Abas, Z.B and Mokhtar, S.S.M., 2020a. Investigating the Influence of Intellectual Capital Dimensions Practices On SMEs Performance. *Academy of Entrepreneurship Journal,* 26 (2) pp.1-7.

AlQershi, N.A, Abas, Z.B and Mokhtar, S.S.M., 2020b. The intervening effect of structural capital on the relationship between strategic innovation and manufacturing SMEs' performance in Yemen. *Management Science Letters* [e-journal], 11(1), pp.21-30. doi: 10.5267/j.msl.2020.8.034.

Anderson, P. and Tushman, M.L. eds., 2004. *Managing strategic innovation and change: A collection of readings*. 2nd Edition. Oxford University Press.

Barney, J.B., 1991. Firm resources and sustained competitive advantage. *Journal of management*, 17(1), pp.99-120.

Barney, J.B., 2001. Resource-based theories of competitive advantage: A ten-year retrospective on the resource-based view. *Journal of management* [e-journal], 27(6), pp.643-650. doi: 10.1177/014920630102700602.

Bontis, N., 1998. Intellectual capital: an exploratory study that develops measures and models. *Management decision* [e-journal], 36(2), pp.63-76. doi: 10.1108/00251749810204142.

Chowhan, J., 2016. Unpacking the black box: understanding the relationship between strategy, HRM practices, innovation and organizational performance. *Human Resource Management Journal* [e-journal], 26(2), pp.112-133. doi: 10.1111/1748-8583.12097.

Davey, K.S. and Sanders, T.J., 2012. Serial strategic innovation and sustainable competitive advantage: A longitudinal case study. *Journal of Case Research in Business and Economics*, 4, pp.1-20.

Delery, J.E. and Roumpi, D., 2017. Strategic human resource management, human capital and competitive advantage: is the field going in circles? *Human Resource Management Journal* [e-journal], 27(1), pp.1-21. doi: 10.1111/1748-8583.12137.

Derrick, P. and Soren, K., 2007. *A framework for strategic innovation*. Managing Principals, InnovationPoint LLC.

Dogan, E., 2017. A strategic approach to innovation. *Journal of Management, Marketing and Logistics* [e-journal], 4(3), pp.290-300. doi: 10.17261/Pressacademia.2017.49.

Drejer, A., 2006. Strategic innovation: a new perspective on strategic management. *Handbook of business strategy* [e-journal], 7(1), pp.143-147. doi: 10.1108/10775730610618756.

Dyer, J.H. and Singh, H., 1998. The relational view: Cooperative strategy and sources of inter organisational competitive advantage. *Academy of management review* [e-journal], 23(4), pp.660-679. doi: 10.2307/259056.

Edeh, J.N., Obodoechi, D.N. and Ramos-Hidalgo, E., 2020. Effects of innovation strategies on export performance: New empirical evidence from developing market firms. *Technological Forecasting and Social Change* [e-journal], 158, p.120167. doi: 10.1016/j.techfore.2020.120167.

Eniola, A.A. and Ektebang, H., 2014. SME firms performance in Nigeria: Competitive advantage and its impact. *International Journal of Research Studies in Management* [e-journal], 3(2), pp.75-86. doi: 10.5861/ijrsm.2014.854.

Fowler Jr., F.J., 2013. *Survey research methods.* 5th Edition. SAGE publications.

Genc, E., Dayan, M. and Genc, O.F., 2019. The impact of SME internationalization on innovation: The mediating role of market and entrepreneurial orientation. *Industrial Marketing Management* [e-journal], 82, pp.253-264. doi: 10.1016/j.indmarman.2019.01.008.

Giachetti, C. and Lanzolla, G., 2016. Product Technology imitation over the product Diffusion cycle: Which Companies and product innovations do competitors imitate more quickly? *Long Range Planning* [e-journal], 49(2), pp.250-264. doi: 10.1016/j.lrp.2015.05.001.

Hair Jr., J.F., Anderson, R.E., Babin, B.J. and Black, W.C., 2010. *Multivariate data analysis: A global perspective.* 7th Edition. Upper Saddle River: Pearson Education.

Hair Jr., J.F., Sarstedt, M., Ringle, C.M. and Gudergan, S.P., 2017. *Advanced issues in partial least squares structural equation modelling*. SAGE publications.

Herrera, M.E.B., 2015. Creating competitive advantage by institutionalizing corporate social innovation. *Journal of Business Research* [e-journal], 68(7), pp.1468-1474. doi: 10.1016/j.jbusres.2015.01.036.

Hinterhuber, A. and Liozu, S.M., 2014. Is innovation in pricing your next source of competitive advantage? *Business Horizons* [e-journal], 57(3), pp.413-423. doi: 10.1016/j.bushor.2014.01.002.

Hitt, M.A., Bierman, L., Shimizu, K. and Kochhar, R., 2001. Direct and moderating effects of human capital on strategy and performance in professional service firms: A resource-based perspective. *Academy of Management journal* [e-journal], 44(1), pp.13-28. doi: 10.5465/3069334.

Hjalager, A.M., 2018. Strategic innovation in tourism business. In: L. Moutinho and A. Vargas-sánchez, eds. 2018. *Strategic management in tourism.* CABI. Chapter 7. doi: 10.1079/9781786390240.0102.

Hsu, B.X. and Chen, Y.M., 2019. Industrial policy, social capital, human capital, and firm-level competitive advantage. *International Entrepreneurship and Management Journal* [e-journal], 15(3), pp.883-903. doi: 10.1007/s11365-019-00584-7.

Huo, B., Ye, Y., Zhao, X. and Shou, Y., 2016. The impact of human capital on supply chain integration and competitive performance. *International Journal of Production Economics* [e-journal], 178, pp.132-143. doi: 10.1016/j.ijpe.2016.05.009.

Jin, Y., Hopkins, M.M. and Wittmer, J.L., 2010. Linking human capital to competitive advantages: Flexibility in a manufacturing firm's supply chain. *Human Resource Management* [e-journal], 49(5), pp.939-963. doi: 10.1002/hrm.20385.

Johnson, M.W. and Lafley, A.G., 2010. *Seizing the white space: Business model innovation for growth and renewal*. Harvard Business Press.

Kahn, K.B., 2018. Understanding innovation. *Business Horizons* [e-journal], 61(3), pp.453-460. doi: 10.1016/j.bushor.2018.01.011.

Kamukama, N. and Sulait, T., 2017. Intellectual capital and competitive advantage in Uganda's microfinance industry. *African Journal of Economic and Management Studies* [e-journal], 8(4), pp.498-514. doi: 10.1108/AJEMS-02-2017-0021.

Kianto, A., Sáenz, J. and Aramburu, N., 2017. Knowledge-based human resource management practices, intellectual capital and innovation. *Journal of Business Research* [e-journal], 81, pp.11-20. doi: 10.1016/j.jbusres.2017.07.018.

Kodama, M., 2018. *Sustainable growth through strategic innovation: Driving congruence in capabilities*. Edward Elgar Publishing.

Kotabe, M. and Kothari, T., 2016. Emerging market multinational companies' evolutionary paths to building a competitive advantage from emerging markets to developed countries. *Journal of World Business* [e-journal], 51(5), pp.729-743. doi: 10.1016/j.jwb.2016.07.010.

Krejcie, R.V. and Morgan, D.W., 1970. Determining sample size for research activities. *Educational and psychological measurement*, 30(3), pp.607-610.

Lee, V.H., Foo, A.T.L., Leong, L.Y. and Ooi, K.B., 2016. Can competitive advantage be achieved through knowledge management? A case study on SMEs. *Expert Systems with Applications* [e-journal], 65, pp.136-151. doi: 10.1016/j.eswa.2016.08.042.

Lilly, L. and Juma, D., 2014. Influence of strategic innovation on performance of commercial banks in Kenya: The case of Kenya Commercial Bank in Nairobi County. *European Journal of Business Management*, 2(1), pp.336-341.

Lin, Y.H. and Chen, Y.S., 2017. Determinants of green competitive advantage: the roles of green knowledge sharing, green dynamic capabilities, and green service innovation. *Quality & Quantity* [e-journal], 51(4), pp.1663-1685. doi: 10.1007/s11135-016-0358-6.

Liu, W. and Atuahene-Gima, K., 2018. Enhancing product innovation performance in a dysfunctional competitive environment: The roles of competitive strategies and market-based assets. *Industrial Marketing Management* [e-journal], 73, pp.7-20. doi: 10.1016/j.indmarman.2018.01.006.

Lynn, G.S. and Kalay, F., 2015. Vision and Its Impact on Team Success. *Journal of Business Economics and Finance* [e-journal], 4(4), pp.744-768. doi: 10.17261/Pressacademia.2015414540.

Ma, Y., Hou, G. and Xin, B., 2017. Green process innovation and innovation benefit: The mediating effect of firm image. *Sustainability* [e-journal], 9(10), p.1778. doi: 10.3390/su9101778.

Markides, C., 1997. Strategic innovation. *Sloan management review*, 38, pp.9-24.

MYIT-Matrade, 2017. *Directory. Small and Medium Enterprises*. MYIT-Yemen.

Mytelka, L.K. and Smith, K., 2002. Policy learning and innovation theory: an interactive and co-evolving process. *Research policy* [e-journal], 31(7-8), pp.1467-1479. doi: 10.1016/S0048-7333(02)00076-8.

Pallant, J. 2013. *SPSS survival manual.* McGraw-Hill Education.

Popa, S., Soto-Acosta, P. and Martinez-Conesa, I., 2017. Antecedents, moderators, and outcomes of innovation climate and open innovation: An empirical study in SMEs. *Technological Forecasting and Social Change* [e-journal], 118, pp.134-142. doi: 10.1016/j.techfore.2017.02.014.

Porter, M.E., 1985. *Competitive Advantage.* New York: Free Press New York.

Quaye, D. and Mensah, I., 2019. Marketing innovation and sustainable competitive advantage of manufacturing SMEs in Ghana. *Management Decision* [e-journal], 57(67), pp.1535-1553. doi: 10.1108/MD-08-2017-0784.

Rajapathirana, R.J. and Hui, Y., 2018. Relationship between innovation capability, innovation type and firm performance. *Journal of Innovation & Knowledge* [e-journal], 3(1), pp.44-55. doi: 10.1016/j.jik.2017.06.002.

Ramezan, M., 2011. Intellectual capital and organizational organic structure in knowledge society: How are these concepts related? *International Journal of Information Management* [e-journal], 31(1), pp.88-95. doi: 10.1016/j.ijinfomgt.2010.10.004.

Roos, G. and Roos, J., 1997. Measuring your company's intellectual performance. *Long range planning* [e-journal], 30(3), pp.413-426. doi: 10.1016/S0024-6301(97)90260-0.

Sabahi, S. and Parast, M.M., 2020. Firm innovation and supply chain resilience: A dynamic capability perspective. *International Journal of Logistics Research and Applications* [e-journal], 23(3), pp.254-269. doi: 10.1080/13675567.2019.1683522.

Schlegelmilch, B.B., Diamantopoulos, A. and Kreuz, P., 2003. Strategic innovation: the construct, its drivers and its strategic outcomes. *Journal of strategic marketing* [e-journal], 11(2), pp.117-132. doi: 10.1080/0965254032000102948.

Sharabati, A.A.A., Jawad, S.N. and Bontis, N., 2010. Intellectual capital and business performance in the pharmaceutical sector of Jordan. *Management decision* [e-journal], 48(1), pp.105-131. doi: 10.1108/00251741011014481.

Sharma, A., 2005. Managing human resource capability of sustainable competitive advantage. *Education and Training* [e-journal], 47(8/9), pp.645-666. doi: 10.1108/00400910510633161.

Simpson, M., Taylor, N. and Barker, K., 2004. Environmental responsibility in SMEs: does it deliver competitive advantage? *Business strategy and the environment* [e-journal], 13(3), pp.156-171. doi: 10.1002/bse.398.

Sisodia, R., Wolfe, D. and Sheth, J.N., 2003. *Firms of endearment: How world-class companies profit from passion and purpose*. Pearson Prentice Hall.

Sky-News, 2012. *Yemen: Combating unemployment through small projects.* [video online]. Available at: <https://www.youtube.com/watch?v=ZW7KWVEdQOY /2012> [Accessed 29 October 2020].

Soosay, C., Nunes, B., Bennett, D.J., Sohal, A., Jabar, J. and Winroth, M., 2016. Strategies for sustaining manufacturing competitiveness: comparative case studies in Australia and Sweden. *Journal of Manufacturing Technology Management* [e-journal], 27(1), pp.6-37. doi: 10.1108/JMTM-04-2014-0043.

Spring, M., Hughes, A., Mason, K. and McCaffrey, P., 2017. Creating the competitive edge: A new relationship between operations management and industrial policy. *Journal of Operations Management* [e-journal], 49-51, pp.6-19. doi: 10.1016/j.jom.2016.12.003.

Stajkovic, A.D. and Sergent, K., 2019. *Cognitive Automation and Organizational Psychology: Priming Goals as a New Source of Competitive Advantage*. Routledge.

The global innovation index (GII), 2014. *Stronger Innovation Linkages for Global.* [pdf] Fontainebleau, Ithaca, and Geneva: orld Intellectual Property Organization (WIPO) and in New Delhi, India, by the Confederation of Indian Industry (CII). Available at: <https://www.globalinnovationindex.org/userfiles/file/reportpdf/GII-2014-v5.pdf> [Accessed 04 November 2020].

The global innovation index, (GII) 2015. *Stronger Innovation Linkages for Global*. [pdf] Fontainebleau, Ithaca, and Geneva: orld Intellectual Property Organization (WIPO) and in New Delhi, India, by the Confederation of Indian Industry (CII). Available at: <https://ec.europa.eu/futurium/en/system/files/ged/22globalinnovationindex-wipo_gii_2015.pdf> [Accessed 04 November 2020].

The global innovation index, (GII) 2016. *Stronger Innovation Linkages for Global*. [pdf] Fontainebleau, Ithaca, and Geneva: orld Intellectual Property Organization (WIPO) and in New Delhi, India, by the Confederation of Indian Industry (CII). Available at: <https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2016.pdf> [Accessed 04 November 2020].

The global innovation index, (GII) 2017. *Stronger Innovation Linkages for Global.* [pdf] Fontainebleau, Ithaca, and Geneva: orld Intellectual Property Organization (WIPO) and in New Delhi, India, by the Confederation of Indian Industry (CII). Available at: <https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2017.pdf> [Accessed 04 November 2020].

Verbano, C. and Crema, M., 2016. Linking technology innovation strategy, intellectual capital and technology innovation performance in manufacturing SMEs. *Technology analysis & strategic management* [e-journal], 28(5), pp.524-540. doi: 10.1080/09537325.2015.1117066.

Vidotto, J.D.F., Ferenhof, H.A., Selig, P.M. and Bastos, R.C., 2017. A human capital measurement scale. *Journal of Intellectual Capital* [e-journal], 18(2), pp.316-329. doi: 10.1108/JIC-08-2016-0085.

Yang, X., 2014. Different choice of strategic innovation among companies in China market. *Journal of Science and Technology Policy Management* [e-journal], 5(2), pp.106-121. doi: 10.1108/JSTPM-02-2014-0006.

Yaseen, S.G., Dajani, D. and Hasan, Y., 2016. The impact of intellectual capital on the competitive advantage: Applied study in Jordanian telecommunication companies. *Computers in Human Behavior* [e-journal], 62, pp.168-175. doi: 10.1016/j.chb.2016.03.075.

Zerenler, M., Hasiloglu, S.B. and Sezgin, M., 2008. Intellectual capital and innovation performance: empirical evidence in the Turkish automotive supplier. *Journal of technology management & innovation* [e-journal], 3(4), pp.31-40. doi: 10.4067/S0718-27242008000200003.

ABOUT AUTHORS

Nagwan Abdulwahab AlQershi – (N.A.A.) University Tun Hussein Onn Malaysia, Faculty of Technology Management and Business, Batu Pahat, Johor, Malaysia, Department of Postgraduate Studies, e-mail: nagwan@uthm.edu.my, Author's ORCID: 0000-0002-7240-6558.

