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The impact of technical and organisational innovation concepts on product characteristics

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A B S T R A C T

The main objective of this paper is to determine the adoption of technologies and organisational concepts in production companies and to analyse how selected technical and organisational concepts affect products' characteristics and their introduction onto the market. A further purpose of this paper is to analyse the impact of technical and organisational concepts on the product complexity and to identify where most impulses for innovation come from, as well as their impact on the product complexity. The results are based on a sample of 89 Slovenian manufacturing companies, the data being obtained through the 2012/13 European Manufacturing Survey edition, providing information on the use and upgrading of the more used technologies and organisational concepts. We found that high usages of technical and organisational concepts have a positive impact on the product characteristics in terms of increasing the proportion of complex products. The results also showed that companies obtained more internal information about new products via sales departments whilst the customers were still the important external source of innovation.

A R T I C L E I N F O

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1. Introduction

Fierce competition, harsh economic conditions in the domestic and international environment are becoming constants for business [1]. With rapid changes in technology, and global competition, the success of many organisations has become progressively more dependent on their ability to bring innovative products to the market [2]. Therefore, companies have to constantly explore, invent, innovate and create a new value, which will ensure the existence and further development of the company [3]. The introduction of new management practices is an important issue for companies as they seek to upgrade their productivity, improve the quality of the supply and retain competitiveness [4]. Most commonly innovations are associated with research and development (R&D) activities of the products. Numerous studies prove that increasing investment in R&D activities leads to innovative products, which enables companies to achieve competitive advantages and achieve greater market shares [5]. Non-technical innovation, which includes organisational (or management) and marketing innovation, are an emerging approach, as they were not recognized as innovations until the third edition of the Oslo Manual [6]. According to Camisón and Villar-López, organisational innovations (OI) currently represent one of the most important and sustainable sources of competitive advantages for businesses, but they have not been sufficiently studied, nor has been their impact on innovation and financial effects [7]. Keupp et al. made an extensive literature review on innovation management, analysing more than 342 articles. They found out that there is a low number of papers dealing with the field of OI, while the number of papers in the field of product (technical) innovation (TI) is very high [8]. Nevertheless, there are studies confirming positive effects of OI (Camisón and Villar-López, 2011; Rosenbusch et al., 2011; Bradley et al. 2012; Laforet 2011) as well as how to identify and measure OI in enterprises (Armbruster et al., 2008) [5, 6, 9-11].

The main objective of this paper is to determine the degree of use of TI and OI concepts in production companies and to analyse how chosen TI and OI concepts affect the product characteristic and their introduction on the market. Furthermore, we wish to identify where the most impulses for innovation are coming from and their impact on the product complexity. We also want to analyse the impact of TI and OI concepts on the product complexity. The structure of the remainder of the paper is as follows. Section 2 includes a review of relevant literature. Section 3 describes used research methodology. Section 4 comprises the results of the analysis and discussion while the conclusions are presented in Section 5.

2. Literature review

Chiva and Alegre claim that due to increasing competition, innovations are rapidly becoming a key factor for the success and survival of businesses [12]. Camisón and Villar-López argue that majority of researches on innovation types has followed a technical view [7]. Armbruster et al. claim that non-technical innovations are having an increasingly important role in a better understanding of innovation and its impact on the competitiveness of enterprises, however they emphasize that the existing literature on OI is diversed and dispersed or does not yet exist [5, 13]. Prester argue that OI are a multidisciplinary area of research, that they are a dynamic and iterative process of creating, developing, and producing products, services, processes or policies that are new to the organisation [14]. Lam claims that there is still no consensus on a definition of the term OI [15]. Damanpour and Aravind have undertaken a major study in which they determined the OI as the use of new management and business concepts and practices and showed the overlap of administrative, organisational and managerial innovations [16]. However, Camisón and Villar-López advocate the OECD definition, which defines the OI as the implementation of a new organisational method in the company's business practices, workplace organisation or external relations. The distinguishing features of OI compared to other organisational changes in a company, is the implementation of an organisational method (in business practices, workplace organisation or external relations) that has not been used before in the company and it is the result of strategic decisions taken by management. OI have a tendency to increase company performance by reducing administrative and transaction costs, improving work-place satisfaction (and thus labour productivity), gaining access to non-tradable assets (such as non-codified external knowledge) or reducing costs of supplies. Examples would be the introduction of practices for codifying knowledge by establishing databases of best practices, lessons learnt and other knowledge, so that they are more easily accessible to others: the introduction of training programs for employee development and improved employee retention or the initiation of a supplier development program [17].

