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Technical Innovation Concepts in Slovenian Manufacturing Companies

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Abstract

This paper deals with the concept of technical innovation in Slovenian manufacturing companies. We have conducted a survey within international project European Manufacturing Survey (EMS). We have asked manufacturing companies with at least 20 employees which technical innovation concepts they use and to what extent they use them. The paper presents also the trends in use of this technical innovation concepts and future plans of companies. The results are presented with the use of descriptive statistics and they show that the use of specific advanced technologies in Slovenian manufacturing companies is quite diverse. The research also shows that the trends in using selected technologies in Slovenian manufacturing companies is positive, although the use of specific advanced technologies is slightly missed.

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Keywords: technical innovation; technology; manufacturing company; manufacturing survey; Slovenia

1. Introduction

Innovation, which is mostly linked to R&D of products [1], remains one of the leading issues in current science. There are many studies on innovation revealing that increased R&D activities lead to innovative products, which enable companies to achieve competitive advantages and to gain market shares [2]. For present purposes, we adopted Nohria and Gulati's [3] definition of innovation as "any policy, structure, method, or process, product or market opportunity that the manager of the innovating unit perceived to be new".

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This paper deals with a specific innovation type – technical innovation concepts in manufacturing companies. The research focus was to map the adoption of selected technical innovation concepts. There are no recent studies on the use of advanced technologies in Slovenia. Besides mapping the adoption of selected technologies in Slovenian manufacturing companies, we have also examined their level of use. This concepts is also hardly found in any studies. We have analysed the use of selected technologies also depending on the company size and technological intensity of the industries to which the companies belong.

Our research was based on the largest European manufacturing survey (EMS), coordinated by the Fraunhofer Institute for Systems and Innovation Research – ISI from Germany. Our results are mostly from the latest round from 2012 and 2013. One of the benefits of such surveys is that enables the analysis of European manufacturing area in a longer period. Therefore, we are able to present some trends in the use of selected technologies in Slovenian manufacturing companies. This is also one of the biggest contributions of this paper.

The paper will present results with the use of descriptive statistics and the results show that the use of specific advanced technologies in Slovenian manufacturing companies is quite diverse. The paper is structured as follows. The theoretical part briefly introduces the concept of (technical) innovation. The methodological section explains the characteristics of EMS and our research. The empirical section analyses the use of selected technologies and presents some trends. Finally, a concluding discussion is provided for the findings with some managerial implications, research limitation and directions for future research.

2. About technical innovation

OECD OSLO Manual [4] defines an innovation as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations.

Referring to Schumpeter and other innovation researchers [5, 6], innovation can be considered to be a complex phenomenon including technical (e.g., new products, new production methods) and non-technical aspects (e.g., new markets, new forms of organization) as well as product innovations (e.g., new products or services) and process innovations (e.g., new production methods or new forms of organization).

Technical innovations are defined as those that occur in the operating component and affect the technical system of an organisation. The technical system consists of the equipment and methods of operations used to transform raw materials or information into product and services [7-11]. A technical innovation, therefore, can be the adoption of a new idea pertaining to a new product or a new service, or the introduction of new elements in an organisation's production process or service operations [12].

OECD OSLO Manual [4] distinguishes four types of innovations: product innovations, process innovations, marketing innovations and organisational innovations. The first two are associated with technical innovation concepts. They define them as follows:

- A product innovation is the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses. This includes significant improvements in technical specifications, components and materials, incorporated software, user friendliness or other functional characteristics.
- A process innovation is the implementation of a new or significantly improved production or delivery method. This includes significant changes in techniques, equipment and/or software.

The technical innovations have been the subject of many studies. Camisón and Villar-López [13] and Armbruster et al. [14] argue that majority of research on innovation types has followed a technical focus.

3. Research methodology

Research methodology used was a survey research. The European Manufacturing Survey (EMS), coordinated by the Fraunhofer Institute for Systems and Innovation Research – ISI, is the largest European survey of manufacturing activities. EMS questionnaire is very extensive with almost 8 pages. The survey's questions concern manufacturing strategies, the application of innovative organisational and technological concepts in production, cooperation issues, production off-shoring, servitisation, and questions of personnel deployment and qualification. In addition, data on performance indicators such as productivity, flexibility, quality and returns is collected. The responding companies present a cross-section of the main manufacturing industries. Included are producers of rubber and plastics, metal

works, mechanical engineering, electrical engineering, textile and others. The survey is conducted among manufacturing companies (NACE Revision 1.1 codes from 15 to 37) having at least 20 employees. The main objectives of EMS project are to find out more about the use of production and information technologies, new organisational approaches in manufacturing and the implementation of best management practices.