Mohd Lizam Bin Mohd Diah – (M.L.B.M.D.) University Tun Hussein Onn Malaysia, Faculty of Technology Management and Business, Batu Pahat, Johor, Malaysia, Department of Real Estate Management, Assoc. Prof., e-mail: lizam@uthm.edu.my, Author's ORCID: 0000-0003-3333-9695.

Aryani Binti Ahmed Latiffi – (A.B.A.L.) University Tun Hussein Onn Malaysia, Faculty of Technology Management and Business, Batu Pahat, Johor, Malaysia, Department of Management and Technology, Assoc. Prof., e-mail: aryani@uthm.edu.my, Author's ORCID: 0000-0003-1082-8111.

Wan Nurul Karimah Wan Ahmad – (W.N.K.W.A.) University Tun Hussein Onn Malaysia, Faculty of Technology Management and Business, Batu Pahat, Johor, Malaysia, Department of Management and Technology, Assist. Prof., e-mail: karimah@uthm.edu.my, Author's ORCID: 0000-0003-1130-0669.

AUTHOR CONTRIBUTIONS

N.A. – conceptualization, software, data curation, original draft preparation; review and editing; M.L.B.M.D. – validation; A.B.A.L. – formal analysis; W.N.K.W.A. – methodology; N.A., M.L.B.M.D. – supervision; N.A., M.L.B.M.D., A.B.A.L., W.N.K.W.A. – resources.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Big Five Personality Traits and Creativity

DOI: 10.12776/QIP.V24I3.1509

Michal Jirásek, František Sudzina

Received: 2020-10-06 Accepted: 2020-10-26 Published: 2020-11-30

ABSTRACT

Purpose: Personality traits represent an important driver of creativity. Several studies linked individual personality traits and creativity, yet in most cases, the literature provides contradictory insights. In this study, we quasi-replicate prior studies using a new sample to assess the reliability of previous research. Furthermore, we explore the topic in greater detail, as we also study the relationship of creativity with personality facets, a more fine-grained alternative.

Methodology/Approach: The study uses a survey-based sample of students from Denmark. To measure personality traits and facets, we asked respondents to fill 44 items Big Five Personality Inventory. We measured creativity using three items from the HEXACO-60 personality inventory. The data were analyzed using generalized least squares models with gender as a control.

Findings: In line with the previous literature, our research showed that Openness to Experience is positively related to creativity. We found similar, yet statistically weaker evidence for the relationship of Extraversion and creativity. In contrast to most of the previous findings, we also reported a negative relationship between Conscientiousness and creativity.

Research Limitation/Implication: Our research contributes to the topic of the relationship between personality traits and creativity. Some of the relationships fall into the area where the literature is not coherent. We propose that the explanation may stem from the too broad formulation of personality traits, and we partially show that using personality facets. For this reason, future research needs to go into detail of individual personality traits.

Originality/Value of paper: The paper provides further insight into the relationship between personality and creativity.

Category: Research paper

Keywords: Big Five; personality traits; creativity

1 INTRODUCTION

The ability to innovate is an important prerequisite of the long term feasibility of organizations. However, what we observe as innovation is actually the result of two interlinked components – creativity and its implementation. Anderson, Poročnik and Zhou (2014, p.1298) described these two components as following: "The creativity stage of this process refers to idea generation, and innovation [implementation] refers to the subsequent stage of implementing ideas toward better procedures, practices, or products".

As they continue, we can speak of creativity (and innovation) on all the levels of the organization, including individuals. In previous years, this area has hosted various research topics (Feist, 1998; Karwowski and Lebuda, 2016; Puryear, Kettler and Rinn, 2017). One of the critical questions addressed is whether certain personality traits are exhibiting more creative or innovative behavior.

Our research focused on the above-mentioned research question and enriched our current understanding by a survey-based study of Danish students. Our study contributes to the field in two aspects. First, it quasi replicated previous research on the relationship between personality traits and creativity. As we show below in the literature review, current findings are far from conclusive for most of the traits. Second, we went into detail of individual personality traits and studied their distinctive facets. Both these aspects enrich our current understanding of whether and how is personality associated with creativity.

2 LITERATURE REVIEW

The question of how Big Five personality traits relate to creativity has been studied in several papers (see Table 1). They show that personality traits are systematically related to creativity. On the other hand, as evident from our overview, their findings are far from conclusive.

The question of the replicability of previous studies is a hot topic in psychology and related fields. Numerous researchers failed to replicate the results of previous studies, opening the debate about methodology and reporting practices. While we admit that in some cases, a fraud may be the core cause of a failure to replicate, Maxwell, Lau and Howard (2015) emphasized another issue. Failure to replicate may also be caused by the low statistical power of replication studies. For this reason, it is meaningful to replicate previous research in various settings and cumulatively built a body of findings on a given topic.

Table 1 – Overview of Findings on the Relationship between Big Five Personality Traits and Creativity

	Extraversion	*Agreeableness*	*Conscientiousness*	*Neuroticism*	*Openness to Experience*
Sung and Choi (2009)	+	Not significant (+)	Not significant (-)	Not significant (+)	+
Batey, Chamorro-Premuzic and Furnham (2010)	+	Not significant (-)	-	Not significant (+/-)	+
Furnham, Hughes and Marshall (2013)	+	Not studied	Not studied	Not studied	+
Hughes, Furnham and Batey (2013)**	Not significant (not reported)	Not significant (not reported)	Not significant (not reported)	Not significant (not reported)	+
Karkowski et al. (2013)**	+	-	+	-	+
Kaufman and Beghetto (2013)	Not significant (not reported)	+	Not significant (not reported)	Not reported	+
Silvia et al. (2014)	Not significant (+)	Not significant (+)	+	Not significant (+)	+
Stock, von Hippel and Gillert (2016)	Not significant (+)	Not significant (+)	Not significant (-)	Not significant (-)	+
Kaspi-Baruch (2017)	Not significant (-)	Not significant (+)	Not significant (+)	Not significant (+)	+

Notes: ** Use Structural Equation Models (otherwise various forms of multivariate regressions).

Extraversion. "Extraversion describes the extent to which people are assertive, dominant, energetic, active, talkative, and enthusiastic," (Zhao and Seibert, 2006: 260). While six out of ten reviewed studies did not provide statistically significant results, the remaining four (Sung and Choi, 2009; Batey, Chamorro-Premuzic and Furnham, 2010; Furnham, Hughes and Marshall, 2013; Karkowski et al., 2013) found a positive relationship between extraversion and creativity. This led us to pose the following hypothesis:

H1. Extraversion is positively related to creativity.

Agreeableness. "Agreeableness assesses one's interpersonal orientation. Individuals high on Agreeableness can be characterized as trusting, forgiving, caring, altruistic, and gullible," (Zhao and Seibert, 2006, p.260). Agreeableness

represents one of the personality traits that is not clearly linked with creativity. Most of the studies we reviewed have not had significant findings. The only exceptions are Karkowski et al. (2013) (studying on self-reported creative self-efficacy and creative personal identity) who showed a negative relationship, and Kaufman and Beghetto (2013) (studying the perceived creative level of described products and people) positive. Based on the contradictory findings, we posed the following hypothesis:

H2. Agreeableness is not related to creativity.

Conscientiousness. "Conscientiousness indicates an individual's degree of organization, persistence, hard work, and motivation in the pursuit of goal accomplishment," (Zhao and Seibert, 2006, p.261). Conscientiousness provides another personality trait with contradictory findings. Out of three studies in our review that reported statistically significant findings, two (Karkowski et al. (2013), focusing on self-reported creative self-efficacy and creative personal identity; Silvia et al. (2014), focusing on real everyday creative activities) voted for positive relationship, while the remaining one (Batey, Chamorro-Premuzic and Furnham (2010), focusing on self-reported ideational behavior) voted otherwise. Based on the contradictory findings, we posed the following hypothesis:

H3. Conscientiousness is not related to creativity.

Neuroticism. "Neuroticism represents individual differences in adjustment and emotional stability," (Zhao and Seibert, 2006, p.260). Neuroticism is the trait that is the least linked with creativity in the previous research. Only Karkowski et al. (2013) reported a negative relationship in their study of creative self-efficacy and creative personal identity. Due to the fact that the majority of the literature has not provided conclusive findings, we posed the following hypothesis:

H4. Neuroticism is not related to creativity.

Openness to Experience. "Openness to Experience is a personality dimension that characterizes someone who is intellectually curious and tends to seek new experiences and explore novel ideas," (Zhao and Seibert, 2006, p.261). Openness to Experience is the only personality trait that has been unanimously confirmed by all reviewed studies. The reason is likely in the fact that it directly reflects creativity as apparent from its description. For this reason, we posed the following hypothesis:

H5. Openness to Experience is positively related to creativity.

3 METHODOLOGY

Data were collected in the spring semester 2014 using an on-line questionnaire. Respondents were students of Aalborg University. Of 186 students who started, 170 (of whom 105 were male and 65 female) fully filled in the questionnaire and were included in our study sample.

Dependent variable:

- *Creativity.* We measured creativity using three items from HEXACO-60 personality inventory (Ashton and Lee, 2009). We used the mean of these items as our final measure of creativity. Specifically, we used items 13, 37, and 49:
    - I would enjoy creating a work of art, such as a novel, a song, or a painting.
    - People have often told me that I have a good imagination.
    - I don't think of myself as the artistic or creative type.

Independent variables:

- *Personality traits.* The research presented in this paper is based on John and Srivastava's (1999) version of the Big Five Inventory questionnaire, which contains 44 statements (individual items are listed in the Appendix). The respondents rated statements on a 1-5 Likert scale where 1 means strongly disagree and 5 means strongly agree. To further explore individual personality traits, we also calculated 10 facets of them based on Soto and John (2009). These facets use 35 of the original 44 statements and are following (corresponding personality traits are in the brackets, details on individual items corresponding to them are again described in the Appendix):
    - Assertiveness (Extraversion),
    - Activity (Extraversion),
    - Altruism (Agreeableness),
    - Compliance (Agreeableness),
    - Order (Conscientiousness),
    - Self-Discipline (Conscientiousness),
    - Anxiety (Neuroticism),
    - Depression (Neuroticism),
    - Aesthetics (Openness to experience),
    - Ideas (Openness to Experience).

We used the means of corresponding items as the final measures.

Control variable:

- *Gender.* We asked respondents to categorize themselves at either male (coded 0) or female (coded 1).

A generalized least squares model (GLS) was used to analyze the impact of personality traits and their corresponding facets on creativity. All the calculations were conducted using R gls function (nlme package).

4 RESULTS

The descriptive statistics (means, standard deviations, and correlations) for the variables used in the model with personality traits are provided in Table 2. Multicollinearity is not an issue, with Variance Inflation Factors at 1.50 in their maximum (Neuroticism).

Table 2 – Descriptive Statistics Personality Traits

Variables			*Correlations*						
	Mean	SD	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
(1) Creativity	2.918	0.796	1.000						
(2) Extraversion	3.312	0.411	0.270	1.000					
(3) Agreeableness	3.620	0.442	-0.037	0.086	1.000				
(4) Conscientiousness	3.547	0.498	-0.092	0.054	0.274	1.000			
(5) Neuroticism	2.615	0.534	0.002	-0.299	-0.323	-0.180	1.000		
(6) Openness to Experience	3.374	0.451	0.597	0.298	0.081	0.110	-0.145	1.000	
(7) Gender	0.382	0.487	0.061	0.077	0.046	0.179	0.328	-0.003	1.000

Regarding the model with personality traits: First, Extraversion is weakly significant (p-value = 0.077) and have a small positive effect (partial eta squared = 0.019), providing weak support for H1. Second, Agreeableness is not significant (p-value = 0.592), supporting H2 of no relationship. Third, Conscientiousness is clearly significant (p-value = 0.020) and have a medium negative effect (partial eta squared = 0.033), against H3. Fourth, Neuroticism is not significant (p-value = 0.592), supporting H4 of no relationship. Finally, five, Openness to Experience is significant (p-value ~ 0.000) and have a large positive effect (partial eta squared = 0.345), supporting H5. Gender was not significantly linked with creativity.

Table 3 – GLS Model with Personality Traits

	B	Std. Error	t-value	p-value	partial eta squared
Intercept	-0.665	0.843	-0.789	0.431	
Extraversion	0.232	0.130	1.782	0.077	0.019
Agreeableness	-0.064	0.119	-0.537	0.592	0.002
Conscientiousness	-0.245	0.104	-2.351	0.020	0.033
Neuroticism	0.096	0.110	0.871	0.385	0.005
Openness to Experience	1.044	0.113	9.275	0.000	0.345
Gender	0.101	0.111	0.908	0.365	0.005
n = 170; R^2 = 0.405; Adj. R^2 = 0.382; AIC = 351.719; BIC = 376.469					

Personality traits consists of facets. In case of the Big Five Inventory with 44 statements, there are two facets per trait (Soto and John, 2009). The descriptive statistics (means, standard deviations, and correlations) for the variables used are provided in Table 3. Multicollinearity is again not an issue, with Variance Inflation Factors at 1.54 in their maximum (Depression).

Table 4 – Descriptive Statistics Personality Trait's Facets

Variables			*Correlations*											
	Mean	SD	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*
(1) Creativity	2.918	0.796	1.000											
(2) Assertiveness	3.234	0.579	0.167	1.000										
(3) Activity	3.674	0.596	0.304	0.302	1.000									
(4) Altruism	3.854	0.521	0.021	0.218	0.313	1.000								
(5) Compliance	3.294	0.600	-0.045	-0.088	0.107	0.313	1.000							
(6) Order	3.368	0.759	-0.170	0.004	0.139	0.265	0.019	1.000						
(7) Self-Discipline	3.508	0.553	-0.086	0.028	0.230	0.226	0.106	0.510	1.000					
(8) Anxiety	2.646	0.696	-0.024	-0.195	-0.291	-0.094	-0.107	0.021	-0.058	1.000				
(9) Depression	2.535	0.689	0.117	-0.289	-0.288	-0.328	-0.235	-0.294	-0.240	0.278	1.000			
(10) Aesthetics	3.006	0.693	0.495	0.088	0.224	-0.032	0.027	-0.066	0.082	-0.025	0.119	1.000		
(11) Ideas	3.498	0.516	0.369	0.187	0.354	0.229	-0.009	0.053	0.130	-0.200	-0.055	0.318	1.000	
(12) Gender	0.382	0.487	0.061	0.025	0.066	0.063	0.045	0.138	0.197	0.310	0.162	0.139	-0.079	1.000

Results of the GLS model indicated three personality facets that are significantly related to creativity (i.e. are below 0.1 threshold for p-value). All of them – Activity, Aesthetics, and Ideas – are positively related with p-values 0.005, ~ 0.000, and 0.006. Activity have a medium positive effect (partial eta squared = 0.048); Aesthetics a large positive effect (partial eta squared = 0.151); and Ideas a medium positive effect (partial eta squared = 0.046). Gender was again not significantly linked with creativity.

Table 5 – GLS Model with Personality Traits' Facets

	B	Std. Error	t-value	p-value	partial eta squared
Intercept	-0.166	0.825	-0.201	0.841	
Assertiveness	0.093	0.098	0.948	0.345	0.006
Activity	0.288	0.102	2.830	0.005	0.048
Altruism	-0.001	0.115	-0.008	0.993	0.000
Compliance	-0.042	0.093	-0.449	0.654	0.001
Order	-0.113	0.081	-1.383	0.169	0.012
Self-Discipline	-0.168	0.110	-1.523	0.130	0.014
Anxiety	0.078	0.083	0.941	0.348	0.006
Depression	0.089	0.090	0.983	0.327	0.006
Aesthetics	0.425	0.080	5.291	0.000	0.151
Ideas	0.312	0.113	2.769	0.006	0.046
Gender	0.025	0.117	0.215	0.830	0.000
n = 170; R^2 = 0.373; Adj. R^2 = 0.330; AIC = 387.594; BIC = 427.408					

5 DISCUSSION AND CONCLUSION

When comparing our findings with the previous literature, we added to the overwhelming evidence that Openness to Experience is a personality trait most directly linked with creativity. We also showed that Extraversion weakly increases creativity. In this trait, the literature is not unified. The cause may lie in the fact that two facets that constitute Extraversion – Assertiveness and Activity – do not both explain creativity, as we showed in our analysis.