Hong, Oxley and McCann, who have studied how our understanding of innovation developed over the past few decades say, that the understanding of innovation and the role of innovation in business systems, greatly evolved over the years. Today, innovation is regarded as a multidimensional issue that can be addressed in several contexts, as sources of innovation can have a crucial impact on the competitiveness of participants in the industry [18]. Although De Faria and Mendonca in a paper on the topic of innovation conclude that a direct and unequivocal link between the growth of the company, its effectiveness and its innovative activity is still very difficult to prove [19], there are several studies proving that adoption of concrete organisational concepts has a remarkable impact on the ability of enterprises to improve their performance. Camisón and Villar-López proved that OI have a positive effect on the competitive advantage of companies and thus on financial performance [7]. Jiménez-Jiménez and Sanz-Valle proved that organisational learning, which falls into domain of Human resources management, does in fact lead to greater innovation and business performance [20]. Mol and Birkinshaw found out that management innovation (another term for OI) is positively associated with company performance in the form of subsequent productivity growth [4]. Laforet conducted the study in order to examine organisational innovation in small and medium-sized enterprises in the district of Sheffield, England. She focused on three types of organisational innovation namely new product development, process innovation and a new way of working. Positive results from the introduction of organisational innovations are reflected as an increase of reputation and corporate image, increase of operational efficiency and reduction of operating costs, an employment of a more educated workforce [21].

The current literature does not specify which OI contribute to which source of competitiveness and measurement in the field of competition, it is also quite a bit of literature. Jin et al. say that only a few studies thoroughly examine the relationship between the types of innovation and business performance of enterprises, especially in the field of OI [22]. Crossan and Apaydin in paper on OI on the basis of a comprehensive meta-analysis concluded that the papers on the topic of OI are narrowly focused. According to them, narrowly focused research otherwise deepens understanding of the different facets, but on the other hand impedes the consolidation of the entire field. Breakdown of innovative activities in the literature shows that only 3 % of papers are dealing with organisational and administrative innovation [23]. A study by Evangelista and Vezzani shows that introduction of some type of organisational change tends to attach more importance (compared to the other companies) to objectives such as the reduction of the time needed to respond to customer or supplier needs and of improvement of the quality of goods or services while no association is found with the objective of reducing the cost for unit of output. The study tested the correlation between sources of innovation but not the links between sources of innovation and competitiveness of enterprises [24]. Gumusluoğlu and Ilsev have investigated the impact of the transformation of company management on OI and tries to determine whether external and internal support for innovation, as an influential factor, have impact on OI. The results showed that the transformation of the company management has a positive impact on OI within the company. This applies especially to micro and small enterprises [25]. Gunday et al. argue that researchers neglect organisational and/or marketing innovations, which in their opinion are also essential for growth and efficient operation of enterprises. Therefore, they studied the effects of innovation impacts on business by examining the technical, process, marketing and organisational innovations, where the company's success was measured in terms of innovative performance, production efficiency, market performance and financial performance [26]. Lin and Chen investigated the link between innovation, organisational effectiveness and performance in small and medium-sized manufacturing and service enterprises. The results of empirical studies have shown that the administrative innovation, rather than technical ones, are the most important factor in selling products on the market [27].