The EMS was conducted in 2003/2004 as a pilot survey in nine European countries. The survey covered Austria, Croatia, France, Germany, United Kingdom, Italy, Slovenia, Switzerland and Turkey. In the year 2006/2007 a new survey was conducted in even more European countries, where Greece, Netherlands and Spain joined the project. The next edition of the EMS was carried out in 2009. The survey became global as China and Russia joined the project team as well as Denmark and Finland. The fourth edition of EMS started in 2012 and finished in 2013. Our family comprises now 17 countries as Czech Republic, Sweden and Brazil joined the survey.

Our research is based on EMS data from Slovenian subsample from the years 2006, 2009 and 2012. Slovenia has always been a partner with one of the highest response rate. In 2006 we sent 474 questionnaires and received 72 answers (15,82% response rate). In 2009 we sent 665 questionnaires and received 71 answers (10,67% response rate). In 2012 we sent 791 questionnaires and 89 were returned (11,25% response rate). Figure 1 presents a structural part of question from EMS 2012 that deals with technical innovation concepts.

For each technical innovation concept we have asked for the following information:

- Use of concept (yes/no).
- Use planned in the upcoming period of three years.
- Year in which this technology has been used for the first time in your factory.
- Extent of actual utilization compared to the most reasonable potential utilization in the factory: Extent of utilized potential “low” for an initial attempt to utilize, “medium” for partly utilized and “high” for extensive utilization.
- Upgrade of the already implemented technical innovation concepts (technologies) in the last three years (yes/no).

In EMS 2012 we have divided 19 technical innovation concepts – technologies used in manufacturing factories – into 5 groups:

- Robotics and automation;
- Processing and production technologies;
- Digital factory/IT cross-linkage;
- Energy and resource efficiency;
- Technologies for generating renewable energy.

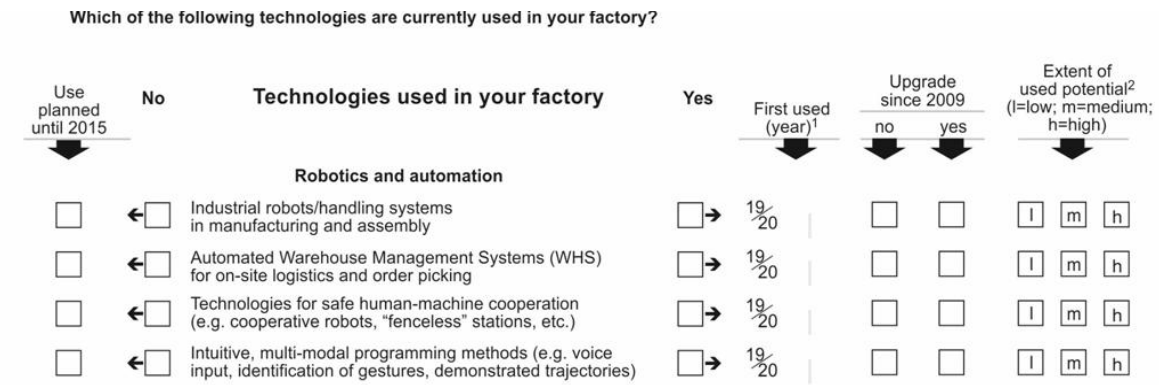

Fig. 1. Question on technical innovation concepts in EMS 2012.

4. The use of technical innovation concepts in Slovenian manufacturing companies

4.1. Frequency use of technical innovation concepts

Table 1 presents share of Slovenian manufacturing companies who use specific technical innovation concept.

Table 1. Share of manufacturing companies who use specific technical innovation concept – technology.