Nevertheless, arguably the most unexpected results are the negative relationship of Conscientiousness and creativity. In this case, most of the literature did not report significant findings, while our sample demonstrated a highly significant association. This corresponded only to the study of Batey, Chamorro-Premuzic and Furnham (2010), while directly contradicted Karkowski et al. (2013) and Silvia et al. (2014). What is also interesting that this time, neither of the trait's facets – Order and Self-Discipline – drove the relationships with creativity directly. Our post-hoc analysis showed that creativity is linked only to some of the items of Conscientiousness personality trait (reversed items 18, 28, and 43 of 44-items Big Five Personality Inventory, see Appendix for these items). Therefore, it appears that similar to Extraversion, Conscientiousness needs to be narrowed down in investigation of creativity.

The study contributes to the literature on the relationship between personality and creativity, which is, in turn, a part of broadly defined creativity research (e.g.,

Kaufman and Sternberg, 2010). The influence of personality on creativity is now a well-established fact rooted in individual brain characteristics (e.g., Feist, 2010). Notwithstanding, creativity is only one of the key components of innovativeness and the ensuing innovation performance of individuals and organizations. While the relationship between Big Five personality traits and creativity has been a popular topic in the literature (see Table 1), research on innovativeness has been scarce. A comprehensive picture is given by the study of Stock, von Hippel and Gillert (2016), who followed the effect of personality traits on success in an innovation process (they distinguished three stages: idea generation, prototyping, and diffusion). They concluded that personality traits leading to a successful conclusion of a given stage differed over the innovation cycle. That points to an important implication for organizations that want to be more creative. Although it is arguably possible to increase creativity by hiring employees with particular personality traits (i.e., those that are open to experience, extravert but not conscientious), this would not perfectly translate into innovativeness. Not wasting one's creativity, therefore, means to complement her or him with someone with a different personality. That means someone who will translate creative ideas into actual products.

The main limitation of our study stems from its method, namely self-reported measures. However, self-reports are a standard approach used in the literature (all of the reviewed studies use self-reports for personality traits, and most of them also for creativity). One the other hand, this limitation also creates an opportunity for studies using personality traits that are assessed externally by other people, in the best case experts. Another limitation lies in the fact that we used only 35 out of 44 BFI items for the calculation of personality facets (see the Appendix). This implies that the observed relationships in models with personality traits may differ from the observed relationships in models with personality facets due to structural reasons. Nevertheless, since Soto and John (2009) worked with the original 44-items scale when establishing these calculations, we believe that such structural differences have only a limited effect on our findings.

We agree with the conclusion of Anderson, Potočnik and Zhou (2014) that the relationship between personality traits and creativity is complex and likely shaped by numerous contextual factors (as shown in, e.g., research of Raja and Johns, 2010). Besides Openness to Experience (Aesthetics and Ideas facets) that directly reflect the personality and for which there is strong evidence in the literature, other personality traits represent a more difficult question. We believe that a more detailed focus on facets may bring in more insight, as we showed in the case of Activity facet. While in our study, Extraversion is only weakly related to creativity, Activity shows a very strong relationship. Besides contextual factors, this may provide another explanation of contradictory findings of the literature.

In conclusion, the relationship between personality traits and creativity is likely to be complex. In our study, we focused on an empirical test of the effect of Big Five Inventory personality traits on creativity. We showed the statistical

significance of two of the traits that seem to be the most closely linked to creativity by previous studies: Openness to Experience and Extraversion. Furthermore, we showed a negative relationship between Conscientiousness and creativity. Finally, our analysis of personality traits' facets indicated that for some of the personality traits, more fine-grained measures are needed if we want to link them with creativity directly.

ACKNOWLEDGEMENTS

The research is supported by the Masaryk University research project MUNI/A/1073/2019 Behavioral aspects of organizations.

REFERENCES

Anderson, N., Potočnik, K. and Zhou, J., 2014. Innovation and creativity in organizations: A state-of-the-science review, prospective commentary, and guiding framework. *Journal of Management* [e-journal], 40(5), pp.1297-1333. doi: 10.1177/0149206314527128.

Ashton, M.C. and Lee, K., 2009. The HEXACO–60: A Short Measure of the Major Dimensions of Personality. *Journal of Personality Assessment* [e-journal], 91(4), pp.340-345. doi: 10.1080/00223890902935878.

Batey, M., Chamorro-Premuzic, T. and Furnham, A., 2010. Individual Differences in Ideational Behavior: Can the Big Five and Psychometric Intelligence Predict Creativity Scores? *Creativity Research Journal* [e-journal], 22(1), pp.90-97. doi: 10.1080/10400410903579627.

Feist, G.J., 1998. A meta-analysis of personality in scientific and artistic creativity. *Personality and Social Psychology Review* [e-journal], 2(4), pp.290-309. doi: 10.1207%2Fs15327957pspr0204_5.

Feist, G.J., 2010. The function of personality in creativity. In: J.C. Kaufman and R.J. Sternberg eds., 2010. *The Cambridge Handbook of Creativity.* Cambridge University Press. pp.113-130.

Furnham, A., Hughes, D.J. and Marshall, E., 2013. Creativity, OCD, Narcissism and the Big Five. *Thinking Skills and Creativity* [e-journal], 10, pp.91-98. doi: 10.1016/j.tsc.2013.05.003.

Hughes, D.J., Furnham, A. and Batey, M., 2013. The structure and personality predictors of self-rated creativity. *Thinking Skills and Creativity* [e-journal], 9, pp.76-84. doi: 10.1016/j.tsc.2012.10.001.

John, O.P. and Srivastava, S., 1999. The Big Five trait taxonomy: History, measurement, and theoretical perspectives. *Handbook of Personality: Theory and Research,* 2, pp.102-138.

Karwowski, M. and Lebuda, I., 2016. The big five, the huge two, and creative self-beliefs: A meta-analysis. *Psychology of Aesthetics, Creativity, and the Arts* [e-journal], 10(2), pp.214-232. doi: 10.1037/aca0000035.

Karwowski, M., Lebuda, I., Wisniewska, E., and Gralewski, J., 2013. Big five personality traits as the predictors of creative self-efficacy and creative personal identity: Does gender matter? *The Journal of Creative Behavior* [e-journal], 47(3), pp.215-232. doi: 10.1002/jocb.32.

Kaspi-Baruch, O., 2017. Big Five personality and creativity: the moderating effect of motivational goal orientation. *The Journal of Creative Behavior* [e-journal], 53(3), pp.325-338. doi: 10.1002/jocb.183.

Kaufman, J.C. and Beghetto, R.A., 2013. Do people recognize the four Cs? Examining layperson conceptions of creativity. *Psychology of Aesthetics, Creativity, and the Arts* [e-journal], 7(3), pp.229-236. doi: 10.1037/a0033295.

Kaufman, J.C. and Sternberg, R.J., 2010. *The Cambridge Handbook of Creativity*. Cambridge University Press.

Maxwell, S.E., Lau, M.Y. and Howard, G.S., 2015. Is psychology suffering from a replication crisis? What does "failure to replicate" really mean? *American Psychologist* [e-journal], 70(6), pp.487-498. doi: 10.1037/a0039400.

Puryear, J.S., Kettler, T. and Rinn, A.N., 2017. Relationships of personality to differential conceptions of creativity: A systematic review. *Psychology of Aesthetics, Creativity, and the Arts* [e-journal], 11(1), pp.59-68. doi: 10.1037/aca0000079.

Raja, U. and Johns, G., 2010. The joint effects of personality and job scope on in-role performance, citizenship behaviors, and creativity. *Human Relations* [e-journal], 63(7), pp.981-1005. doi: 10.1177/0018726709349863.

Silvia, P.J., Beaty, R.E., Nusbaum, E.C., Eddington, K.M., Levin-Aspenson, H. and Kwapil, T.R., 2014. Everyday creativity in daily life: An experience-sampling study of "little c" creativity. *Psychology of Aesthetics, Creativity, and the Arts* [e-journal], 8(2), pp.183-188. doi: 10.1037/a0035722.

Soto, C.J. and John, O.P., 2009. Ten facet scales for the Big Five Inventory: Convergence with NEO PI-R facets, self-peer agreement, and discriminant validity. *Journal of Research in Personality* [e-journal], 43(1), pp.84-90. doi: 10.1016/j.jrp.2008.10.002.

Stock, R.M., von Hippel, E. and Gillert, N.L., 2016. Impacts of personality traits on consumer innovation success. *Research Policy* [e-journal], 45(4), pp.757-769. doi: 10.1016/j.respol.2015.12.002.

Sung, S.Y. and Choi, J.N., 2009. Do big five personality factors affect individual creativity? The moderating role of extrinsic motivation. *Social Behavior and Personality: An International Journal* [e-journal], 37(7), pp.941-956. doi: 10.2224/sbp.2009.37.7.941.

Zhao, H. and Seibert, S.E., 2006. The big five personality dimensions and entrepreneurial status: A meta-analytical review. *Journal of Applied Psychology* [e-journal], 91(2), pp.259-271. doi: 10.1037/0021-9010.91.2.259.

ABOUT AUTHORS

Michal Jirásek – (M.J.) Masaryk University, Faculty of Economics and Administration, Brno, Czech Republic, Department of Corporate Economics, Assist. Prof., e-mail: mijirasek@mail.muni.cz, Author's ORCID: 0000-0002-0407-4045.

František Sudzina – (F.S.) Aalborg University, Faculty of Engineering and Science, København SV, Denmark, Department of Materials and Production, Assoc. Prof., e-mail: sudzina@business.aau.dk, Author's ORCID: 0000-0003-1867-9237.

AUTHOR CONTRIBUTIONS

F.S. – initial conceptualization and data collection; M.J. – analysis, writing and editing the paper.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

APPENDIX

BFI-44 Personality inventory

For calculating personality traits we used following combinations of items below (note that "R" labels reverse-scored items):

- Extraversion: 1, 6R, 11, 16, 21R, 26, 31R, 36;
- Agreeableness: 2R, 7, 12R, 17, 22, 27R, 32, 37R, 42;
- Conscientiousness: 3, 8R, 13, 18R, 23R, 28, 33, 38, 43R;
- Neuroticism: 4, 9R, 14, 19, 24R, 29, 34R, 39;
- Openness to Experience: 5, 10, 15, 20, 25, 30, 35R, 40, 41R, 44.

For calculating personality facets we used following combinations of items below (note that "R" labels reverse-scored items):

- Assertiveness (Extraversion): 1, 6R, 21R, 26, 31R;
- Activity (Extraversion): 11, 16;
- Altruism (Agreeableness): 7, 22, 27R, 32;
- Compliance (Agreeableness): 2R, 12R, 17;
- Order (Conscientiousness): 8R, 18R;
- Self-Discipline (Conscientiousness): 13, 23R, 28, 38, 43R;
- Anxiety (Neuroticism): 9R, 19, 34R, 39;
- Depression (Neuroticism): 4, 29;
- Aesthetics (Openness): 30, 41R, 44;
- Ideas (Openness): 10, 15, 25, 35R, 40.

I am someone who...

1. ... *is talkative.*
2. ... *tends to find fault with others.*
3. ... *does a thorough job.*
4. ... *is depressed, blue.*
5. ... *is original, comes up with new ideas.*
6. ... *is reserved.*
7. ... *is helpful and unselfish with others.*
8. ... *can be somewhat careless.*
9. ... *is relaxed, handles stress well.*

10. ... *is curious about many different things.*
11. ... *is full of energy.*
12. ... *starts quarrels with others.*
13. ... *is a reliable worker.*
14. ... *can be tense.*
15. ... *is ingenious, a deep thinker.*
16. ... *generates a lot of enthusiasm.*
17. ... *has a forgiving nature.*
18. ... *tends to be disorganized.*
19. ... *worries a lot.*
20. ... *has an active imagination.*
21. ... *tends to be quiet.*
22. ... *is generally trusting.*
23. ... *tends to be lazy.*
24. ... *is emotionally stable, not easily upset.*
25. ... *is inventive.*
26. ... ha*s an assertive personality.*
27. ... *can be cold and aloof.*
28. ... *perseveres until the task is finished.*
29. ... *can be moody.*
30. ... *values artistic, aesthetic experiences.*
31. ... *is sometimes shy, inhibited.*
32. ... *is considerate and kind to almost everyone.*
33. ... *does things efficiently.*
34. ... *remains calm in tense situations.*
35. ... *prefers work that is routine.*
36. ... *is outgoing, sociable.*
37. ... *is sometimes rude to others.*
38. ... *makes plans and follows through with them.*
39. ... *gets nervous easily.*
40. ... *likes to reflect, play with ideas.*

41. ... *has few artistic interests.*

42. ... *likes to cooperate with others.*

43. ... *is easily distracted.*

44. ... *is sophisticated in art, music, or literature.*

Does Foreign Direct Investment Boost Innovation? The Case of the Visegrad and Baltic Countries

DOI: 10.12776/QIP.V24I3.1519

Aneta Bobenič Hintošová, Michaela Bruothová, Iveta Vasková

Received: 2020-10-11 Accepted: 2020-11-12 Published: 2020-11-30

ABSTRACT

Purpose: The purpose of the paper is to examine the impact of inward and outward foreign direct investment on innovation performance of the Visegrad and Baltic countries.

Methodology/Approach: The study follows an open-system approach to consider the determinants of national innovation performance, taking into account both inward and outward FDI. We use two-step analysis that combines panel data regression analysis with the design of two FDI – innovation performance matrixes.

Findings: The results of the study provide evidence that only outward foreign direct investment of domestic firms contributes significantly to the innovation performance of these countries and that this effect is more visible in the case of the Visegrad countries.

Research Limitation/Implication: The limitations of the study are associated in particular with the selection of SII as a measure of national innovation performance. The use of this indicator is also related to the relatively short period of availability of consistent data, especially in connection with changes in the methodology of SII calculation.

Originality/Value of paper: The policy implications of the paper suggest the need for stronger support of domestic bearers of cross-border capital movements in an attempt to boost national innovation performance.

Category: Research paper

Keywords: innovation performance; inward foreign direct investment; outward foreign direct investment; the Visegrad countries; the Baltic countries

1 INTRODUCTION

There are substantial differences among countries in terms of their innovation performance, which has provoked and stimulated a great academic debate on drivers of countries' innovative progress (e.g. Furman, Porter and Stern, 2002; Krammer, 2009; Carayannis and Grigoroudis, 2014). An important role in this respect is attributed to the flows of foreign direct investment (FDI), especially from an open perspective point of view (e.g. Ramzi and Salah, 2018). It is widely believed that openness to foreign investment promotes the international diffusion of technology (Gong and Keller, 2003). According to the most influential theories of FDI (e.g. Dunning, 1981; Ozawa, 1992) the progression in foreign direct investment flows is closely linked to technological shift and improved innovation capabilities of countries, which leads to the strengthening of their international competitiveness.

Many cross-country empirical studies are dealing with FDI – innovation performance nexus conducted mainly in conditions of developed economies and focusing predominantly on the inward direction of FDI flows. However, not much is known about the effect of investment abroad (e.i. outward FDI) on the innovation performance of the investing country, as it was recently highlighted also by Sarin and Kumar (2019). This is especially the case of developing and transition countries, which are trying to catch up with developed countries in terms of their technological and scientific development. The present research attempts to fill in the outlined gap in the empirical literature by examining the impact of inward as well as outward foreign direct investment on national innovation performance in the case of the Visegrad and Baltic countries. The analysis covers the period from 2009 to 2019 and, from a methodological point of view, combines panel data regression analysis with the design of FDI – innovation performance matrixes.