The question that arises by itself is how to measure innovation. That is also one of the main reasons why the OI are neglected by researchers since the success of the innovation process is rather difficult to measure. Several authors argue that the measurements of the efficiency of innovating are difficult to measure since the widely used innovation performance measures were conceptualized for new product development [28-32]. Evangelista et al. conducted a study measuring innovation in European industry in a way that they have pursued the proportion of newly introduced products on the market, share of development of the new product, depending on the size of companies and sector that companies operate, and the proportion of expenditure devoted to innovation [33]. Based on the research of papers, Hong, Oxley and McCannin argue that currently are in use two types of measurements, namely direct and indirect measurement. Indirect measurement is determined by measuring approximations of indicators in R&D research and patent base, which is reflection of the successfully introduced new innovative products on the market. For the economic analysis more important is direct measurement of innovation, which are objective or subjective. If a result of the measurement is indicated by summarization of numbers of innovations in new product / process, then such a measurement is considered as an objective. This form of measurement is bias because it excludes radical innovation of products that are contrary to the primary processes of innovation repeatedly unsuccessful; measurements automatically excludes unsuccessful innovations [18]. On the other hand, Belderbos argues that one way to address process innovations could be to employ productivity measures that are closely related to process innovations but underrepresented as dependent variables [28]. Armbruster et al. however argue, that with the use of definition based on a Damanpour and Evan research, it is possible to measure not only whether companies have changed their organisation (structure and processes) within a defined time period, but also to analyse ratios of adopted concrete organisational concepts in different companies and company types (sector, company size, etc.) and the extent of use within one company [5]. According to Camisón and Villar-López organisational innovation represent one of the most important sources of competitive advantage of companies, but on the other hand, there is a very limited evidence on predisposition to innovate and very few papers on organisational innovations. Therefore, in this work we concentrate on organisational innovations and their impact on innovation, and contribute to theory by researching this under investigated field.

3. Methodology

Presented data on technical and organisational issues in Slovenian manufacturing companies is a result of European Manufacturing Survey (EMS). The coordinator of the project is the Fraunhofer Institute, Karlsruhe, Germany. The research was first conducted in 1993. The first survey of manufacturing activities in Slovenia was carried out in 2004. It was repeated it in years 2006-07, 2009-10 and 2012-13. The target group are the companies from manufacturing sector with more than 20 employees. The questionnaire has 20 sections and it is eight pages long. It covers future competitive priorities of the company, the use of organisational and technological concepts, characteristics of the production process and the characteristics of the company's core product. It also covers human resource issues, and innovation issues measured in terms of generated profits by incrementally new products and radically new products (description is in accordance to OSLO Manual, 2005). The last version of questionnaire was thoroughly upgraded as we added several important topics, especially in the field of energy and material efficiency, product related services, and the use of project-oriented work in companies. We have also expanded the field of research and covered companies classified in NACE 13-15, 22-28, 30 and 32 codes (version 2).

The study included 19 TI concepts and 22 OI concepts. TI concepts were divided into 5 groups: robotics and automations (4 concepts), process and manufacturing technology (4), digital factory/IT connectivity (5), efficient use of energy and resources (4) and technologies for generating renewable energy sources (2). OI concepts were divided into 4 groups: the organisation of production (6), the organisation of work (5), standardization and conformity assessment (6), and human resource management (5). We asked companies to reveal information about upgrading already introduced concepts and the level of use (high, medium, low). For further analysis we selected TI used in at least 15 % of companies and OI concepts used in at least of 30 % of companies.

Field of new products in the survey questionnaire dealt with two issues. The first was asking if the company has launched a significantly improved new product in last three years or has it launched a radically new product in last three years – a product that is new also to the market. In both cases, the additional question was raised on a share of revenues generated by these new products.

Product characteristics or a group of company's key products were divided into four groups: product development (4 properties), manufacturing (4), the batch size (3) and the complexity of the product (3).

We asked the companies where the impulses for innovations are coming from. For internal and external resources we have included 3 areas of innovation (new products, new technical production processes and new organisational concepts).

In 2012 we sent 791 questionnaires and received 89 responses, representing 11.25 % response. If we look at companies who have returned a completed questionnaire in 2012, among them 29.2 % small, 44.9 % medium-sized and 25.8 % large companies. The results of the survey will be presented with descriptive statistics.

4. Results and discussion

First, using the frequency analysis, we are going to present the level of use and the upgrade of specific TI and IO concepts in Slovenian manufacturing companies. Our research included 19 TI concepts and 22 OI concepts. We asked companies whether they use specific innovation concept and if they upgraded it in past three years. Table 1 presents the level of use of TI concepts and their upgrade in Slovenian manufacturing companies. As we can see the most widely used TI concept are industrial robots which are used in more than half of manufacturing companies (share of 55.06 %). Other technologies are present in less than half of manufacturing companies.