Technology	Share	Rank
Robotics and automation		
Industrial robots/handling systems in manufacturing and assembly	55,06%	1
Automated Warehouse Management Systems (WHS) for on-site logistics and order picking	15,73%	9
Technologies for safe human-machine cooperation (e.g. cooperative robots, "fenceless" stations, etc.)	6,74%	15
Intuitive, multi-modal programming methods (e.g. voice input, identification of gestures, demonstrated trajectories	4,49%	16
Processing and production technologies		
Processing techniques for alloy construction materials (aluminium, magnesium, titanium alloys, etc.)	15,73%	9
Processing techniques for composite materials (e.g. carbon fibre, fibreglass)	3,37%	18
Manufacturing technologies for micromechanical components (micromachining, lithography, microinjection)	1,12%	19
Nano-technological production processes (e.g. surface processing)	4,49%	16
Digital factory/IT cross-linkage		
Digital exchange of operation scheduling with data suppliers/customers (supply chain management systems)	49,44%	2
Virtual reality and/or simulation in production reconfiguration (e.g. production flows, single process steps)	21,35%	8
Virtual reality and/or simulation in product design/development (e.g. digital prototyping, FEM)	35,96%	3
Product Lifecycle Management (PLM)	13,48%	13
IT systems for storage and management of ideas (idea management systems)	25,84%	5
Energy and resource efficiency		
Dry processing/minimum lubrication	14,61%	11
Control system for shut down of machines in off-peak periods	23,60%	6
Recuperation of kinetic and process energy (waste heat recovery)	30,34%	4
Combined cold, heat and power (Bi-/Tri-generation)	8,99%	14
Technologies for generating renewable energy		
Technologies for power generation via solar or wind energy, hydropower, biomass or geothermal energy	22,47%	7
Technologies for heat generation via solar energy, biomass or geothermal energy	14,61%	11

The analysis shows that the most frequently used technology are industrial robots and handling systems in manufacturing and assembly, used in over 50% of Slovenian manufacturing companies. All the other technologies are present in manufacturing companies in less than 50% of cases.

We can observe that on average the highest usage share have the technologies from the ICT section. These technologies support manufacturing and business processes. There is an increase in the usage of technologies for direct communication with suppliers (inventory level status, production operation schedules). The same applies for software technologies for virtual reality and/or simulation in production reconfiguration and product design/development. A bit surprising is the increase in usage of IT systems for storage and management of ideas.

Slovenian manufacturing companies are obviously more and more aware of the importance of sustainable energy and resources management. We can see the increase of recuperation of kinetic and process energy technologies and technologies for power generation via different means. Still, the share of manufacturing companies who implement these technologies is rather low (less than 25%). Analysis also shows a very low share of manufacturing companies using processing techniques for composite materials and manufacturing technologies for micromechanical components and nano-technological production processes.

4.2. Extent of use of technical innovation concepts

As we have already mentioned we have also analysed technical innovation concepts based on the extent of use (low, medium, high). This assessment is partly subjective, but still provides some interesting information. We included top 10 most often used technologies (see Table 1). Figure 2 presents that the order of technologies has changed. Processing techniques for alloy construction materials and technologies for power generation have been ranked 7 and 9 based on frequency of use, but are in the top two positions based on their high extent of use. These are the only two technologies that have more than 50% of implementations with the high extent of use. All the other eight technologies have predominant medium extent of use (except virtual reality and/or simulation in product design that has also very high share of highly used implementations). It is interesting to notice that only 6% of

manufacturing companies thinks that they are using their virtual reality in production software at a high extent of use. A quarter of manufacturing companies admits a very low extent of use of this software.