In terms of innovation performance, the Visegrad and Baltic countries belong to the group of moderate innovators compared to the other European Union Member States (EU Member States). One of the positive exceptions in this regard is Estonia, which has seen a positive shift to a group of strong innovators in the last year due to strengthening of its human resources and intellectual assets (European Commission, 2020). Although the other Visegrad and Baltic countries have also made positive changes in their innovation performance, this is still not enough to constantly close the performance gap between them and the highly developed European countries (Kondratiuk-Nierodzińska, 2016). However, the role of foreign direct investment in this context is not clear and is not sufficiently empirically justified. Moreover, there is a large discrepancy between inward and outward FDI, in terms of its evolution over time, volume, nature, and motives. Because the Visegrad and Baltic countries first became prime targets for inward FDI (Gauselmann, Knell and Stephan, 2011) and the increase in the volume of outward FDI is more evident only in recent years, there is little research examining the impact of outward FDI on their innovation performance.

The rest of the paper is organized as follows: The second part introduces the theoretical background related to the issue with special emphasis on the results of studies conducted within the Visegrad and/or the Baltic countries. The third part explains the objective, methodology, and data used within own research. The fourth part presents the results of panel data regression analysis and construction of two FDI – innovation performance matrixes where the position of the Visegrad and Baltic countries is visible in the broader European context, followed by the discussion of own empirical findings. The fifth part brings concluding remarks with outlined future research directions.

2 THEORETICAL BACKGROUND

Countries are increasingly trying to stimulate their innovation activities as a path toward enhanced international competitiveness. This stimulation can be done locally and/or through foreign involvement. As pointed out by Matusik, Heeley and Amorós (2019) stimulation of innovativeness on a local level can include means like investment aid, special projects targeted at innovation knowledge sharing among home country firms, or another kind of supports, e.g. tax allowances. On the other hand, countries may also attract foreign investors especially through the favorable business environment as well as various foreign investment promotion tools. There is a rich literature on direct and spillover effects associated with FDI, however, our focus is on studies examining the impact of FDI on innovation performance at a more aggregated level.

One of the first studies to examine the impact of foreign direct investment flows on the technology diffusion was a study by Borensztein, De Gregorio and Lee (1998), which utilized data on FDI flow from industrialized countries to 69 developing countries. Based on the results, FDI can be considered as an important means of technology transfer, which contributes to growth relatively more than domestic investment.

Subsequently, many studies appeared, which in most cases proved a positive impact of inward FDI on the innovation performance of the host country (e.g. Blind and Jungmittag, 2004; Gorodnichenko, Svejnar and Terrell, 2010; Ghazal and Zulkhibri, 2015; Arun and Yildrim, 2017; Wu, Ma and Zhuo, 2017; Li, Lee and Park, 2020). The most common reasons for this finding lie in direct increase of innovation output through innovations of foreign-owned firms and in indirect spillovers effecting domestic firms through supply chain technology transfer. However, there are also some studies proving in some situations insignificant (Qu et al., 2013; Arun and Yildrim, 2017) or negative effects (e.g. Fu, Pietrobelli and Soete, 2011; Filippetti, Frenz and Ietto-Gillies, 2017; Song and Zhang, 2017), especially in the case of countries with low absorptive capacity, where inward FDI could crowd out local innovation activities and restrain further development of related local knowledge.

With regard to the impact of outward FDI on the innovation performance, the empirical evidence is not so rich, mostly showing the positive impact of outward FDI on the innovation level of the host country (e.g. Pradhan and Singh, 2009; Li et al., 2016; Filippetti, Frenz and Ietto-Gillies, 2017; Li, Lee and Park, 2020). A common explanation for this is connected with the learning process, i.e. knowledge transfers from local firms in the host country.

However, only a limited number of studies dealing with similar issues have been conducted in conditions of the Visegrad and Baltic countries. Fifeková and Nemcová (2015) studied among others also the impact of inward FDI on innovation-related performance growth in conditions of the Visegrad countries. They concluded that the presence of foreign investors in these countries not only contributed to technology transfer, but also brought intangible assets such as marketing and management skills, knowledge capital and innovation skills. However, the extent to which inward FDI positively affects the innovation-led growth of the Visegrad countries depends predominantly on the formation of the economic environment that is capable to absorb positive effects brought by inward FDI and to foster them further.

A contradictory effect of inward FDI on the national innovative capacity was detected by Andrijauskiene and Dumciuviene (2019) within their investigation of 28 EU Member States. They found that inward FDI supports a country's national innovative capacity by encouraging the employment in knowledge-intensive sectors and having a positive effect on trademark and design applications, while no significant effect on patents was shown. On the other hand, no relationship between marketing and organization innovation as non-technological innovation output and inward FDI was detected.

To sum up, there is no empirical consensus on the FDI flows – national innovation performance nexus. At the same time, according to the best knowledge of the authors, there is no study that would compare specifically a group of the Visegrad and Baltic countries in this regard, while paying attention also to the outward FDI. Hence, the results of the study can enrich the existing literature in this field.

3 METHODOLOGY

The research is based on the assumption, that foreign direct investment flows affect national innovation performance, but the strength and direction of dependence appear to be country-specific (Arun and Yildrim, 2017; Wu, Ma and Zhuo, 2017). Hence, the objective of the present paper is to identify the impact of inward and outward foreign direct investment on national innovation performance in conditions of the Visegrad and Baltic countries.

The key variable we focus on in our research is innovation performance at the country level. To ensure the comparability of the data and to assess innovation performance in its complexity, the composite indicator, namely Summary

Innovation Index (SII) introduced by the European Commission, is used. Despite some critiques of this indicator in the existing literature (see e.g. Edquist et al., 2018; Švandová and Jirásek, 2019), it is a commonly used indicator of innovation performance within empirical literature (e.g. Albulescu and Drăghici, 2016; Janoskova and Kral, 2019). The SII provides a comparative assessment of the research and innovation performance of the EU Member States and selected third countries. The measurement framework previously distinguished among three main types of indicators and eight innovation dimensions, capturing a total of 25 different indicators. However, the methodology for calculation of SII was significantly modified in 2017 and SII currently consists of a total of 27 different indicators. At the same time, the European Commission (2018) in the European Innovation Scoreboard notes that the results for previous years are not comparable to those reported for 2017 and later. For this reason, our analysis of the impact of FDI flows on innovation performance was divided into two main periods and steps, i.e. before and after revision of the methodology of SII calculation, using different analytical approaches, namely:

In the first step, in line with previous studies addressing similar issues (e.g. Qu et al., 2013; Arun and Yildirim, 2017; Andrijauskiene and Dumčiuvienė, 2019), the regression analysis using panel data was performed with SII as a key dependent variable, for the period 2009 to 2016. As key independent variables, we used the volume of FDI inflows (*IFDI*) and outflows (*OFDI*), values of which were taken from the UNCTADSTAT (2020). As additional independent variables within our models, we used indicator of gross domestic product per capita (*GDP*), inflation rate measured by the harmonized index of consumer prices (*IR*) and unemployment rates (*UR*). All the values were taken from Eurostat. In accordance with other similar works (e.g. Wu, Ma and Zhuo, 2017) we added a one-year lag in our analysis to consider the delay in the innovation performance induced by foreign direct investment flows and other variables. Since we operate with panel data, we used the following general panel regression model (1):

$$Y_{it} = \beta_0 + \sum_{k=1}^{K} X_{i(t-1)k}\beta_{ik} + \varepsilon_{i(t-1)}, t = 1, 2, \dots, T, i = 1, 2, \dots, N \qquad (1)$$

where, β_0 is a constant, $X_{i(t-1)k}$ represents the k^{th} explanatory variable of the $(t-1)^{\text{th}}$ year in the country i, $\varepsilon_{i(t-1)}$ is the error term. K is the number of explanatory variables excluding the constant, N represents the number of countries, T is the time period. Concerning countries included in the analysis, three regression models were run, namely Model (1a) covered all Visegrad and Baltic countries, Model (1b) included only the Visegrad countries (i.e. Czechia, Hungary, Poland and Slovakia) and Model (1c) included only the Baltic countries (i.e. Estonia, Latvia and Lithuania).

We estimated the coefficients of the models with use of a pooled OLS method, or the panel data estimations – fixed-effect or random-effect estimation methods. The appropriate estimation method was selected according to several tests,

namely F-test for testing, whether there exist panel effects in the model; the Breusch – Pagan Lagrange multiplier test (LM-test) for testing significance of difference across units; and finally the Hausman test for selection between the random- and fixed-effect methods.

In the second step, our ambition was to include the latest available data in the analysis and to evaluate the position of the Visegrad and Baltic countries in the broader context. Based on this, we used a similar approach as in other studies (e.g. Remeikiene et al., 2020) and compiled two FDI – innovation performance matrixes. To capture the longer trend in the development of variables and to follow the one-year lag applied in the first step, the average values of the variables over a three-year period were used, namely: in the case of SII, average values calculated by modified methodology for 2017-2019 were used; in the case of FDI inflows and outflows, average FDI performance indexes for 2016-2018 were calculated, in accordance with following methodological approach:

The relative success of a particular country in attracting FDI can be measured through the inward FDI performance index (*IFDIPI*) developed by UNCTAD (2002). Later, the outward FDI performance index (*OFDIPI*) was introduced (UNCTAD, 2004) as a measure of ownership advantage of the firms based in a particular country. Some further empirical studies (e.g. Rodríguez, Gómez and Ferreiro, 2009; Lei et al., 2013) also applied these indexes to evaluate advantages connected with FDI flows. Both indexes, depending on the direction of FDI flows, relate inward (outward) FDI to the economic size of the particular country measured by GDP. They are calculated (Eq. (2)) as the ratio of a country's share in global FDI to its share in global GDP as follows:

$$IFDIPIi\ (OFDIPIi) = \frac{IFDIi\ (OFDIi)/IFDIw\ (OFDIw)}{GDPi/GDPw} \tag{2}$$

where, $IFDIPI_i$ – the inward FDI performance index of the i^{th} country, $OFDIPI_i$ – the outward FDI performance index of the i^{th} country, $IFDI_i$ – inward FDI of the i^{th} country, $OFDI_i$ – outward FDI of the i^{th} country, $IFDI_w$ – world inward FDI, $OFDI_w$ – world outward FDI, GDP_i – GDP of the i^{th} country, and GDP_w – world GDP.

Values above one indicate that the country receives (or allocates abroad) a higher portion of FDI than its relative economic size. Values below one indicate that the country receives (or allocates abroad) a lower portion of FDI than its relative economic size. The data for calculation of FDI performance indexes were taken from the UNCTADSTAT (2020).

In the two matrixes that put into relation inward/outward FDI performance index and the innovation performance measured through the SII the positions of the EU Member States (including the United Kingdom as the EU member at the time to which the data refer), are recorded. The classification of countries into particular quadrants was performed based on critical values of individual indexes as

follows: in the case of both FDI performance indexes the critical value refers to one; in the case of SII, the critical value refers to the average value of the index of EU Member States.

4 RESULTS AND DISCUSSION

In the first step of our analysis, the impact of inward and outward FDI as well as other variables on the innovation performance of the Visegrad and Baltic countries was examined. Results of the panel data regression with use of appropriate estimation technique selected according to several tests, i.e. random-effect regression for all countries (Model 1a); fixed-effect regression for the Visegrad countries (Model 1b) and fixed-effect regression for the Baltic countries (Model 1c), are reported in Table 1.

Table 1 – Panel Estimation – Dependent Variable SII

	Model 1a *RE, all countries*	*Model 1b* *FE, Visegrad countries*	*Model 1c* *FE, Baltic countries*
Constant	0.012 (0.384)	0.024** (0.015)	11.879* (6.721)
IFDI	0.025 (0.041)	0.036 (0.031)	0.054 (0.146)
OFDI	0.043* (0.022)	0.047* (0.018)	0.013 (0.122)
GDP	-0.271 (0.182)	0.071 (0.372)	16.32* (7.841)
IR	0.073 (0.061)	-0.016 (0.043)	-0.085 (0.143)
UR	-0.054 (0.083)	0.113 (0.111)	0.208 (0.134)
R^2	0.352		
Adjusted R^2	0.291		
LSDV R^2		0.971	0.931
Within R^2		0.385	0.357

Notes: Standard errors are in parentheses. The asterisks denote the statistical significance of coefficients at a level of 10% (*), 5% (**), and 1% (***), based on p-values.

For all models, the errors are normally distributed, based on the Chi-square test. Since the tests revealed possible heteroscedasticity and serial correlation in errors, the Arellano estimator (suitable in the case of heteroscedasticity and serial/cross-sectional correlation) was used for computation of coefficients in all models.

Based on the results of Model 1, only the independent variable - the outward FDI is a statistically significant determinant of the innovation performance in the Visegrad and Baltic region. In the case of results for the Visegrad countries (Model 1b), with the exception of the constant, only outward FDI significantly affects the innovation performance of these countries. Surprisingly, this is not the

case of the Baltic countries (Model 1c), where international capital flows seem not to affect significantly the innovation. The results rather indicate that domestic activities and size of the economy (proved by the positive significant impact of GDP) are more important drivers of national innovativeness.

Within the second step of our analysis, the relationship between foreign direct investment flows and innovation performance was conducted on a basis of FDI – performance matrix, where the positions of the EU Member States (including the United Kingdom as the EU member at the time to which the data refer) are reported. Two matrixes are designed to put into relation the Summary Innovation Index and inward/outward FDI performance index separately. To capture the longer trend in the development of these indexes, average values over a three-year period were used, with a one-year lag in the case of FDI performance indexes. The division of countries into individual quadrants was carried out on the basis of critical values as follows: for both FDI performance indexes, the critical value refers to one; in the case of SII, the critical value refers to the average innovation performance of the EU Member States.

Figure 1 shows the position of the EU Member States in terms of their innovation performance in relation to the performance of inward foreign direct investment that the countries received. Cyprus and Malta are not included in the matrix due to the extremely high positive values of the inward FDI performance index.

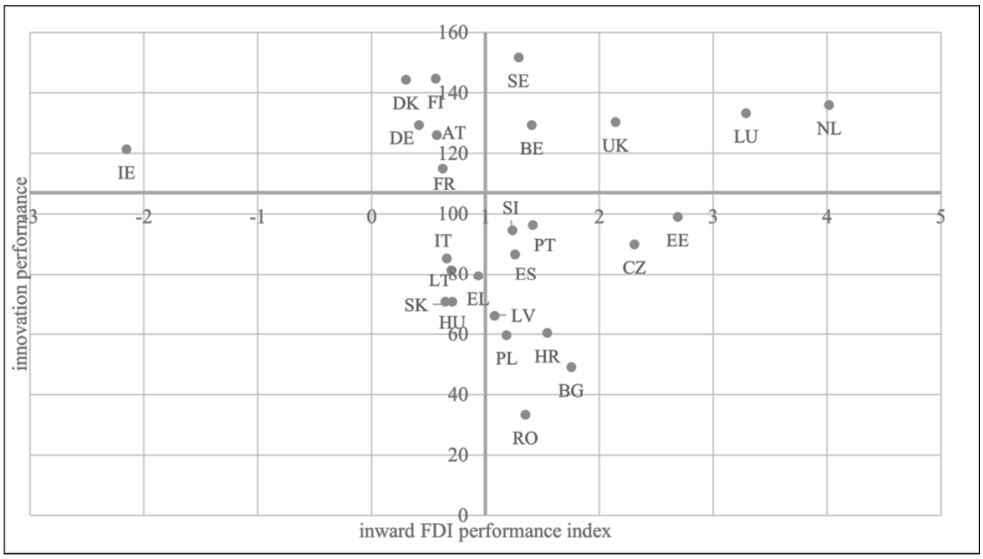


Figure 1 – Inward FDI – Innovation Performance Matrix

Overall, based on the positions of the countries in the matrix, the existence of neither a linear nor a non-linear relationship between the inward FDI performance index and SII is confirmed. At the same time, the Visegrad and Baltic countries cannot be considered as separate and homogenous groups of countries in this regard. Although both groups of countries show below-average

innovation performance compared to the EU average, their inward FDI performance is different. The worst positions are occupied by Slovakia and Hungary, followed by Lithuania, which countries attract relatively less inward FDI when compared to their economic size. On the other hand, Poland and Latvia attract the volume of inward FDI slightly outweighing their economic size. This positive ratio, however, does not result in superior innovation performance. The best positions from the inward FDI performance index as well as SII point of view are detected by the Czech Republic and Estonia. Especially, in the case of Estonia, the relatively high inward FDI performance is associated with the higher innovation performance that in the last observed year, i.e. 2019 moved Estonia to the group of strong innovators (European Commission, 2020). The heterogeneities identified among the Baltic as well as the Visegrad countries in terms of inward FDI – innovation performance relationship, call for further single country studies in this regard.