On average, the highest technology use frequency is found in information and communication technologies, so called ICT support for the production processes. The most widely concept used in this group is computer exchange of information on time schedules with suppliers and customers. This concept is used in nearly half of manufacturing companies included in the survey (49.4 %). We also observed that more than a third of Slovenian manufacturing companies use software that enables the simulation of product development and production process (36 %). Slovenian manufacturing companies are increasingly realizing the importance of efficient management of resources and energy. The analysis shows that around a quarter of companies use the technology of efficient use of energy and resources, especially are forefront technologies for recapitulation of kinetic energy and process technologies to generate power. Lower on the table are companies that use nanotechnology manufacturing process or and production of micro-mechanical components and technologies in the field of nanotechnology (with less than 5 % share of use). At the bottom are companies that use technology for the production of micro-mechanical components (1.1 % share of use).

Table 1 Use of technical innovation

Technology	Share [%]	Rang	Share of upgrades [%]
Robots and automation systems			
industrial robots	55.1	1	71.4
automated warehouse management	16.9	9	60.0
collaborative robots (man-machine)	7.9	15	
intuitive software methods	4.5	16	
Process and manufacturing technologies			
technology for the processing of alloys	15.7	10	64.3
technology for the processing of composites	3.4	18	
technology for the manufacture of micro mechanical components	1.1	19	
production processes in nanotechnology	4.5	17	
Digital factory / IT connection			
computer data exchange with suppliers	49.4	2	61.4
virtual reality in production	21.3	8	52.6
virtual reality in product design	36.0	3	65.6
PLM	13.5	13	
IT systems for management ideas	25.8	5	65.5
Efficient use of energy and resources			
dry manufacture	14.6	11	
control systems to stop at light load	22.5	6	55.0
recapitulation of kinetic and process energy	31.5	4	32.1
dual- and three-generation	9.0	14	
The effectiveness of generating renewable energy			
technology for generating power	22.5	7	45.0
technologies for generating heat	14.6	12	

In terms of upgrading the TI concepts since 2009, we took into account that the use of each TI concept must be at least 15 %. This means that we excluded from further analysis those concepts that are used in less than 15 % of companies. The analysis showed that on average more than 50 % of companies upgraded previously installed technologies in their production in the last three years (from 2009 until 2012). The biggest share of upgrading can be seen in the field of industrial robots (71.4 %), followed by virtual reality in product design and management of ideas (65.6 %). Technologies for energy efficiency and technologies for generating renewable energy were upgraded in less than 50 % of cases. These technologies require higher financial investments and are quite young, therefore a lower share of upgrading is not surprising.

Share of OI concepts use in Slovenian manufacturing companies is presented in Table 2. As we can see among the top 10 most frequently used OI concepts all five concepts from the group "work organisation" are ranked among them and only one concept from the group "standardization and assessment" is in top 10 (use of quality standard ISO 9000). Teamwork in production and assembly is considered as the most widespread method of organising work, since more than 78 % of Slovenian manufacturing companies are using it. Teamwork is followed by the quality management ISO 9001 concept, present in more than 77 % of the companies. The same applies to the standardization of manual work in production. There are two more OI concepts that are represented in more than half of Slovenian manufacturing companies, namely the 5S concept (52.81 %) from the group "work organisation" and training to enhance creativity (52.81 %) from the group "management of human resources". The other OI concepts are implemented in less than 50 % of Slovenian manufacturing companies.

We have asked the companies, which OI concepts are they planning to implement in their systems in the period from 2012 until 2015. Most companies (10.1 %) plan to introduce TQM (total quality assurance methods) by 2015. This is followed by a program of staff development (9 %), while share of use of other OI concepts is below 6 %. It is obvious that the implementation of any OI is a very complex project, therefore the share of companies that are planning to introduce any of the proposed OI concepts is very low. It is also a fact that none of the proposed OI concepts is applicable to all companies (size, production type).

Fig. 1 depicts the level of use of the 10 most used technologies. Companies estimated the degree of use as low (first contact with the concept), medium (partial use of the concept) and high use (full application of the concept, for OI concepts at least 70 % of employees involved). If we classify technologies according to the share of high use, we can observe that the order of technologies is quite different. Process technologies for the processing of alloys and technologies for generating power have been, according to the use frequency, on the 10^{th} and 7^{th} place, but they are the in top two places among companies in terms of high utilisation of their potential.

