The Effect of Industry 4.0 Concepts and E-learning on Manufacturing Firm Performance: Evidence from Transitional Economy

Bojan Lalic[1], Vidosav Majstorovic[2], Ugljesa Marjanovic[1(✉)], Milan Delić[1], and Nemanja Tasic[1]

[1] Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia
{blalic,umarjano,delic,nemanja.tasic}@uns.ac.rs
[2] Department for Production Engineering, University of Belgrade, Belgrade, Serbia
vidosav.majstorovic@sbb.rs

Abstract. With the application of smart technology concepts, the fourth stage of industrialization, referred to as Industry 4.0, is believed to be approaching. This paper analyzes the extent to which smart factory concepts and e-learning have already deeply affected manufacturing industries in terms of performances in transitional economy. Empirical results indicate that manufacturing companies that have introduce both e-learning and selected smart factory technology concepts differ significantly. E-learning is mainly applied on graduates in production. Results reveal that two smart factory concepts are significantly and positively related to the firm performance when e-learning is applied.

Keywords: Industry 4.0 · E-learning · Smart factory · European Manufacturing Survey

1 Introduction

Industry 4.0, a new fundamental paradigm shift in industrial production [1] is a result of the basis of an advanced digitalization within factories, the combination of Internet technologies and future-oriented technologies in the field of "smart" objects (machines and products) [2]. "Industry 4.0 represents a smart manufacturing networking concept where machines and products interact with each other without human control" [3]. This concept does not consider less employees in production, the contrary, human resources are acknowledged as the most flexible parts in the production system being maximally adaptive to the more and more challenging work environment [4].

The success of manufacturing enterprises depends on their capability to quickly adapt in more and more complex environments [4]. The implementation of adequate qualification measures is required comprising both the organizational and technological concepts [4] in order to enable the employees at all levels (i.e. unskilled, technicians, graduates) to fulfil their tasks efficiently. The company will succeed only if the rate of acquisition of knowledge is greater than the rate of change of environment and

H. Lödding et al. (Eds.): APMS 2017, Part I, IFIP AICT 513, pp. 298–305, 2017.
DOI: 10.1007/978-3-319-66923-6_35

discontinuous, unforeseen impacts [5]. The purpose of this paper is to analyze and understand the extent to which smart factory concepts and computer-aided technologies for training purposes have already deeply affected manufacturing industries in terms of performances in transitional economy.

2 Background and Related Work

2.1 Industry 4.0

The term Industry 4.0 was firstly introduced in Germany at the Hanover Fair in 2011 [6]. This concept has emerged as a popular catchphrase in German industry to cover functional areas such as efficient, individual production at lot size 1 under the condition of highly flexible mass production by the emergence of cyber-physical systems and internet of things technologies in the production domain [4]. The similar terms were also introduced in other main industrial countries – "Industrial Internet" in the USA and "Internet +" in the PRC [7].

One of the fundamental concepts of Industry 4.0 is "smart factory" [2]. This concept assumes that all manufacturing is completely equipped with sensors, actors, and autonomous systems. Smart factory exists when manufacturing site is using "smart technology" related to holistically digitalized models of products and factories (digital factory) [8]. Work in progress products, components and production machines are collecting and sharing data in real time [9]. This type of a factory is autonomously controlled and includes following technological concepts:

- Software for production planning and scheduling (e.g. ERP) [10],
- Systems for automation and management of internal logistics (e.g. RFID) [2],
- New systems in the development of products and services [8],
- Product-Lifecycle-Management-Systems (PLM) [11],
- Mobile/wireless devices for programming and operation of equipment and machinery [1],
- Digital solutions in production (e.g. tablets, smartphones) [1].

With the use of technological concepts, companies are reaching higher targets. Russmann et al. [12] found that smart factory Industry 4.0 concepts will make production systems as much as 30 percent faster and 25 percent more efficient. Manufacturing companies that have introduced and fully utilized smart factory technologies are continuously upgrading their performance [13]. 82 percent of organizations that claim to have implemented smart manufacturing say that they have experienced increased efficiency, 49 percent experienced fewer product defects and 45 percent experienced increased customer satisfaction [9].

2.2 Computer-Aided Technologies for Training Purposes

With the implementation and usage of smart factory concepts the manufacturing site is facing with new boundary conditions. Workers are facing on the shop floor increased product complexity, shortened product development cycles and quickly changing production processes [4]. To achieve consistent high performance, company needs to have skilled workforce in production adaptable to innovative environments. To bypass the limitations of traditional training, computer-aided technologies for training purposes need to be developed and deployed in the existing IT and organizational infrastructures of the manufacturers. Hence, automated learning systems are vital to smart factory [6]. In this context, computer-based training is a solution.