Figure 2 shows the position of the EU Member States in terms of their innovation performance in relation to the performance of outward foreign direct investment, i.e. volume of investment that the countries allocated abroad. Luxembourg and Malta are not included in the matrix due to the extremely high values of the outward FDI performance index.

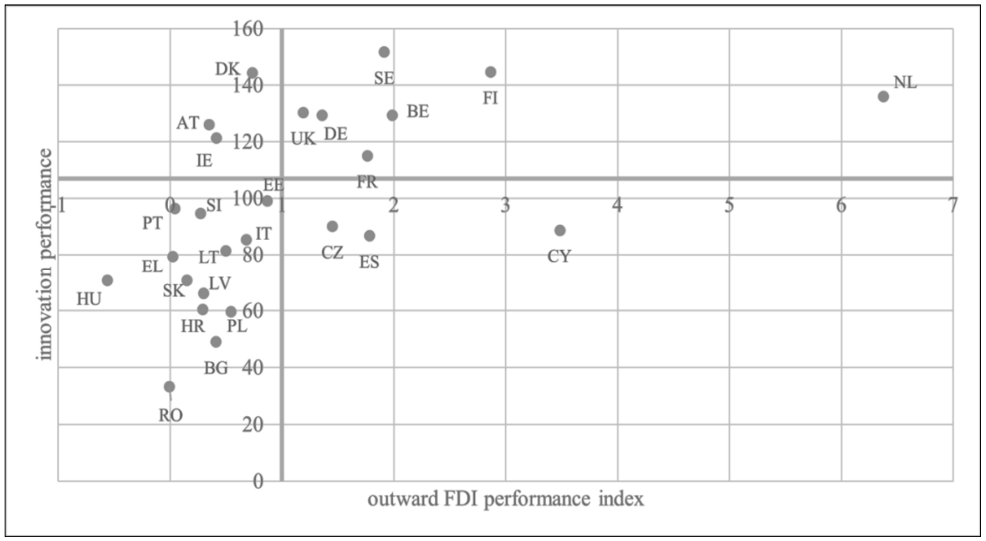


Figure 2 – Outward FDI – Innovation Performance Matrix

Overall, the positions of the countries in the matrix to some extent confirm the results of our previous panel regression, which showed a significant positive relationship between outward FDI and innovation performance; however, this relation appears to be rather non-linear. The majority of countries of our interest lie in the quadrant below the EU average SII and outward FDI performance index below 1. However, there is an obvious trend of increased outward FDI performance index being associated with higher innovation performance. This is

particularly the case of Estonia, where local companies as bearers of international capital movement, have also potentially contributed to the shift of the country toward strong European innovators in recent year. An exception from this group is the Czech Republic, which achieved the highest outward FDI performance. Thus, it seems that local companies with strong ownership advantages being able to allocate their investments abroad contribute to the highest innovation performance of the country among the Visegrad countries.

Despite expected, theoretically, and empirically underpinned assumptions about the positive impact of inward FDI on innovation performance, this was not proven either in the conditions of the Visegrad nor the Baltic countries. The possible reasons can be found in the nature of inward FDI targeted to the manufacturing industry due to the tendency of the old EU Member States to relocate part of their manufacturing activities there (Fifeková and Nemcová, 2015). Another important reason is generally connected with insufficient absorptive capacity of host countries, as it has already been noticed e.g. by Filippetti, Frenz and Ietto-Gillies (2017). According to Sultana and Turkina (2020) the country can benefit from inward FDI only through a better understanding of absorptive capacity and the transformation of its related factors. Concerning the policy implications, our findings suggest targeting efforts on the development of the absorptive capacity of the home economy, especially the human resource-related component, as a prerequisite for the ability to absorb new external technologies and knowledge. Dimensions connected with human resources and innovators are among the most frequently mentioned weaknesses of the innovation performance of the Visegrad and Baltic countries (European Commission, 2020). The necessity to focus more intensively on human capital accumulation in terms of generating positive effects of inward FDI on innovation in the host country has been highlighted also by other studies (e.g. Konstandina and Gachino, 2020).

On the other hand, our research provides some evidence that outward FDI of domestic firms contributes significantly to the innovation performance of the analyzed countries and that this effect is more visible in the case of the Visegrad countries. These results are to some extent similar to those presented by Filippeti, Frenz and Ietto-Gillies (2017) who found that outward FDI is positively associated with patenting. However, we cannot confirm that outward FDI directly influences patenting activities within the home country, since the SII used as a measure of innovation performance is a composite indicator that mixes input and output innovation indicators and calculates an average of them (Edquist et al., 2018). On the other hand, the innovativeness of the Baltic countries seems to be significantly influenced by factors other than outward FDI, such as the volume of gross domestic product. The factors determining national innovation performance are therefore rather country-specific, probably due to the existence of borders and administrative divisions, which could have a considerable impact on economic conditions (Urbančíková and Zgodavová, 2019).

So, in the case of the Visegrad countries, domestic firms as drivers of international capital movement, seem to utilize their ownership advantages at the foreign market or/and learn from innovation-advanced host countries, and thus potentially create significant positive synergy effects on the home country's innovation performance. In this context, focus on the idea management system as a potential driver of innovation may be important (Santos et al., 2018). Policymakers should also focus more on implementing policies that support local innovativeness and strengthen it through international capital links with innovative host economies and their firms.

Hence, we can agree with Li, Lee and Park (2020), and this also seems to be the case of the Visegrad and Baltic countries that inward FDI does not induce a substantial knowledge and technology transfer from the home country to the host country due to efforts by foreign multinationals not to disseminate their technologies to the host country but rather to foster their technologies by taking advantage of the competitive advantages of the host country. On the other hand, outward FDI can evoke positive and significant effects from the host country to the home country as a result of acquiring a foreign technology base. From the policy implication point of view, it seems that governments of the Visegrad and Baltic countries should encourage outward FDI to promote domestic innovativeness.

5 CONCLUSION

In the presented research we have primarily tested whether foreign direct investment flows boost innovation performance, as measured by the Summary Innovation Index, in the case of the Visegrad and Baltic countries. Our study followed an open-system approach to consider the determinants of national innovation performance, taking into account both inward and outward FDI. We used a two-step analysis that combined panel data regression analysis with the design of two FDI – innovation performance matrixes.

Based on the values of the Summary Innovation Index, the Visegrad as well as the Baltic countries belong to the group of moderate innovators, except Estonia in the recent year, with the innovation performance below the EU average. The overall results of our study suggest a positive and significant impact of outward FDI, i.e. capital investments of domestic firms allocated abroad, on boosting national innovation performance. These outward investors are most likely able to exploit their innovation base through foreign presence and technology transfer. However, even though outward foreign direct investment appears to be a common driving force of the innovation performance of these countries, we found certain differences in the drivers of national innovation performance between the analyzed groups of countries.

In the case of the Visegrad countries, we found that not foreign investors allocating their capital investments in these countries but rather strong domestic

firms as bearers of outward foreign direct investment are positively influencing national innovation performance. On the other hand, this does not apply to the group of the Baltic countries, where rather other factors, such as the volume of gross domestic product, significantly contribute to innovation performance. Based on these results it seems that factors determining national innovation performance are country-specific.

Our study suffers from certain limitations associated in particular with the selection of SII as a measure of national innovation performance. The use of other indicators could probably lead to slightly different results. The usage of this indicator is also connected with a relatively short period of availability of consistent data, especially concerning changes in the methodology of SII calculation. Future research should therefore also focus on the use of other national innovation performance indicators or combinations thereof.

Since the results indicate some differences between the Visegrad and Baltic countries in terms of significant drivers of national innovation performance, further single-country studies would shed more light on this issue. Another interesting future research direction stems from differences in the motives of foreign direct investment. It is reasonable to predict that strategic assets-seeking outward FDI contributes differently to the innovation performance compared e.g. to resource-seeking outward FDI. Our research suggests the need to focus in more detail on outward investment activities, especially in the case of the Visegrad countries, as these investments will play a potentially crucial role in the innovative development of these countries.

REFERENCES

Albulescu, C.T. and Drăghici, A., 2016. Entrepreneurial activity and national innovative capacity in selected European countries. *The International Journal of Entrepreneurship and Innovation* [e-journal], 17(3), pp.155-172. doi: 10.1177/1465750316655902.

Andrijauskiene, M. and Dumčiuvienė, D., 2019. Inward Foreign Direct Investment and National Innovative Capacity. *Engineering Economics* [e-journal], 30(3), pp.339-348. doi: 10.5755/j01.ee.30.3.22832.

Arun, K. and Yıldırım, D.C., 2017. Effects of foreign direct investment on intellectual property, patents and R&D. *Queen Mary Journal of Intellectual Property* [e-journal], 7(2), pp.226-241. doi: 10.4337/qmjip.2017.02.05.

Blind, K. and Jungmittag, A., 2004. Foreign Direct Investment, Imports and Innovations in the Service Industry. *Review of Industrial Organization* [e-journal], 25(2), pp.205-227. doi: 10.1007/s11151-004-3537-x.

Borensztein, E., De Gregorio, J.D. and Lee, J., 1998. How does foreign direct investment affect economic growth? *Journal of International Economics* [e-journal], 45(1), pp.115-135. doi: 10.1016/s0022-1996(97)00033-0.

Carayannis, E. and Grigoroudis, E., 2014. Linking innovation, productivity, and competitiveness: Implications for policy and practice. *The Journal of Technology Transfer* [e-journal], 39(2), pp.199-218. doi: 10.1007/s10961-012-9295-2.

Dunning, J.H., 1981. *International production and the multinational enterprise*. London: Allen & Unwin.

Edquist, C., Zabala-Iturriagagoitia, J.M., Barbero, J. and Zofío, J.L., 2018. On the meaning of innovation performance: Is the synthetic indicator of the Innovation Union Scoreboard flawed? *Research Evaluation* [e-journal], 27(3), pp.196-211. doi: 10.1093/reseval/rvy011.

European Commission, 2018. *European Innovation Scoreboard 2018*. Luxembourg: Publications Office of the European Union.

European Commission, 2020. *European Innovation Scoreboard 2020*. Luxembourg: Publications Office of the European Union.

Fifeková, E. and Nemcová, E., 2015. Impact of FDI on Economic Growth: Evidence from V4 Countries. *Periodica Polytechnica Social and Management Sciences*[e-journal], 23(1), pp.7-14. doi: 10.3311/ppso.7993.

Filippetti, A., Frenz, M. and Ietto-Gillies, G., 2017. The impact of internationalization on innovation at countries' level: The role of absorptive capacity. *Cambridge Journal of Economics* [e-journal], (41)2, pp.413-439. doi: 10.1093/cje/bew032.

Fu, X., Pietrobelli, C. and Soete, L., 2011. The Role of Foreign Technology and Indigenous Innovation in the Emerging Economies: Technological Change and Catching-up. *World Development* [e-journal], 39(7), pp.1204-1212. doi: 10.1016/j.worlddev.2010.05.009.

Furman, J.L., Porter, M.E. and Stern, S., 2002. The determinants of national innovative capacity. *Research Policy* [e-journal], 31(6), pp.899-933. doi: 10.1016/s0048-7333(01)00152-4.

Gauselmann, A., Knell, M. and Stephan, J., 2011. What drives FDI in Central–Eastern Europe? Evidence from the IWH-FDI-Micro database. *Post-Communist Economies* [e-journal], 23(3), pp.343-357. doi: 10.1080/14631377.2011.595148.

Ghazal, R. and Zulkhibri, M., 2015. Determinants of innovation outputs in developing countries. *Journal of Economic Studies* [e-journal], 42(2), pp.237-260. doi: 10.1108/jes-01-2013-0016.

Gong, G. and Keller, W., 2003. Convergence and polarization in global income levels: A review of recent results on the role of international technology diffusion. *Research Policy* [e-journal], 32(6), pp.1055-1079. doi: 10.1016/s0048-7333(02)00136-1.

Gorodnichenko, Y., Svejnar, J. and Terrell, K., 2010. Globalization and Innovation in Emerging Markets. *American Economic Journal: Macroeconomics* [e-journal], 2(2), pp.194-226. doi: 10.1257/mac.2.2.194.

Janoskova, K. and Kral, P., 2019. An in-depth analysis of the summary innovation index in the V4 countries. *Journal of Competitiveness* [e-journal], 11(2), pp.68-83. doi: 10.7441/joc.2019.02.05.

Kondratiuk-Nierodzińska, M., 2016. Innovation Capabilities In Eu Countries: Have Central And Eastern European Countries Been Catching Up? *Journal of Business Economics and Management* [e-journal], 17(5), pp.765-779. doi: 10.3846/16111699.2015.1114016.

Konstandina, M.S. and Gachino, G.G., 2020. International technology transfer: Evidence on foreign direct investment in Albania. *Journal of Economic Studies* [e-journal], 47(2), pp.286-306. doi: 10.1108/jes-02-2018-0076.

Krammer, S.M., 2009. Drivers of national innovation in transition: Evidence from a panel of Eastern European countries. *Research Policy* [e-journal], 38(5), pp.845-860. doi: 10.1016/j.respol.2009.01.022.

Lei, M., Zhao, X., Deng, H. and Tan, K.C., 2013. DEA analysis of FDI attractiveness for suitable development: Evidence from Chinese provinces. *Decision Support Systems* [e-journal], 56(1), pp.406-418. doi: 10.1016/J.DSS.2012.10.053.

Li, J., Strange, R., Ning, L.T. and Sutherland, D., 2016. Outward foreign direct investment and domestic innovation performance: Evidence from China. *International Business Review* [e-journal], 25(5), pp.1010-1019. doi: 10.1016/j.ibusrev.2016.01.008.

Li, Q., Lee, S. and Park, S.W., 2020. The effect of inward and outward foreign direct investment on regional innovation performance: Evidence from China. *Global Business & Finance Review* [e-journal], 25(1), pp.65-88, doi: 10.17549/gbfr.2020.25.1.65.

Matusik, S.F., Heeley, M.B. and Amorós, J.E., 2019. Home court advantage? Knowledge-based FDI and spillovers in emerging economies. *Global Strategy Journal* [e-journal], 9(3), pp.405-422. doi: 10.1002/gsj.1324.

Ozawa, T., 1992. Theory of FDI as a dynamic paradigm of economic development. *Transnational Corporations*, 1(1), pp.27-54.

Pradhan, J.P. and Singh, N., 2009. Outward FDI and knowledge flows: A study of the Indian automotive sector. *Institutions and Economies*, 1(1), pp.156-187.

Qu, T., Chen, J., Li, S. and Xiang, H., 2013. Impact of inward FDI, import on domestic innovation: evidence from China. *The International Journal of Business and Finance Research*, 2013, 7(3), pp.119-136.

Ramzi, T. and Salah, A.B., 2018. The Determinants of Innovation Capacity in the Less Innovative Countries in the Euro-Mediterranean Region. *Journal of the Knowledge Economy* [e-journal], 9(2), pp.526-543. doi: 10.1007/s13132-015-0347-3.

Remeikiené, R., Belas, J., Kliestik, T. and Smrcka, L., 2020. Quantitative assessment of dynamics of economic development in the countries of the European Union. *Technological and Economic Development of Economy* [e-journal], 26(4), pp.933-946. doi: 10.3846/tede.2020.12892.

Rodríguez, C., Gómez, C. and Ferreiro, J., 2009. A proposal to improve the UNCTAD's inward FDI potential index. *Transnational Corporations* [e-journal], 18(3), pp.85-114. doi: 10.18356/d3e73f33-en.