Table 2 Use of organisational innovation

Organizational concepts	Share [%]	Rang	Share of use till 2015 [%]
Organization of production			
value stream mapping	13.5	19	10.1
customer-oriented cell / line	28.1	11	3.4
zero stock principle	27.0	12	7.9
SMED	19.1	14	4.5
TPM	49.4	6	5.6
TQM	40.4	8	10.1
Organization of work			
5S	52.8	4	5.6
standardized work instructions	77.5	2	3.4
integration tasks	40.4	8	3.4
methods for continuous improvement of processes	43.8	7	3.4
teamwork in production and assembly	78.7	1	2.2
Standardisation and assessment			
visual display of the process and status of equipment	25.8	13	4.5
ISO 9000 and other	77.5	2	4.5
6 Sigma	14.6	18	6.7
ISO 14001	16.9	17	9.0
ISO 50001: 2011	2.2	21	6.7
TCO	5.6	20	7.9
Management of human resources			
formalized workshops to generate ideas	34.8	11	4.5
instruments for retention of knowledge in the enterprise	18.0	15	9.0
part-time dedicated to creativity	18.0	15	5.6
program of staff development	39.3	10	9.0
training to enhance creativity	52.8	4	5.6

Share of high use for all other technologies is below 50 %. At the bottom of the table with 5.3 % is the technology of virtual reality in production. The prevailing opinion of companies is that they use technologies not to their full potential (medium level of use).

Fig. 2 shows the level of use of the ten most widely used OI concepts. The analysis shows that only ISO 9000 concept is highly used in more than 50 % of the manufacturing companies. Only one tenth of the companies considered use of ISO 9000 concept as low. The share of all other highly used concepts in companies is less than 50 %. The lowest shares of the highly used concepts are linked to the management of human resources (staff development programs 22.9 % and training of employees 12.8 %), which is quite concerning.