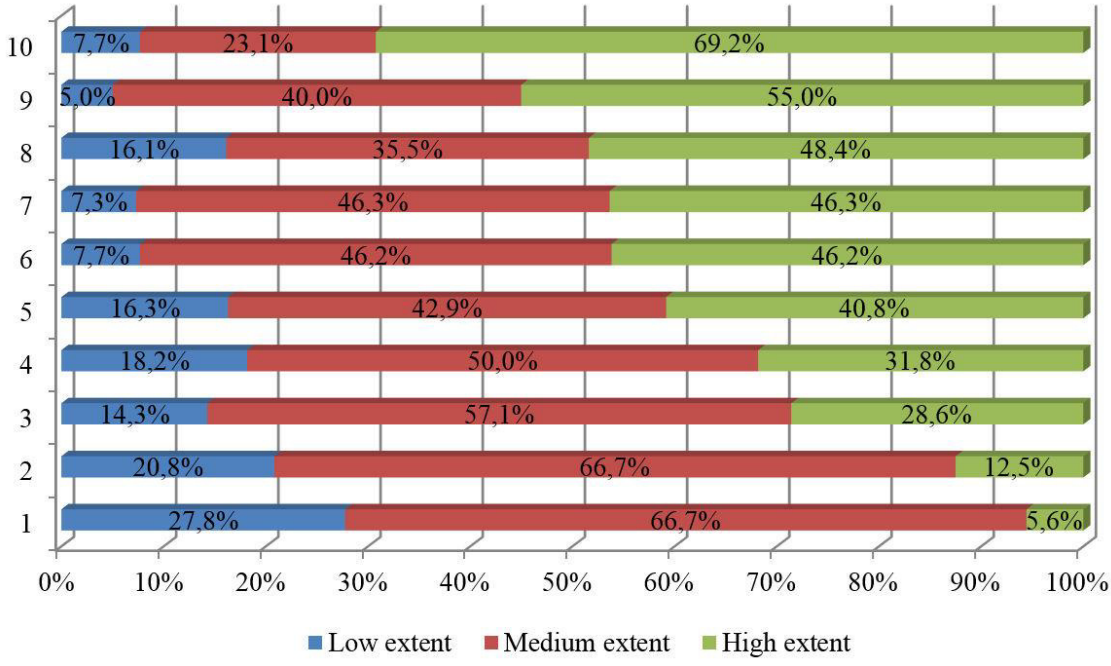

Fig. 2. Technical innovation concept extent of use.

Numbers on the ordinate axis in Figure 2 present analysed technologies:

1. Virtual reality in production
2. Recuperation of kinetic and process energy
3. Control system for shut down of machines
4. IT systems for storage and management of ideas
5. Industrial robots/handling systems
6. Automated warehouse management systems (WHS)
7. Digital exchange of operation scheduling
8. Virtual reality and/or simulation in product design
9. Technologies for power generation
10. Processing techniques for alloy construction materials

4.3. Use of technical innovation concepts and company size

Our analysis about the diffusion of technical innovation concepts has been upgraded with some additional insights. First we have analysed the relationship between innovation concepts diffusion and company size (small, medium and large based on number of employees). As already mentioned we have included in our survey only companies with 20 employees and more. Still, it was a bit surprising that the largest share of respondents is from middle sized companies (around 50%) and that the share of large companies was the same as for the small companies (each around 25%).

We have selected 5 most frequently used technical innovation concepts (industrial robots, digital exchange of operation scheduling, virtual reality and/or simulation in product design, recuperation of kinetic and process energy and IT systems for storage and management of ideas).