Santos, G., Afonseca, J., Lopes, N., Félix, M.J. and Murmura, F., 2018. Critical success factors in the management of ideas as an essential component of innovation and business excellence. *International Journal of Quality and Service Sciences* [e-journal], 10(3), pp.214-232. doi: 10.1108/IJQSS-05-2017-0051.

Sarin, V. and Kumar, S., 2019. Investment abroad and impact at home: A literature review. *Global Economy Journal* [e-journal], 19(4), pp.419-433. doi: 10.1142/S2194565919300011.

Song, H. and Zhang, M., 2017. Spatial Spillovers of Regional Innovation: Evidence from Chinese Provinces. *Emerging Markets Finance and Trade* [e-journal], 53(9), pp.2104-2122. doi: 10.1080/1540496x.2017.1284061.

Sultana, N. and Turkina, E., 2020. Foreign direct investment, technological advancement, and absorptive capacity: A network analysis. *International Business Review* [e-journal], 29(2), 101668. doi: 10.1016/j.ibusrev.2020.101668.

Švandová, E. and Jirásek, M., 2019. On Measuring Countries' Innovation Performance: Organisational Level Perspective. *Acta Universitatis Agriculturae Et Silviculturae Mendelianae Brunensis* [e-journal], 67(3), pp.871-881. doi: 10.11118/actaun201967030871.

UNCTAD, 2002. *World Investment Report: Transnational Corporations and Export Competitiveness*. New York and Geneva: United Nations Publication.

UNCTAD, 2004. *World Investment Report: The Shift Towards Services*. New York and Geneva: United Nations Publication.

UNCTADSTAT, 2020. *DataCenter.* [online] Available through: <https://unctadstat.unctad.org/EN/> [Accessed 02 October 2020].

Urbančíková, N. and Zgodavová, K., 2019. Sustainability, resilience and population ageing along Schengen's eastern border. *Sustainability* [e-journal], 11(10), 2898. doi: 10.3390/su11102898.

Wu, J., Ma, Z. and Zhuo, S., 2017. Enhancing national innovative capacity: The impact of high-tech international trade and inward foreign direct investment. *International Business Review* [e-journal], 26(3), pp.502-514. doi: 10.1016/j.ibusrev.2016.11.001.

ABOUT AUTHORS

Aneta Bobenič Hintošová – (A.B.H.) University of Economics in Bratislava, Faculty of Business Economics with seat in Košice, Košice, Slovakia, Assoc. Prof., e-mail: aneta.bobenic.hintosova@euba.sk, Author's ORCID: 0000-0001-8728-6328.

Michaela Bruothová – (M.B.) University of Economics in Bratislava, Faculty of Business Economics with seat in Košice, Slovakia, Assist. Prof., e-mail: michaela.bruothova@euba.sk, Author's ORCID: 0000-0002-1116-3273.

Iveta Vasková – (I.V.) Technical University of Košice, Faculty of Materials, Metallurgy and Recycling, Košice, Slovakia, Assoc. Prof., e-mail: iveta.vaskova@tuke.sk, Author's ORCID: 0000-0001-6820-4876.

AUTHOR CONTRIBUTIONS

A.B.H. – conceptualization, methodology, resources, original draft preparation; M.B. – formal analysis, data curation, review and editing, visualization; I.V. – validation, review, supervision.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Learning Needs Determination for Industry 4.0 Maturity Development in Automotive Organisations in Slovakia

DOI: 10.12776/QIP.V24I3.1521

Andrea Sütőová, Ľubomír Šooš, Ferdinand Kóča

Received: 2020-10-12 Accepted: 2020-11-13 Published: 2020-11-30

ABSTRACT

Purpose: This paper aims to present the results of the study focused on the assessment of Industry 4.0 (I4.0) maturity level and adoption level of Quality 4.0 (Q4.0) intelligent technologies in organisations operating in the automotive industry in Slovakia (OEMs, Tier 1 and Tier 2 suppliers). The results serves as inputs for identification of learning and development needs.

Methodology/Approach: The background of the study was a literature review and quantitative research. The I4.0 maturity model published by PwC (2016) was used in the study, while dimension elements were adjusted to the specifics of the automotive industry.

Findings: Tier 1 and Tier 2 automotive suppliers are in the early stages of I4.0 maturity and adoption of Q4.0 intelligent technologies. OEMs achieve the level of horizontal collaborators in most of the dimensions. Q4.0 intelligent technologies are mostly adopted at an average level. Further development of OEMs to achieve the level of digital champions requires new disruptive business models and a fully integrated partner ecosystem.

Research Limitation/Implication: The research is limited by the sample size and target levels of particular dimensions, related elements and Q4.0 intelligent technologies, which were not examined.

Originality/Value of paper: The results bring more in-depth insight into the current state of I4.0 maturity and Q4.0 technology adoption level of the automotive organisations in Slovakia. There is no evidence of the study examining holistically the I4.0 maturity and Q4.0 technologies in the automotive.

Category: Research paper

Keywords: Industry 4.0; Quality 4.0 intelligent technologies; self-assessment; automotive industry; learning and development

1 INTRODUCTION

Nowadays, the automotive industry is facing incredible challenges like changing customer needs, mass customization, pressures to accelerate innovation and increase efficiency and issues of sustainability shifting production to electric vehicles. The increasing demand for the customized product from the customer end is a significant theme forcing transformation in the automotive industry. Traditional car production involving hundreds of identical vehicles lined up in a row is no longer possible. The current megatrends on the automotive market require the implementation of new technologies and business models.

A century later, after Henry Ford introduced mass production, the concept of Industry 4.0 (I4.0) is penetrating in the automotive industry as well as other sectors. Getting on the 4th Industrial Revolution train is not an option, but rather an obligation for organisations to be competitive. The new industrial paradigm brings together the digital and physical worlds through the Cyber-Physical Systems (CPS) enhanced by the Internet of Things (IoT), and it is expected that this novel has consequences on industry, markets, and economy, improving production processes and increasing productivity (Pereira and Romero, 2017). I4.0 is also getting to the field of quality management. Quality 4.0 (Q4.0) leverages intelligent technologies and can help to improve the quality of products and services and differentiate a brand within its market. Several studies have presented the positive impact of I4.0 on firm's performance and competitiveness, e.g. (Llopis-Albert, Rubio and Valero, 2021; Buchi, Cugno and Castagnoli, 2020; Sanders, Elangeswaran and Wulfsberg, 2016). In comparison to other sectors, the automotive industry belongs among the front runners in terms of digital maturity (Wellner, Manolian and Laaper, 2018; Geissbauer, Vedsø and Schrauf, 2016). Some Original Equipment Manufacturers (OEMs) and leading players in a supply chain are already experiencing the benefits resulting from I4.0. The Slovak automotive industry does not stand away from the digital transformation, and the future success of the sector is a key for the whole economy of Slovakia. For OEMs and especially automotive suppliers the adoption of I4.0 is challenging. To implement the route appropriately, a tool such as Maturity Model (MM) can be useful and help to guide on the way to I4.0 excellence. Holistic assessment of I4.0 maturity and identification of problematic fields and elements for defining future learning and development needs can help to achieve improvements and ensure competitiveness in the future. Several MMs have been developed, which will be discussed within the theoretical overview, however, there is no evidence of the study focusing on I4.0 maturity assessment in the automotive industry or adjustment of dimensional elements of existing MMs to the specifics of the automotive industry. The paper contributes to fill the knowledge gap and contributes to the possibility of identification of learning and development needs to fulfil I4.0 strategy and related Q4.0 intelligent technologies adoption in OEMs, Tier 1 and Tier 2 suppliers operating in Slovakia.

The structure of the paper is as follows. The theoretical overview deals with the I4.0 impact on the automotive industry and quality assurance, it also presents the main information regarding the automotive industry in Slovakia and summarizes I4.0 MMs published by academics and consulting organisations. The methodology section provides an overview of the selected and adjusted MM used in the study and presents the flowchart describing the steps carried out within the study by the authors. The results of I4.0 maturity assessment and adoption level of Q4.0 intelligent technologies are presented individually for OEMs, Tier 1, and Tier 2 in the following section.

2 THEORETICAL BACKGROUND

2.1 Industry 4.0 and Quality 4.0 Intelligent Technologies in the Automotive Industry

The automotive industry is undergoing a massive transformation and much of it is being driven by I4.0. I4.0 is a name for the current trend of automation and data exchange in the manufacturing industry. Within the modular structured Smart Factories of I4.0, Cyber-Physical Systems (CPS) monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the Internet of Things (IoT), CPS communicate and cooperate with each other and humans in real-time (Boyes et al., 2018). I4.0 brings a new level of organisation and control of the entire value-chain, it is geared towards increasingly individualized customer requirements. I4.0 aim is to work with a higher level of automation, flexibility and efficiency (Alcácer and Cruz-Machado, 2019).

I4.0 affects the automotive value chain, including design, production, distribution, and services. The interconnection of the value creation process takes place across corporate functions, companies, and entire value creation chains, where IoT provides connectivity from end-to-end (Markulik, Sinay and Pačaiová, 2019). Data generated in each area are also available to other areas in real-time and provides information transparency. I4.0 organizes suppliers, manufacturers, and customers in a virtual, vertically and horizontally integrated value chain. Therefore, automotive suppliers need to implement I4.0 strategy and appropriate technologies to avoid losing their position and fully integrate into the customer's network. Improved connectivity between each part of the supply chain allows stakeholders to adjust to customer demand more quickly and ultimately reduce time to market.

Big Data, automation, interconnections along the value chain and digital customer interfaces create a foundation for new business models (Rachinger et al., 2019). Advanced OEMs are switching to customer-centric business models with more services. In the past, OEMs saw themselves primarily as providers of hardware. Now, they are beginning to evolve into providers of digital services.

The shifting focus from products to services leads to new value propositions to consumers, requires new value creation activities, new partnerships, and asks for new revenue models (Athanasopoulou et al., 2019). Innovative, interconnected business models are necessary to deal with new actors in the ecosystem. Companies must develop ecosystems of partners, establish multi-speed capabilities, and completely rewire their product development processes. Thus, vehicles are no longer regarded as isolated tangible goods, but as objects that integrate different stakeholders, devices, functions, and data into coherent systems of value co-creation (Grieger and Ludwig, 2019). Regarding the connectivity, security should be incorporated as a part of any design principle parallel to business strategy. A cyber-secure architecture using IT security needs as a design standard and not as an additional layer that increases complexity enables greater multichannel integration, supporting modularity and protected application programming interfaces (APIs) to permit integration among ecosystem partners.

Increasing vehicles complexity (above all increasing of electronics and software elements) and variety, complex value chains and shortened time-to-market bring new challenges for quality assurance in the automotive industry. Q4.0 leverages the technologies of I4.0, which help to solve quality challenges and provide novel solutions driving organisations toward operational excellence. Quality improvement at industrial transformation is a critical differentiator for businesses. Q4.0 technologies enable real-time data collection, remote monitoring and advanced visualization, big data analysis, predictive quality management, remote diagnosis and maintenance, advanced supply chain management as well as deep integration of quality management methods and processes, such as quality risk analysis and validation, and innovations in production (Krubasik et al., 2017). Q4.0 doesn't replace traditional quality methods, but rather builds and improves upon them (Dan, 2017). According to (Radziwill, 2018) the system of Q4.0 tools is created by Statistics and Data Science; Enabling Technologies (Sensing technologies, Cloud Computing, Extended Reality, IoT, 5G networks, Internet Protocol Version 6, etc.); Big Data, Blockchain; Deep Learning; Machine Learning and Artificial Intelligence.

Even though Q4.0 is fuelled by technology, success requires a multifaceted approach that addresses the full range of strategic, cultural and already mentioned technological issues. Most studies discuss technical aspects of I4.0 and only a few of them pay attention to organisational culture, which largely influences the success of the implementation of this concept. Appropriate managerial approaches play a vital role in the cultural changes (Mohelska and Sokolova, 2018). Management should top-down initiate cultural changes and serve as a role model, leading by example and providing an unambiguous vision. I4.0 adequate cultural characteristics are high level of willingness to learn, openness to new things, promotion of creativity and idea generation, entrepreneurial mind-set and democratic leadership. Communication is to be opened up so that employees can

freely communicate and discuss across both hierarchical levels and organisational borders (Veile et al., 2019).

2.2 Industry 4.0 and Automotive Industry in Slovakia

Many studies confirm differences in I4.0 readiness and adoption on a country level in the European Union (EU) and world. According to (WEF, 2018) only 25 countries are poised to take advantage of I4.0. The top 10 rated leaders are Switzerland, USA, Germany, Singapore, the United Kingdom, Japan, Sweden, South Korea, Ireland, and Finland. Slovakia is among the so-called "Legacy" group of countries, which need to invest in technology and innovation capacity. The I4.0 readiness index, classifying the countries of the EU on the basis of their effort and progress into 4 groups (frontrunners, potentials, traditionalists, hesitators) showed that countries like Germany, Sweden, Ireland, Finland or Austria belong to frontrunners. Slovakia is in the group of a traditionalist, which means that it has launched few initiatives to take its manufacturing industry into a Digital era so far, but it is behind the leader countries (Berger, 2014). According to Digital Economy and Social Index, especially to the dimension reflecting the Integration of Digital Technology, Slovakia belongs to the group of lower-performing countries among the EU Member States (European Commision, 2019). The studies show that European leading countries are Finland, Sweden, Ireland, United Kingdom, Germany and Slovakia is lagging behind the leaders in I4.0.

The automotive value chain is highly integrated across different EU Member States (Tkáč, Verner and Tkáč, 2019). Therefore, there is a need to increase the level of smart manufacturing in the countries that stay currently behind those who are leading (Konrad and Stagl, 2018). It requires actions on the level of the country as well as organisations to ensure the future competitiveness of the automotive industry. EU supports digital transformation through its industrial policy and through research and infrastructure funding. Member States are also sponsoring national initiatives such as I4.0 in Germany, Alliance pour l'Industrie du Futur in France, High-Value Manufacturing Catapult and Digital Catapult in the United Kingdom, Produktion 2030 in Sweden, etc. Slovakia has supported the concept of Slovakia: Smart Industry from 2016 to foster I4.0 thinking and strengthen the Slovak economy. The Government of the Slovak Republic has recently approved the framework document – Strategy of Digital Transformation 2030. The purpose of the strategy is to increase the involvement of Slovakia into the European Digital Single Market and make Slovakia become a modern country with an innovative and ecological industry by 2030 benefiting from the knowledge-based digital and data economy. The strategy gives priority to current innovative technologies like Artificial Intelligence, IoT, 5G Technology, Big data analysis, BlockChain, and High-Performance Computing, which will become the new engine of economic growth.

Automotive sector is one of the main pillars of Slovak economy, accounting for 13% of its gross domestic product and 35% of its exports (OECD, 2019). Slovakia belongs to the 20 biggest world's car producer and it is the 7th in the list of the top vehicle producing countries of the EU (ACEA, 2018). Taking into consideration the number of inhabitants, Slovakia is the global leader in car production per pepita. Slovakia has a long term tradition in labour and production quality (Zgodavová, Hudec and Palfy, 2017) and so-called Industry 3.0 was sufficiently developed. After all, the strategic goal of the 1980s in Czechoslovakia was to have 3,000 robots and manipulators until the year 2000. This goal was never achieved because of the state-controlled market economy, and there was a downturn in the 1990s, but people were prepared for automation (Slimák and Zgodavová, 2011; Zgodavová, 2002). Over the last 20 years, large foreign direct investments have developed the automotive industry in Slovakia. There are currently 4 OEMs automobile production plants in Slovakia: Volkswagen Slovakia, Kia Motors Slovakia, PSA Peugeot Citroën Slovakia and Jaguar Land Rover. Not only the mentioned automotive producers but also a well-developed supplier network makes the core of the Slovak automotive industry. More than 300 suppliers are operating in Slovakia, and some of Tier 1–2 suppliers also export their products to plants located around Europe and to other overseas locations (SARIO, 2018).