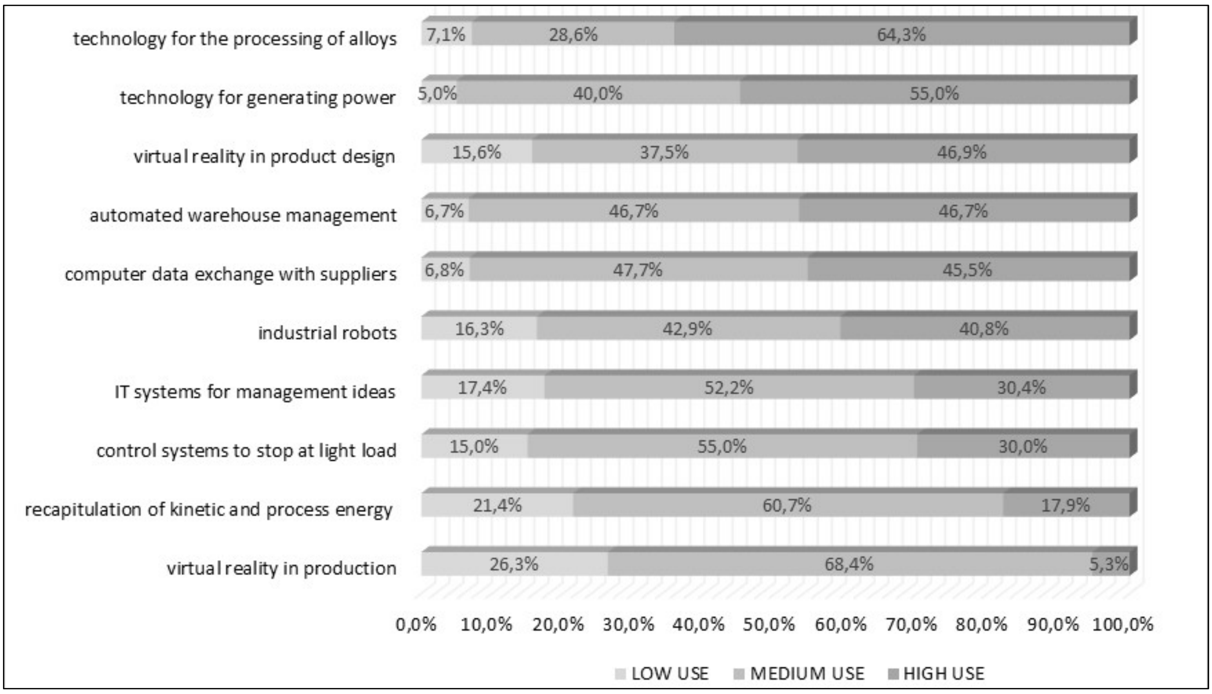

Fig. 1 Rate of use of the ten most commonly used technologies

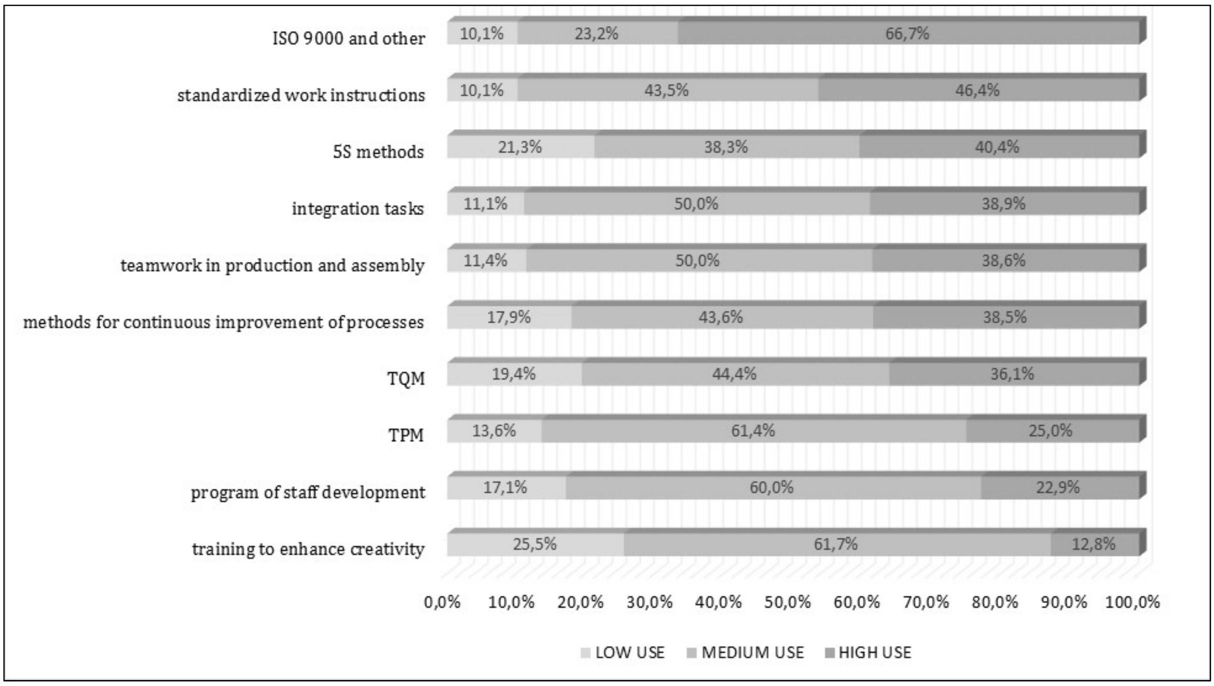

Fig. 2 Rate of use of the ten most commonly used organisational concepts

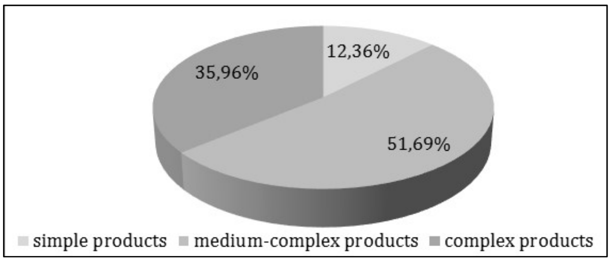

Fig. 3 Product characteristic

Fig. 3 shows product's characteristics manufactured by Slovenian manufacturing companies in terms of product complexity. This estimation is a bit subjective, but shows relatively real situation. The results of the analysis of the product complexity show that majority of companies (around 52 %) manufactures medium-complex products (e.g., pumps, several parts and technologies used, simple assembly). A little over a third of companies (35.96 %) produces complex products (machines or manufacturing systems). The remaining companies produce simple products.

Table 3 depicts impact of the number of introduced TI and OI on the complexity of the products. Companies are divided based on the number of used TI and OI concepts. Besides product complexity we have also included production type (make-to-order, assembly-to-order, make-to-stock). The results depict that more than half of the companies have introduced 1-3 proposed TI concepts, 31 % of companies have introduced 4-6 TI concepts, share of companies that have introduced 7 or more TI is around 18 %. We can observe that by increasing the number of introduced TI concepts the share of simple products is decreasing, while the share of complex products is increasing. Companies that have introduced more than 7 TI concepts no longer produce simple products. In those companies the share of complex products increased to almost 50 %. The results show that regardless of the number of TI concepts introduced, the prevailing product complexity type is medium-complex product (always share above 50 %). The prevailing production type is make-to-order production, and that is the only production type for companies with more than 9 TI concepts implemented. Another very important observation is that with the increase of installed technologies the share of companies that have introduced new product to the market in the past three years also increases.