With the popularization of e-learning systems, many companies have developed computer-based training programs for their employees [14]. The use of technology allows some advantages over traditional learning methods [4]. Firstly, worker in production can independently read material posted on the computer and then test the acquired knowledge [14]. Secondly, during the learning process, worker can interact with other participants, such as the instructor or other employees [15]. Thirdly, employees have greater control over learning, which makes learning self-paced. Compared to the traditional learning process, where workers usually learn in a group by sitting in the same room with the instructor or other employees, the e-learning process is usually designed for studying by sitting in front of the computer and the workers are given control over learning elements [16]. Finally, e-learning in the workplace is cost efficient [17]. Costs can be reduced if the training is targeted to manufacturing goals that can effectively provide employees with the kind of training that will increase their knowledge and skills to enable the employees in production (i.e. unskilled, semiskilled, technicians, graduates) to fulfil their tasks efficiently [18].

2.3 Research Questions

Based on literature review, the following research questions were proposed in attempt to identify the effect of smart factory industry 4.0 concepts and e-learning on performance of manufacturing products:

- *RQ1: Since Republic of Serbia is considered as developing economy* [19]*, the question is whether companies from manufacturing sector that utilize some of the technology concepts related to Industry 4.0 are deploying e-learning?*
- *RQ2: If yes, for which employees in production those companies use e-learning (semiskilled/unskilled, technicians, graduates)?*
- *RQ3: How smart factory concepts, along with the use of computer-aided technologies for training purposes, are affecting organizational performances (e.g. time-to-market, product defects, revenue-per-employee)?*

3 Data and Methodology

Our analysis used the Serbian dataset from the European Manufacturing Survey [20], a survey on the manufacturing strategies, the application of innovative organizational and technological concepts in production, and questions of personnel deployment and qualifications in European manufacturing industry [21]. The written survey set has been carried out by the Fraunhofer Institute for Systems and Innovation Research (ISI) since 1995 [22]. The current Serbian dataset of 2015 includes 302 observations of Serbian firms of all manufacturing industries. The survey was conducted among manufacturing firms (NACE Rev 2 codes from 10 to 33) having at least 20 employees. About 41.4% of the firms in the sample are small firms between 20 and 49 employees, another 48.0% of the firms have between 50 and 249 employees, and 10.6% of the firms have more than 250 employees. The largest industry in the sample is the manufacture of food products (NACE 10; 18.2%), followed by manufacture of fabricated metal products, except machinery and equipment (NACE 25; 13.6%) and the manufacture of rubber and plastic products (NACE 22; 8.3%). To analyze the relationships between smart factory concepts, e-learning offerings, and organizational performances we employed a multivariate data analyzes.

4 Results and Discussion

Descriptive statistics for smart factory technological concepts use are shown in Table 1. Companies were asked which of the selected technological concepts related to smart factory Industry 4.0 were they using. Software for production planning and scheduling was considered as the most widespread “smart technology”, as more than 33% of Serbian manufacturing companies used it. It is worth mentioning two more concepts, which are implemented in at least 20% of Serbian manufacturing companies namely the technology concept of near real-time production control system (27.2%) and digital exchange of product/process data (22.4%).

Table 1. Usage of Industry 4.0 technology concepts in Serbian manufacturing companies

Industry 4.0 technology concepts	Share (%)	Rank
Software for production planning and scheduling	33.8	1
Near real-time production control system	27.2	2
Digital exchange of product/process data	22.4	3
Systems for automation and management of internal logistics	19.5	4
Devices for programming and handling of machines	8.1	8
Product lifecycle management systems	9.2	7
Technologies for safe human-machine interaction	11.8	6
Digital visualization	13.3	5

The results for our research question 1, “*whether companies from manufacturing sector that utilize some of the technology concepts related to Industry 4.0 are deploying computer-aided technologies for training purposes (e-learning)?*” indicate that 48% of the manufacturers in Serbia with more than 20 employees, that have introduced at least one smart factory concept, have deployed IT-based self-learning programs (e-learning) for their employees in production. In addition, results show that manufacturing companies that have introduce both e-learning and selected smart factory technology concepts differ significantly. Results indicate that highest percent of companies from manufacturing sector that utilize the technology concept software for production planning and scheduling are deploying computer-aided technologies for training purposes (40.9%).

On the other hand, only 12 per cent of Serbian manufacturers declared that they used e-learning and utilized technologies for safe human-machine interaction. Table 2 depicts the data in detail.

Table 2. Share of e-learning related to Industry 4.0 technology concepts

Industry 4.0 technology concepts	e-learning (%)	
	Yes	No
Software for production planning and scheduling	40.9*	27.3*
Near real-time production control system	34.6*	20.3*
Digital exchange of product/process data	25.4	19.7
Systems for automation and management of internal logistics	22.6	16.7
Devices for programming and handling of machines	12.5*	3.9*
Product lifecycle management systems	12.8	5.9
Technologies for safe human-machine interaction	12.0	11.7
Digital visualization	18.9*	7.9*

*Note: * statistical significance Chi-Square test, at < .05*

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For which employees in production companies use e-learning (research question 2)? The results are presented in Table 3. These data indicate that manufacturing companies in Serbia that are deploying e-learning are applying it on all employees in production. We found that IT-based self-learning programs are mainly applied on graduates in production (77.3%). On the contrary, only 6% of manufacturers are using e-learning programs for their unskilled/semiskilled employees.