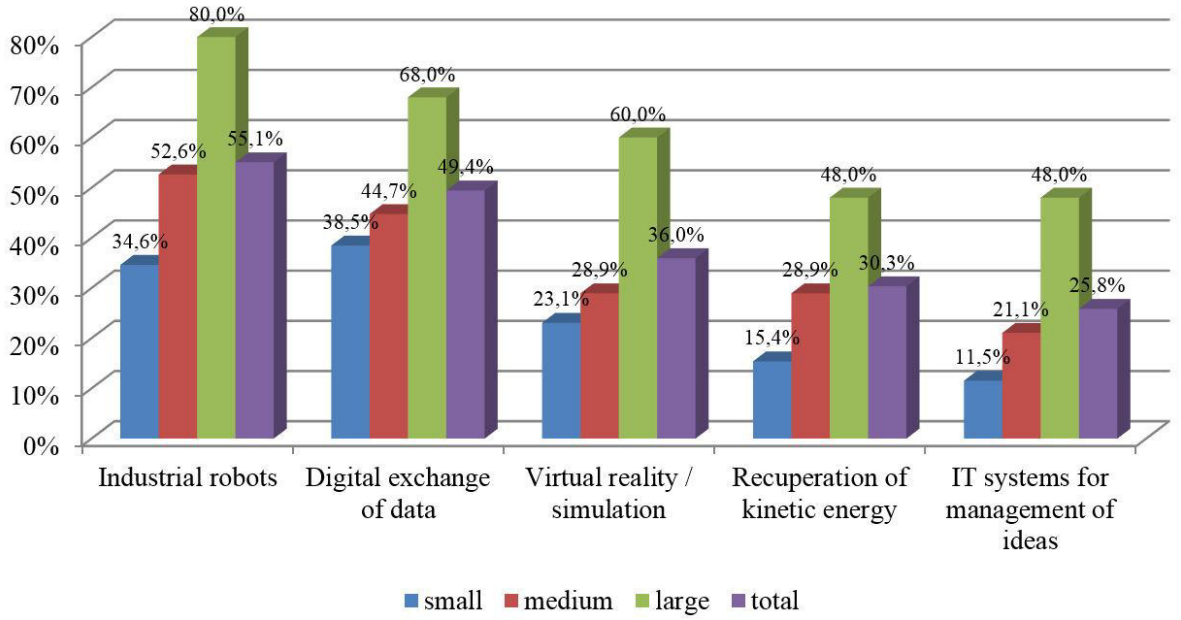

Fig. 3. Technical innovation concept and company size

The use of 5 selected technical innovation concepts depending on a company size shows, that the large companies contribute the highest share of selected technologies implementation. For example 80% of all large manufacturing companies have adopted industrial robots, while on the other hand only around 35% of small manufacturing companies did the same (Figure 3). Industrial robots are in general the most widely adopted technology regardless of the company size. We were surprised that the use of virtual reality and simulation software has a rather low usage share in both small and medium-sized companies. Within all analysed technologies the lowest share of their implementation can be found in small manufacturing companies. Of course, we have to admit that several of included technologies are not suitable for very small manufacturing environments.

4.4. Use of technical innovation concepts and technological intensity

We have classified manufacturing companies based on technological intensity, using OECD classification for high-, medium- and low-tech sectors. We have formed two groups:

- Low-medium technological intensity – LMT, including companies from low-tech and medium-low-tech industries – NACE codes 13, 14, 15, 22, 23, 24, 25 and 32;
- Medium-high technological intensity – MHT, including companies from medium-high-tech and high-tech industries – NACE codes 26, 27, 28, 29 and 30.

We have used the same technical innovation concepts as in previous sub-chapter. The results show that technological intensity of manufacturing companies has no direct impact on the share of companies that adopted technical innovation concepts (exception is IT systems for storage and management of ideas with much higher use in MHT). In the case of the whole group Process and production technologies (see Table 1) the adoption of all four technologies is higher in LMT than in MHT companies. The same applies for both technologies to generate power and heat (Figure 4).

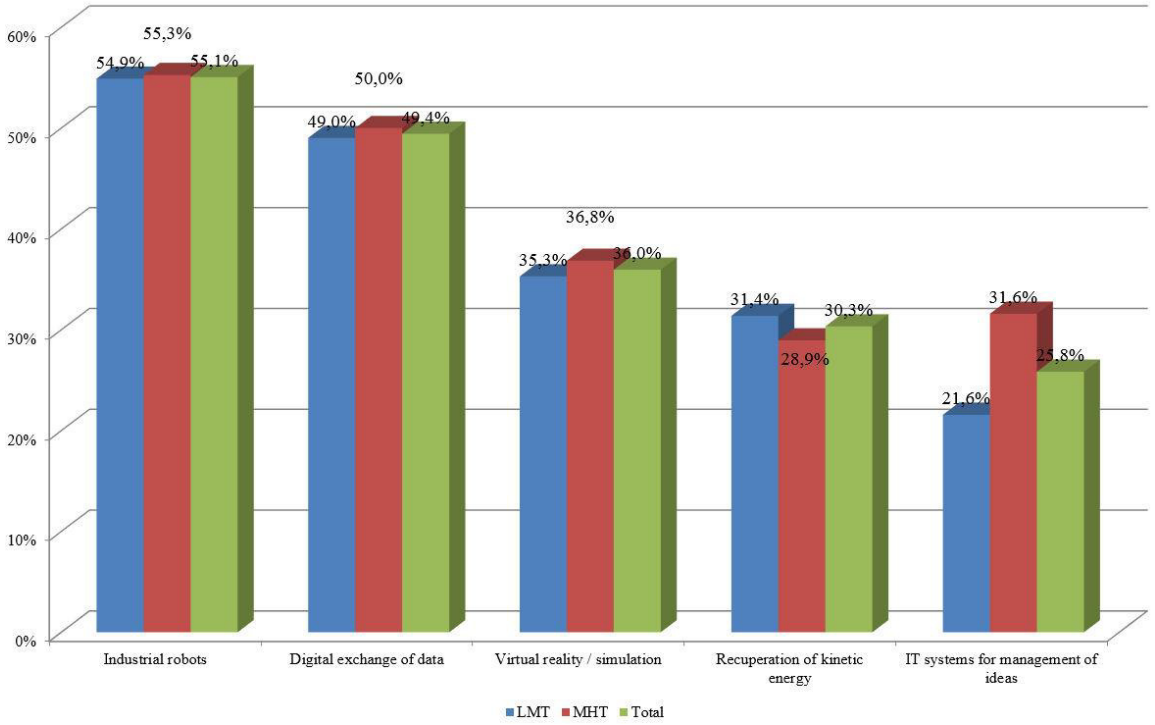

Fig. 4. Technical innovation concept and technological intensity.