Entry into the era of I4.0 and the development of autonomous, shared and connected cars are challenges for the automotive industry in Slovakia. Economic history teaches that significant technological changes can strongly alter the functioning and structure of a certain sector (OECD, 2019). As it was mentioned above, Slovakia has already launched some initiatives to support technological development and digitization of the industry. Actions have to be taken also on the level of organisations. OEMs and especially supplier organisation along the value chain have to be aware that increasing digitalization has a significant impact on their future competitiveness (Nagyová et al., 2019). It means that the topic is not only for large but also small and medium-sized organisation down the supply chain (Konrad and Stagl, 2018).

There are many organisations, where only some of the I4.0 elements are present and selected Q4.0 intelligent technologies are implemented, but holistic approach to I4.0 is missing. Some organisations have difficulties to link the I4.0 concept with their business strategy. They also experience problems in determining their state of development with regard to I4.0 and therefore fail to identify a concrete field of actions, programs and projects (Schumacher, Erol and Sihn, 2016). The appropriate model enabling complex assessment of I4.0 maturity helps to identify the organisations current state of development, identify and prioritize learning and development needs and take relevant actions.

2.3 Existing Industry 4.0 Maturity Models

In general, the term "maturity" refers to a "state of being complete, perfect, or ready" and implies some progress in the development of a system. The concept of maturity incorporates the notion of gradual evolution through intermediate stages. The concept of maturity is not new in the industrial engineering and management field. Crosby was among the first to propose, in 1979 the "Quality Management Maturity Grid" model with fives levels of maturity (Facchini et al., 2020). Except the field of Quality Management, the maturity concept has spread into other disciplines. MMs are generally used as tools to conceptualize and measure the maturity of an organisation or a process regarding some specific target state (Schumacher, Erol and Sihn, 2016). MMs are adequate tools for (1) defining and documenting the status quo, (2) developing a strategy of excellence and providing guidance on that development path, and (3) comparing capabilities between business units and organisations (Felch, Asdecker and Sucky, 2019; Bibby and Dehe 2018). MMs can contribute to organisation transformation and renewed competencies in organisation by initiating a change process. In the context of the I4.0 concept, several maturity/readiness models have been developed to identify I4.0 state of development from different perspectives, as it is shown in Table 1.

Table 1 – Existing Maturity Models

Model name	*Consulting organisation/Author*	*Model focus and assessment approach*
Connected Enterprise Maturity Model	Rockwell Automation (2014)	Technology-focused assessment in four dimensions; 5 stages approach to I4.0 implementation.
IMPULSE– 4.0 Readiness	Lichtblau et al. (2015)	Focus is on the definition of barriers for progressing to the next stage and creation of an action plan to overcome them; based on six dimensions and 6 maturity levels.
I4.0 Maturity Model	Schumacher, Erol and Sihn (2016)	Focus on strategic decisions and definition of specific projects and programs on the base of nine dimensions assessment; 5 maturity levels.
I4.0 Maturity Model	Bakertilly (2019)	Consulting tool; Focus on I4.0 maturity assessment of manufacturing organisation using nine dimensions and five maturity stages.
I4.0 Digital Operations Self-Assessment	PwC (2016)	Application as consulting tool; Focus on benchmarking and identification of needs for action; Assessment of six I4.0 dimensions; four maturity levels.
Maturity Model for Data-Driven Manufacturing	Weber et al. (2017)	Focus on IT architecture of manufacturing organisation, assessment of IT with regard to the requirements of vertical and horizontal system integration; Only one dimension; five maturity levels.

Model name	*Consulting organisation/Author*	*Model focus and assessment approach*
Logistic 4.0 Maturity Model	Facchini et al. (2020)	Focus on I4.0 technologies in logistic processes; Assessment of seven dimensions and defining a roadmap for improvement in five maturity levels.
Digital Maturity Model	Capgemini (2018)	Consulting tool; Focus on holistic Industry 4.0 readiness; Assessment of 4 main dimensions; four maturity stages.
I4.0 Maturity Model for delivery in supply chain	Asdecker and Felch (2018)	Focus on the delivery process in the supply chain; Assessment of three dimensions and developing a path in five stages to achieve delivery excellence.

On the basis of existing literature sources, it is possible to classify I4.0 MMs into two main categories: holistic and specific. The holistic models aim to assess and utilize elements of I4.0 from all perspectives and hence derive encompassing success factors. The specific MMs focus on the specific areas of I4.0 application or a limited number of aspects related to I4.0 such as logistics (Facchini et al., 2020), supply chain (Asdecker and Felch, 2018), information technologies (Weber et al., 2017). There aren't any modifications of generic I4.0 MMs that take into account the specifics of certain industry sectors in the literature not even specific approaches focusing on the field of Q4.0.

The research presented in this paper is built on the base of so-called holistic I4.0 MMs published by PwC (2016), while the items in the questionnaire related to individual I4.0 dimensions were adjusted to the specifics of the automotive industry and items related to the field of Q4.0 intelligent technologies were added. Our model systematically assesses the OEMs'; Tier 1 (T1); and Tier 2 (T2) suppliers state-of-development concerning the I4.0 strategy and Q4.0 intelligent technologies adoption. MM serves both a scientific and a practical purpose. The scientific purpose aims at learning and development model for organisations operating in the automotive industry in Slovakia. The research aims to contribute to the possibility of identification of learning and development needs to fulfil I4.0 strategy and related intelligent technologies Q4.0.

3 RESEARCH METHODOLOGY

Concerning I4.0, we understand the maturity of the automotive industry as an "industry being driven by digitization and integration of vertical and horizontal value chains, digitization of product and service offerings and the development of new digital business models and customer access platforms" (PwC, 2016). As the framework methodology (Becker, Knackstedt and Pöppelbuß, 2009) step-by-step process was used for the development of the MM which has a theoretical foundation in the design science approach (Hevner, March and Park, 2004) and offers a rigorous methodology. The systematic literature research and review,

expert interviews, conceptual modelling, and validations as well as testing of the model in automotive organisations were conducted. The Seven-Step I4.0 and Q4.0 Learning and Development Model was designed by the authors, which involves steps carried out within the study by the authors. The designed model is shown in Figure 1. The following of the stages presented in the model enables to measure, identify and graphically present the I4.0 and Q4.0 intelligent technologies state of development at OEMs, Tier 1 and Tier 2 suppliers and identify and discuss main learning and development needs based on the results of the study.

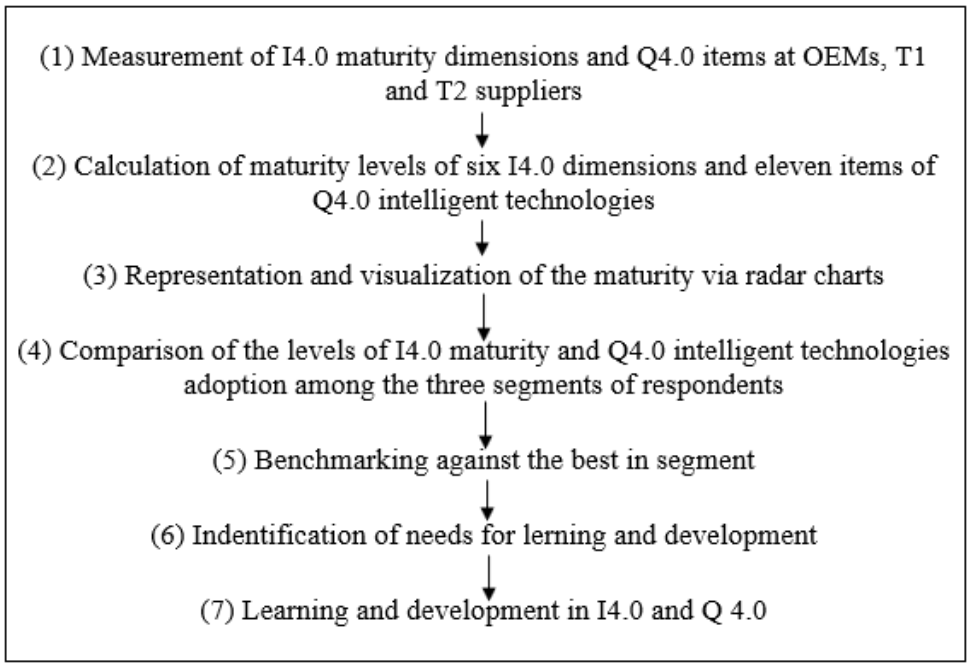


Figure 1 – Seven-Step I4.0 and Q4.0 Learning and Development Model

Quantitative research was conducted using the structure of (PwC, 2016) questionnaire with adjusted questions to the specifics of the automotive industry. Six dimensions according to (PwC, 2016) were assessed to identify I4.0 maturity level:

- *Dimension 1 (D1):* Business Model, Product and Service Portfolio – business model, product and service digitalization (6 items);
- *Dimension 2 (D2):* Market and Customer Access – channels used for customer interactions (6 items);
- *Dimension 3 (D3):* Value Chains and Processes – internal manufacturing integration, supply chain management (5 items);

- *Dimension 4 (D4):* IT Infrastructure – technical capabilities and IT support of processes and services (6 items);
- *Dimension 5 (D5):* Compliance, Legal, Risk, Security – technical implementation of compliance assurance, risk focusing, cyber trust ensuring (6 items);
- *Dimension 6 (D6):* Organisation and Culture – collaboration and culture supporting I4.0 (4 items).

The evolution path of each dimension undergoes five maturity levels, where Level 1 describes a complete lack of attributes supporting the strategy of I4.0, Level 2 represents a Digital Novice, Level 3 is a Vertical Integrator, Level 4 is a Horizontal Collaborator and Level 5 represents a Digital Champion, what means the state-of-the-art of required attributes. The example of a question to assess one of the items related to *D1* is shown in Table 2.

Table 2 – Example of the Guestion Related to Dimension 1

Question	1	2	3	4	5
To which degree are the life cycle phases of your products digitized (digitization and integration of design, planning, engineering, production, services & recycling)?	□	□	□	□	□
1 – Low level of digitization & integration: Isolated IT enablement of different steps in product life cycle (e.g. no integration of engineering and production) 5 – Complete digitization & integration: All phases in the product life cycle are completely digitized (e.g. producibility can directly be tested during product development via virtual prototyping)					

The second part of the questionnaire examining the intensity of Q4.0 intelligent technologies adoption included 11 items based on the study of (Radziwill, 2018): Sensing Technologies including QR codes, sensors, actuators; IoT; Big Data (BD); Cloud Computing (CC); Machine Learning (ML); Deep Learning (DL); Artificial Intelligence (AI); Data Science (DS); Blockchain (BCh); Additive Manufacturing (AM); Extended Reality (ER) including augmented reality, virtual reality, mixed reality. Five-point Likert-scale was used to assess the level of adoption of intelligent technologies in the field of quality management. The example of the question is shown in Table 3.

Table 3 – Example of the Question Related to Q4.0 Technology Adoption

Question	1	2	3	4	5
To what extent do you use sensing technologies such as "QR codes, sensors, and actuators" within quality management?	□	□	□	□	□
1 – Not at all 5 – To a very great extent					

The online questionnaire was sent to three types of organisations operating in the automotive industry in Slovakia – OEMs, Tier 1 suppliers, and Tier 2 suppliers. The respondents represented by quality managers, and production managers of organisations were contacted personally or by phone to give them more detailed information and ensure feedback relevance. It was very important to explain to them the concept of I4.0 a related Q4.0 meaning because the questionnaire can only be adequately answered if all respondents have a basic understanding of the theme. This is how we ensured the questionnaire's representability and the MM's accuracy. The organisations involved in the study were selected from the database. Totally 308 organisations are operating in the automotive industry in Slovakia. Organisations with financial data were selected for the research. E-mail based distribution of questionnaires to 107 respondents resulted in 73 responses. The OEM segment was represented by all 4 car manufacturers (6%) and the remaining responses were accounted for 51% of Tier 1 suppliers and 43% of Tier 2 suppliers. The data were graphically represented by radar charts and compared.

4 RESULTS AND DISCUSSION

Figure 2 shows the average values of individual dimensions for the three segments of respondents, where OEMs achieve the highest values in all dimensions. The OEMs achieved the level of Horizontal Collaborator except for the lowest-rated *D3* and *D6*, where the average values are below 4.0. The OEMs need to focus on horizontal integration of processes and data flows with customers and suppliers and strengthening of collaboration across company boundaries and support knowledge sharing. Further development to achieve the level of Digital Champions requires new disruptive business models with innovative product and service portfolio, a fully integrated partner ecosystem with self-optimized and virtualized processes, and related secure data exchange.

Most of the dimensions at Tier 1 suppliers achieve the level of Vertical Integrator with vertical digitization and integration of processes and data flows within company and homogenous IT architecture in-house. The *D2* and *D6* were rated on the level of Digital Novice. Attention should be focused on an individualized customer approach, building customer platforms and channels and developing of a cross-functional collaborative culture. Half of the dimensions at Tier 2 suppliers achieved the level of Vertical Integrator (*D1*, *D3* and *D5*), however, the values of the *D2*, *D4* and *D6* are on the level of Digital Novice. The weaknesses are fragmented IT architecture in-house, isolated applications, low customer focus and culture, which doesn't support enough cross-functional collaboration. Average dimension levels achieve the lowest values at Tier 2 suppliers. Tier 1 suppliers rated the dimensions slightly higher than Tier 2 suppliers. To remain in supply chains and be competitive, suppliers must focus on the critical areas, which don't even reach the level of Vertical Integrator. To fully integrate into customer's network suppliers need to move their I4.0 maturity to the next level of Horizontal Collaborator, what requires horizontal process integration and data

flows with customers and external partners, common IT architectures and collaborative culture supporting I4.0 concept. Figure 2 shows the average values of individual dimensions for the three segments of respondents, while OEMs achieves the highest values in all dimensions.