Table 3. Share of companies with deployment of e-learning and its application

	Eligible employees in production		
	Semiskilled/unskilled	Technicians	Graduates
Application of e-learning	6.0%	43.9%	77.3%

Figure 1 depicts the results for our research question 3, “How smart factory concepts, along with the use of computer-aided technologies for training purposes (e-learning), are affecting organizational performances” which we gained by analyzing EMS data.

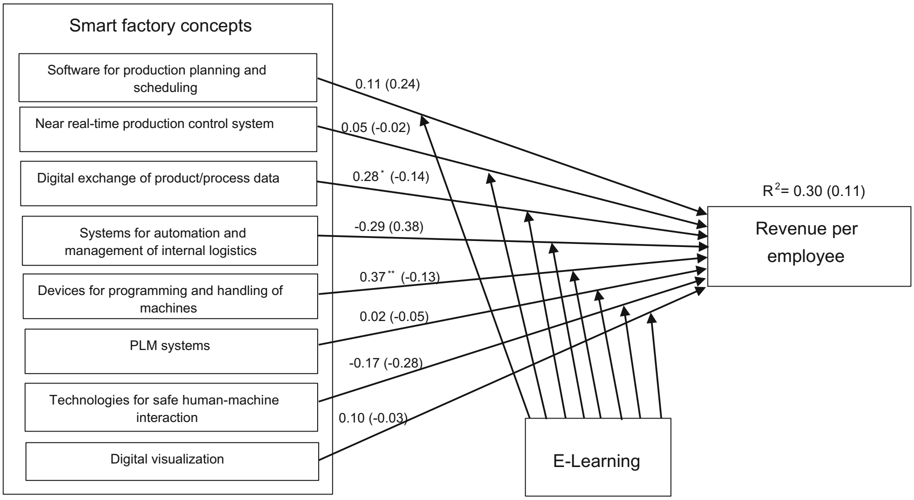

Fig. 1. Linear regression model. *Note.* Values w/e-learning (w/o e-learning); $^{*}p < .05$, $^{**}p < 0.01$.

To identify relevant smart factory concepts on different organizational performances (i.e. time-to-market, product defects, revenue-per-employee) we tested the two models (1) with the application of e-learning and (2) without application of e-learning. For organizational performances time-to-market and product defects no statistically significance of the model is found. In the model estimating the revenue-per-employee with moderating role of e-learning (without application of e-learning), none of the smart factory concept is significantly related to the probability to organizational performance indicator. The change of the variable e-learning to manufacturing companies that applied it, model shows the expected significant and positive impact, providing support to research question 3. The R^2 improves significantly from 0.11 (without application of e-learning) to 0.30 (with the application of e-learning). The results for the model with the application of e-learning within company show that two smart factory concepts (i.e. digital exchange of product/process data, devices for programming and handling of machines) are significantly and positively related to the revenue-per-employee. Once again, the change of e-learning significantly sharpens the differences between the models. This is in line with the previous research [9, 14, 15].

5 Conclusion

Using large-scale survey data, this paper provides a representative picture of smart factory concepts and e-learning in manufacturing industries and related causal relationships in transitional economy. To conclude, we found that 48% of the manufacturers in

Serbia with more than 20 employees, that have introduced at least one smart factory concept, have deployed e-learning for their employees in production. Furthermore, IT-based self-learning programs are mainly applied on graduates in production. Finally, manufacturing companies in Serbia that are utilizing industry 4.0 concepts and are deploying computer-aided technologies for training purposes are showing higher performances through revenue-per-employee.

This research has also practical and managerial implications. Our results show that the use of specific smart factory concepts, along with computer-aided technologies for training, clearly positively affects the ability to manufacture with higher performances (i.e. revenue-per-employee). This is a clear message to managers in developing countries that deployment of digital exchange of product/process data, and devices for programming and handling of machines along with the application of e-learning on technicians and graduates in manufacturing will produce greater results.

The sample was drawn from a single developing country, probably lacking the diversity that can be expected from a comparable sample chosen from across different economies, both developed and developing. Further research should test the model and relationships in the manufacturing companies within developed economies. Another limitation is within the industry specificities. We selected the manufacturing companies from different industries not taking into consideration the specificity of each sector. Thus, the primary focus in future research will be on the comparative analysis of the different manufacturing sectors. In our research, we did not examine the content of e-learning. Attention to various types of e-learning (e.g. video, audio, training simulations, interactive scenarios, gamification, virtual reality) should be paid in future studies to investigate the relationships more thoroughly.

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