4.5. Trends in using technical innovation concepts in Slovenian manufacturing companies

This paper is concluded with the analysis of innovation use trends in Slovenian manufacturing companies based on the data from EMS 2003, 2006, 2009 and 2012. Four EMS rounds enable to monitor different trends in the innovation concepts use in the last decade. Over the years we have changed our questionnaire and updated the list of technical innovation concepts. Only 3 innovation concepts are a part of survey in all four rounds and for these technologies we present changes in their adoption.

Figure 5 presents the use of three selected technologies: industrial robots, virtual reality / simulation and digital exchange of data from 2003 until 2013. We can observe an extreme increase in the use of industrial robots. We define industrial robots as a specific class of automated handling devices, used to handle the material flow of work pieces or tools from one spot to another, carrying the right volume of parts with the accurate orientation at the proper time to the exact position [15]. An industrial robot is officially defined by ISO (Standard 8373:1994) as an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes. In 10 years the share of their use has more than doubled. In the last decade several manufacturing companies that produce industrial robots found home in Slovenia. Many of these companies are just a part of world-wide industrial robots manufacturers. This might be one of the reasons for such a substantial increase in industrial robots adoption in Slovenian manufacturing companies. The second reason is associated with the rise of personnel costs in Slovenian manufacturing companies. In order to substitute labour intensive manufacturing for automated, capital intensive manufacturing started to pay off. The third reason is extreme export orientation of Slovenian manufacturing companies, where many companies suddenly experience overall volumes that are sufficient to realise the necessary batch sizes for a profitable industrial robots application.

Similar increase in use applies to the use of digital exchange of data with suppliers. Slovenian manufacturing companies are widely introducing Enterprise Resource Planning (ERP) information systems, and that also enables the possibility for direct information exchange with suppliers [16, 17]. The share of use of virtual reality and simulation software is stagnating. The value from 2006 may be a bit misleading as the questions was formed a bit differently.

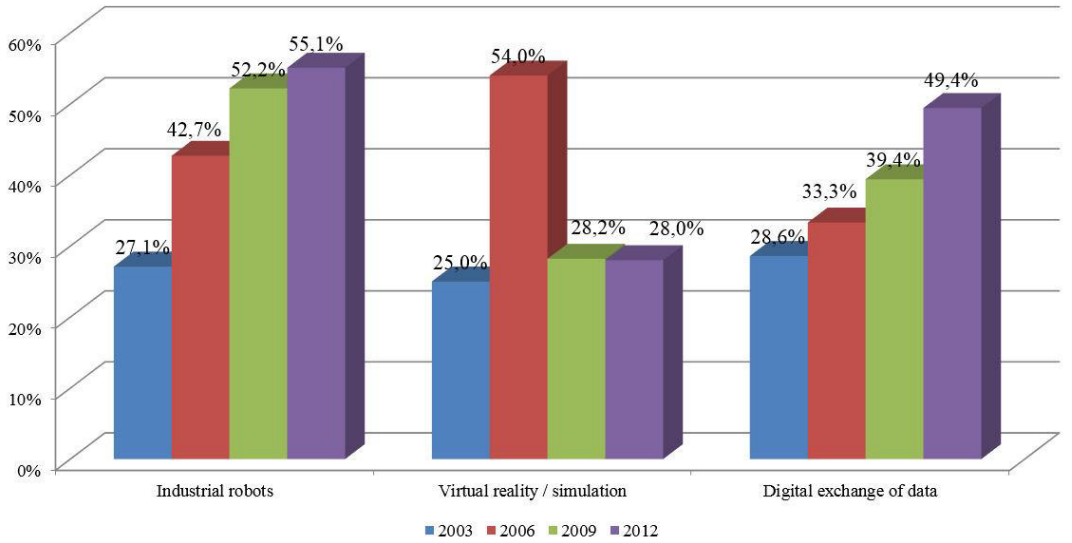

Fig. 5. The use of selected technical innovation concepts in the period 2003-2013.