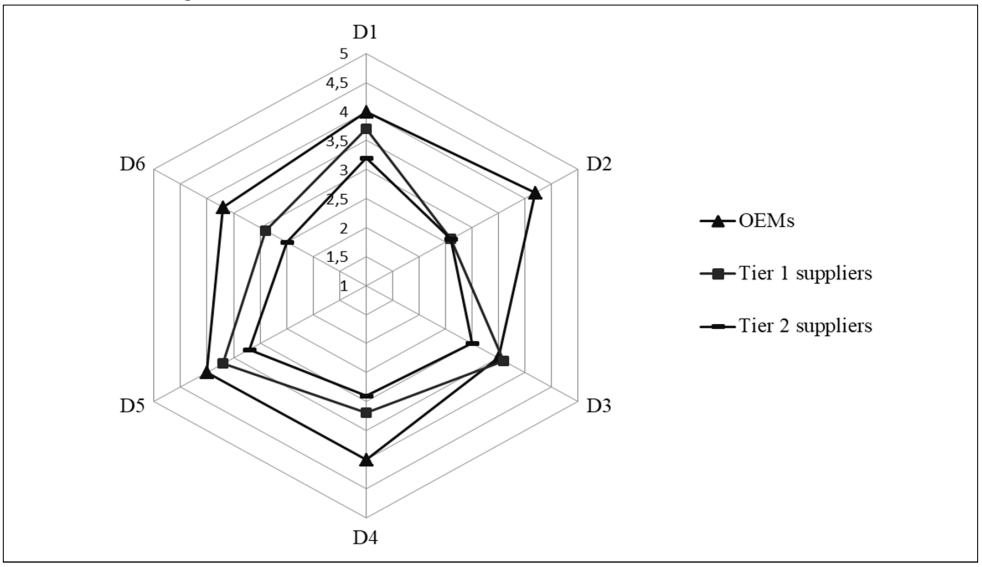


Figure 2 – Average Values of the Industry 4.0 Dimensions

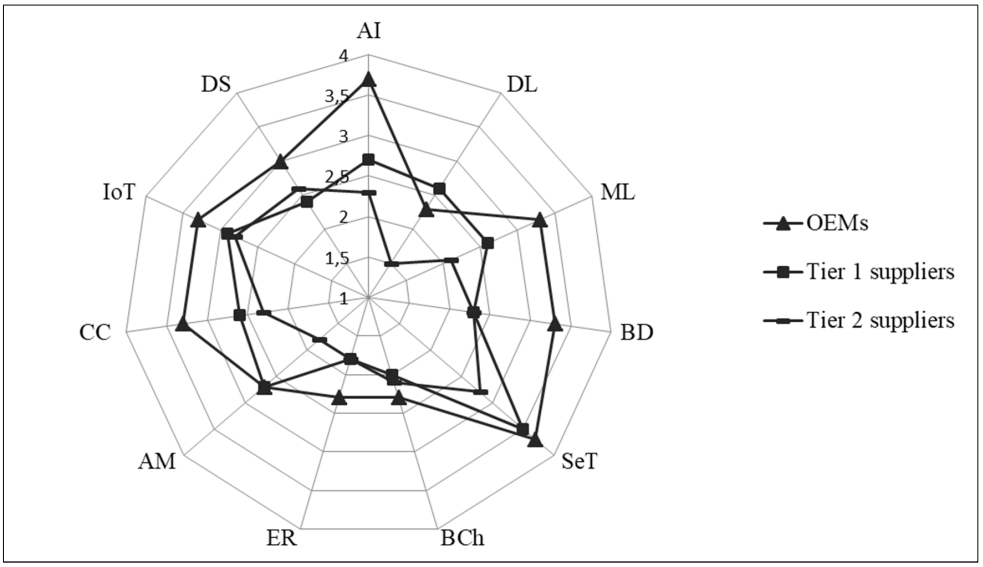


Figure 3 – Average Adoption Level of the Q4.0 Intelligent Technologies

The average adoption of Q4.0 technologies achieves the highest level at OEMs. The statistically, significant differences are only in the application of artificial intelligence and machine learning in comparison to Tier 2 suppliers (t = 2.5280,

p = 0.0162). There is no significant difference in Q4.0 adoption between OEMs and Tier 1 suppliers. OEMs have adopted the Q4.0 technologies (Artificial Intelligence, Sensing Technologies, Big data technologies, Cloud Computing, and IoT) mostly at an average level. However, they are early adopters of Deep Learning, Extended Reality, and Blockchain, which have the potential in achieving of the high level of quality. The lowest adoption levels of Q4.0 technologies are in the case of Tier 2 suppliers. Tier 2 suppliers don't use Extended Reality, Blockchain, Additive Manufacturing and Deep Learning or to a very small extent and they are in the early stages of implementation of the other Q4.0 technologies. Tier 1 suppliers rated the usage of Q4.0 technologies slightly higher than Tier 2 suppliers. However, the statistically significant difference between Tier 1 and Tier 2 suppliers (t = 2.8468; p = 0.0056) is only in the application of deep learning. Sensing technologies were rated by Tier 2 suppliers on the level of the intermediate adopter. Figure 3 shows the average adoption level of Q4.0 technologies of the three groups of respondents.

Resulting from the literature review and studies highlighting the differences in I4.0 readiness and maturity on country levels, the organisation with the highest I4.0 maturity and Q4.0 adoption level and their headquarters location were identified. The best results among Tier 1 suppliers achieve organisations with their headquarters in Germany, USA, and France (totally from 9 countries) and among the Tier 2 suppliers organisations having headquarters in Germany, Australia and Norway (totally from 8 countries). The headquarter organisations have a specific impact on the I4.0 strategy, processes, and technologies used in subsidiary companies operating in Slovakia, but there is also the impact of digital skills of employees as well as organisation culture. One of the key challenges for organisations operating in the automotive industry in Slovakia is the lack of qualified employees. Learning and development form part of the organisation's management strategy and aims to improve group and individual performance by increasing skills and knowledge for I4.0 and the usage of intelligent technologies. The study identified the training and development needs of OEMs, Tier 1, and Tier 2 suppliers and provides input for the systematic learning and development process.

5 CONCLUSION

The research contributes to the possibility of identification of learning and development needs to fulfil I4.0 strategy and related Q4.0 intelligent technologies adoption in OEMs, Tier 1 and Tier 2 suppliers operating in Slovakia on the base of the Seven-Step I4.0 and Q4.0 Learning and Development Model. It also contributes to filling the knowledge gap related to I4.0 MM application in the concrete industry sector. The model can be used by any organization operating in the automotive industry for the systematic assessment of I4.0 maturity and related Q4.0 technology adoption and identification of the current state as well as internal and external benchmarking and developing a roadmap to

achieve improvement. To begin with the systematic approach, it is vital to understand the current maturity and define the path that needs to undertake learning and development towards improvement and higher competitiveness of automotive organisation operating in Slovakia.

The results of the study are limited by the sample size and identification of the target levels and significance of particular dimensions and related elements as well as Q4.0 intelligent technologies which should be achieved from the perspective of organisations and its strategic direction to determine gaps between the current state and future goals and to identify the priorities of learning and development for individual organizations, what will be the subject of further research. Future research will be also focused on the clustering of automotive organizations based on the data obtained from respondents.

ACKNOWLEDGEMENTS

The study was carried out as a part of the research project VEGA 1/0633/20 "Research of the variability of properties and functions of products made of composite materials produced by additive manufacturing" supported by the Ministry of Education, Science, Research and Sport of the Slovak Republic.

REFERENCES

Alcácer, V. and Cruz-Machado, V., 2019. Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing Systems. *Engineering Science and Technology, an International Journal* [e-journal], 22(3), pp.899-919. doi: 10.1016/j.jestch.2019.01.006.

Asdecker, B. and Felch, V., 2018. Development of an Industry 4.0 maturity model for the delivery process in supply chains. *Journal of Modelling in Management* [e-journal], 13(4), pp.840-883. doi: 10.1108/JM2-03-2018-0042.

Athanasopoulou, A., Reuver, M., Nikou, S. and Bouwman, H., 2019. What technology enabled services impact business models in the automotive industry? An exploratory study. *Futures* [e-journal], 109, pp.73-83. doi: 10.1016/j.futures.2019.04.001.

Bakertilly, 2019. *Industry 4.0 and the Industrial Internet of Things (IIoT).* [online] Available at: <https://bakertilly.com/industry-4.0/> [Accessed 09 January 2020].

Becker, J., Knackstedt, R. and Pöppelbuß, J., 2009. Developing Maturity Models for IT Management: A Procedure Model and its Application for IT Management. *Business & Information Systems Engineering* [e-journal], 1(3), pp.213-222. doi: 10.1007/11576-009-0167-9.

Berger, R., 2014. *Industry 4.0: The New Industrial Revolution*. Munich: Operations Strategy Competence Center.

Bibby, L. and Dehe, B., 2018. Defining and assessing industry 4.0 maturity levels– case of the defence sector. *Production Planning & Control*, 29(12), pp.1030-1043.

Boyes, H., Hallaq, B., Cunningham, J. and Watson, T., 2018. The industrial internet of things (IIoT): An analysis framework. *Computers in Industry* [e-journal], 101, pp.1-12. doi: 10.1016/j.compind.2018.04.015.

Buchi, G., Cugno, M. and Castagnoli, R., 2020. Smart factory performance and Industry 4.0. *Technological Forecasting and Social Change* [e-journal], 150, 119790. doi: 10.1016/j.techfore.2019.119790.

Capgemini, 2018. *Industry 4.0 Maturity Model – Mirroring today to sprint into the future*. [online] Available at: <https://www.capgemini.com/fi-en/2018/09/industry-4-0-maturity-model-mirroring-today-to-sprint-into-the-future/> [Accessed 10 May 2019].

Dan, J., 2017. *LNS research*. [online] Available at: <https://blog.lnsresearch.com/quality40> [Accessed 05 May 2019].

European Automobile Manufacturers Association (ACEA), 2018. *EU Motor Vehicle Production*. [online] Available at: <https://www.acea.be/statistics/article/motor-vehicle-production-in-the-eu> [Accessed 20 Juny 2020].

European Commision, 2019. *Integration of Digital Technology*: *DESI Report.* Brussels: European Commision.

Facchini, F., Oleśków-Szłapka, J., Ranieri, L. and Urbinati, A., 2020. A Maturity Model for Logistics 4.0: An Empirical Analysis and a Roadmap for Future Research. *Sustainability* [e-journal], 12(1), pp.1-18. doi: 10.3390/su12010086.

Felch, V., Asdecker, B. and Sucky, E., 2019. Maturity Models in the Age of Industry 4.0 – Do the Available Models Correspond to the Needs of Business Practice? In: Tung Bui, ed. *52nd Hawaii International Conference on System Sciences.* Maui, Hawaii, 08 - 11 January 2019. Honolulu: HICSS. pp.5165-5174. doi: 10.24251/hicss.2019.620.

Geissbauer, R., Vedsø, J. and Schrauf, S., 2016. A Strategist's Guide to Industry 4.0. *Srategy + Business*, 83(3), pp.10-18.

Grieger, M. and Ludwig, A., 2019. On the move towards customer-centric business models in the automotive industry - a conceptual reference framework of shared automotive service systems. *Electronic Markets* [e-journal], 29(3), pp.473-500. doi: 10.1007/s12525-018-00327-6.

Hevner, A., March, S. and Park, J.R.S., 2004. Design science in information systems research. *MIS Quarterly* [e-journal], 28(1), pp.75-105. doi: 10.2307/25148625.

Konrad, K. and Stagl, S., 2018. *Competitiveness of the European automotive manufacturing industry*. Berlin: Institute for Innovation and Technology.

Krubasik, S., Dirlea, V., Kidambi, R. and Sachseneder, C., 2017. *A.T.Kearney*. [online] Available at: <https://www.atkearney.com/industrial-goods-services/article/?/a/quality-4-0-preventive-holistic-future-proof> [Accessed 28 May 2019].

Lichtblau, K., Stich, V., Bertenrath, R., Blum, M., Bleider, M., Millack, A., Schmitt, K., Schmitz, E. and Schröter, M., 2015. *Industrie 4.0 Readiness*. Cologne: Aachen University.

Llopis-Albert, C., Rubio, F. and Valero, F., 2021. Impact of digital transformation on the automotive industry. *Technological Forecasting and Social Change* [e-journal], 162, 120343. doi: 10.1016/j.techfore.2020.120343.

Markulik, Š., Sinay, J. and Pačaiová, H., 2019. Quality Assurance in the Automotive Industry and Industry 4.0. In: D. Cagáňová, M. Balog, L. Knapčíková, J. Sociar and S. Mezarcioz, eds. 2019. *Smart Technology Trends in Industrial and Business Management.* Switzerland: Springer. pp.217-225. doi: 10.1007/978-3-319-76998-1_15.

Mohelska, H. and Sokolova, M., 2018. Management Approaches for Industry 4.0 – The Organizational Culture Perspective. *Technological and Economic Development of Economy* [e-journal], 24(6), pp.2225-2240. doi: 10.3846/tede.2018.6397.

Nagyová, A., Pačaiová, H., Gobanová, A. and Turisová, R., 2019. An Empirical Study of Root-Cause Analysis in Automotive Supplier Organisation. *Quality Innovation Prosperity* [e-journal], 23(2), pp.34-45. doi: 10.12776/qip.v23i2.1243.

Organisation for Economic Cooperation and Development (OECD), 2019. *OECD Economic Surveys: Slovac Republic 2019.* OECD.

Pereira, A. and Romero, F., 2017. A review of the meanings and the implications of the Industry 4.0 concept. *Procedia Manufacturing* [e-journal], 13, pp.1206-1214. doi: 10.1016/j.promfg.2017.09.032.

PricewaterhouseCoopers (PwC), 2016. *Industry 4.0 Self Assessment*. [online] Available at: <https://i40-self-assessment.pwc.nl/i40/landing/> [Accessed 05 March 2019].

Radziwill, N., 2018. Let's Get Digital: The many ways the fourth industrial revolution is reshaping the way we think about quality. *Quality Progress*, pp.24-29.

Rachinger, M., Rauter, R., Müller, C., Vorraber, W. and Schirgi, E., 2019. Digitalization and its influence on business model innovation. *Journal of Manufacturing Technology Management* [e-journal], 30(8), pp.1143-1160. doi: 10.1108/JMTM-01-2018-0020.

Rockwell Automation, 2014. *The Connected Enterprise Maturity Model.* Rockwell Automation.

Sanders, A., Elangeswaran, C. and Wulfsberg, J.P., 2016. Industry 4.0 implies lean manufacturing: Research activities in industry 4.0 function as enablers for lean manufacturing. *Journal of Industrial Engineering and Management* [e-journal], 9(3), pp.811-833. doi: 10.3926/jiem.1940.

Schumacher, A., Erol, S. and Sihn, W., 2016. A Maturity Model for Assessing Industry 4.0 Readiness and Maturity of Manufacturing Enterprises. *Procedia CIRP* [e-journal], 52, pp.161-166. doi: 10.1016/j.procir.2016.07.040.

Slimák, I. and Zgodavová, K., 2011. Focus on Sucess. *Quality Innovation Prosperity* [e-journal], 15(1), pp.1-4. doi: 10.12776/qip.v15i1.36.

Slovak Investment and trade development agency (SARIO), 2018. *Automotive Sector in Slovakia*. Bratislava: SARIO.

Tkáč, M., Verner, R. and Tkáč, M., 2019. Perception of trust building mechanisms in EU countries. In: P. Doucek, C. Chroust and V. Oškrdal, eds., *IDIMT-2019: Proceedings of the 27th Interdisciplinary Information Management Talks*. Kutná Hora, Czech Republic, 04 - 06 September 2019. Linz: TRAUNER Verlag. pp.275-283.

Veile, J., Kiel, D., Muller, J. and Voigt, K., 2019. Lessons learned from Industry 4.0 implementation in the German manufacturing industry. *Journal of Manufacturing Technology Management* [e-journal], 21p. doi: 10.1108/jmtm-08-2018-0270.

Weber, C., Königsberger, J., Kassner, L. and Mitschang, B., 2017. M2DDM – A Maturity Model for Data-Driven Manufacturing. *Procedia CIRP* [e-journal], 63, pp.173-178. doi: 10.1016/j.procir.2017.03.309.

Wellner, P., Manolian, A.H. and Laaper, S., 2018. Distinctive traits of digital frontrunners in manufacturing. *Deloitte.Insigts* [online] 23 August 2018. Available at: <https://www2.deloitte.com/insights/us/en/focus/industry-4-0/digital-leaders-in-manufacturing-fourth-industrial-revolution.html> [Accessed 12 December 2018].

World Economic Forum (WEF), 2018. *Readiness for the Future of Production*. Geneva: WEF.

Zgodavová, K., 2002. Factors of intensive product and service quality improvement. *Ekonomický časopis*, 50(6), pp.1005-1021.

Zgodavova, K., Hudec, O. and Palfy, P., 2017. Culture of quality: insigth into foreign organisations in Slovakia. *Total Quality Management & Business Excellence* [e-journal], 28(9-10), pp.1-22. doi: 10.1080/14783363.2017.1309120.

ABOUT AUTHORS

Andrea Sütőová – (A.S.) Technical University of Kosice, Institute of Materials and Quality Engineering, Košice, Slovakia, Assist. Prof., e-mail: andrea.sutoova@tuke.sk, Author's ORCID: 0000-0002-6689-046X.

Ľubomír Šooš – (Ľ.Š.) Slovak University of Technology in Bratislava, Institute of Manufacturing Systems, Environmental Technology and Quality Management, Bratislava, Slovakia, Prof., e-mail: lubomir.soos@stuba.sk, Author's ORCID: 0000-0003-3161-5609.

Ferdinand Kóča – (F.K.) Technical University of Kosice, Institute of Materials and Quality Engineering, Košice, Slovakia, PhD. Student, e-mail: ferdinand.koca@student.tuke.sk.

AUTHOR CONTRIBUTIONS

A.S. – conceptualization, methodology, data curation, original draft preparation; Ľ.Š. – data acquisition, review and editing; F.K. – investigation, visualization.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.