Conclusion

In this paper we have analysed how widely selected technical concepts are used in Slovenian manufacturing companies, what is the extent of their use, what differences exist in the use and extent of use of these concepts and which are the characteristics of the adopters (company size, technological intensity). Overall, there is an increase in the use of technical innovation concepts in Slovenian manufacturing companies over the last 10 years. Comparing to some other countries from EMS Slovenian share of use of selected technologies is similar. Unfortunately, the extent of use of these technical innovation concepts is pretty low. As expected, the use of analysed technical innovation concepts depends on company size, where large companies mostly employ these technologies. An in-depth analysis also shown that the use of several technologies that are considered in European industrial strategy until 2020 as key technologies is in Slovenian manufacturing companies extremely low.

As with all research, the present study has certain limitations. The first limitation of the study is its focus on specifically selected industries and manufacturing companies with at least 20 employees. The next limitation is that we only focused on Slovenian manufacturing companies, where comparison with other European is very desirable in the future. Future lines of research could propose relationship between the number and the extent of use of technical innovation concepts and company financial and R&D performance. Nevertheless, we believe that results of the study enrich the literature on the adoption of technical innovation concepts and depict the current situation in a selected part of Europe.

References

[1] A. Bikfalvi, Innovation, Entrepreneurship and outsourcing: essays on the use of knowledge in business environments, doctoral dissertation, Girona (2007).
[2] C. Freeman, L. Soete, The Economics of Industrial Innovation, Pinter Publisher, London, 1997.
[3] N. Nohria, R. Gulati, Is slack good or bad for innovation, Academy of Management Journal, 39 (1996) 1245-1264.
[4] OECD, Oslo manual. Guidelines for collecting and interpreting innovation data, third ed., OECD EUROSTAT, Paris, 2005.
[5] F. Damanpour, W.M. Evan, Organizational innovation and performance: the problem of "Organizational Lag", Administrative Science Quarterly, 29 (1984), 392-409.
[6] P. Totterdell, D. Leach, K. Birdi, C. Clegg, T. Wall, An investigation of the contents and consequences of major organizational innovations, International Journal of Innovation Management, 6(4) (2002) 343-368.
[7] T.G. Cummings, Self-regulating work groups: a socio-technical Systems Approach, Academy of Management Review, 3 (1978) 625-634.

[8] G.-D. Wu, Project-Based Supply Chain Cooperative Incentive Based on Reciprocity Preference, International Journal of Simulation Modelling, 13(1) (2014) 102-115.
[9] S.T. Kim, S.R. Hong, C.O. Kim, Product Attribute Design Using an Agent-Based Simulation of an Artificial Market, International Journal of Simulation Modelling, 13(3) (2014) 288-299.
[10] G. Harih, B. Dolsak, Tool-handle design based on a digital human hand model, International Journal of Industrial Ergonomics, 43(4) (2013) 288-295.
[11] M. Nicolov, I. Dolca, Open Innovation in Practice - Case of Romania, in B. Katalinic (Ed.), Annals of DAAAM for 2012 & Proceedings of the 23rd International DAAAM Symposium, Vienna, Austria, 2012, pp. 1055–1058.
[12] F. Damanpour, K.A. Szabat, W.M. Evan, The relationship between types of innovation and organizational performance, Journal of Management Studies, 26(6) (1989) 587-601.
[13] C. Camisón, A. Villar-López, Non-technical innovation: Organizational memory and learning capabilities as antecedent factors with effects on sustained competitive advantage, Industrial Marketing Management, 40 (2011) 1294–1304.
[14] H. Armbruster, A. Bikfalvi, S. Kinkel, G. Lay, Organizational innovation: The challenge of measuring non-technical innovation and large-scale surveys, Technovation, 28 (2008) 644–657.
[15] P. Chatterjee, S. Mondal, S.A. Chakraborty, A comparative study of preference dominance-based approaches for selection of industrial robots, Advances in Production Engineering & Management, 8(1) (2014) 5-20.
[16] N. Sajko, S. Kovacic, J. Balic, Simulation based CAD/CAM model for extrusion tools, Advances in Production Engineering & Management, 8(1) (2013) 33-44.
[17] F. Costantino, G. Di Gravio, A. Shaban, M. Tronci, Inventory control system based on control charts to improve supply chain performances, International Journal of Simulation Modelling, 13(3) (2014) 263-275.