We can see a slightly different picture when we look at the results of introduced OI concepts (Table 4). Less than a half of companies have introduced at least 6 OI concepts, around two thirds of the companies uses up to 9 OI concepts. The distribution of OI concepts used is quite equal in all five groups based on the number of OI concepts used. We can see that by increasing the number of introduced OI concepts, share of simple products is again decreasing, while by increasing the number of OI concepts used the share of complex products is increasing. In companies that use up to 9 OI concepts the share of complex products is around 30 %, the share of complex products in companies that use more than 9 OI concepts rises over 40 %. Production type does not depend on the number of OI used, especially considering the most frequent make-to-order production type. In general we can make very similar observation as with TI concepts: more OI concepts implemented increases the share of companies that have introduced new product to the market in the past three years.

Table 3 Product characteristic depending on the number of TI

Product characteristic					Type of production			
No. of TI	Share of companies [%]	Simple [%]	Medium complex [%]	Complex [%]	Make to order [%]	Assembly to order [%]	Make to stock [%]	Share of new products [%]
n=1-3	50.7	18.4	55.3	26.3	76.3	15.8	7.9	52.6
n=4-6	31.0	4.2	58.3	37.5	75.0	25.0	0.0	75.0
n=7-9	9.3	0.0	57.1	42.9	57.1	14.3	28.6	71.4
n=10-12	6.3	0.0	50.0	50.0	100.0	0.0	0.0	100.0
n ≥ 13	2.7	0.0	100.0	0.0	100.0	0.0	0.0	100.0

Table 4 Product characteristic depending on the number of OI

No. of OI	Share of companies [%]	Simple [%]	Medium complex [%]	Complex [%]	Make to order [%]	Assembly to order [%]	Make to stock [%]	Share of new products [%]
	Product characteristic				Type of production			
n=1-3	20.7	27.8	38.9	33.3	83.3	11.1	5.6	55.6
n=4-6	24.1	19.0	52.4	28.6	81.0	14.3	4.8	38.1
n=7-9	23.0	10.0	60.0	30.0	70.0	25.0	5.0	65.0
n=10-12	18.4	0.0	56.3	43.8	81.3	18.8	0.0	81.3
n ≥ 13	13.8	0.0	58.3	41.7	83.3	0.0	16.7	78.6

Table 5 shows the product characteristics in terms of complexity based on the use of selected technologies. We selected 10 technologies with the highest frequency of use (see Table 1). Companies who use any of these 10 technologies have lower share of simple products manufactured comparing to average share of simple products in all analysed companies (12.36 %). On the other hand the share of medium-complex products increased for all 10 of the analysed technologies and companies that use them (51.69 %). Industrial robots have the highest share of use in companies. It was interesting to find out that the share of complex products in companies with industrial robots installed is quite below average, meaning that industrial robots are mostly used to manufacture medium-complex products. IT systems for management of ideas is a technology installed in companies that do not manufacture simple products and where the share of complex products is the highest (almost 50 %).

Table 5 Product characteristic in relation to the level of use of the 10 most used technologies

No.	Top 10 technologies	Share of use in companies [%]	Products: Simple [%]	Medium complex [%]	Complex [%]
1	industrial robots	55.1	10.2	63.3	26.5
2	computer data exchange with suppliers	49.9	9.1	56.8	34.1
3	virtual reality in product design	36.0	3.1	62.5	34.4
4	recapitulation of kinetic and process	31.5	5.0	65.0	30.0
5	IT systems for management ideas	25.8	0.0	52.2	47.8
6	technology for generating power	22.5	5.0	65.0	30.0
7	control systems to stop at light load	22.5	5.0	65.0	30.0
8	virtual reality in production	21.3	5.3	57.9	36.8
9	automated warehouse management	16.9	0.0	60.0	40.0
10	technology for the processing of alloys	15.7	0.0	71.4	28.6

We also analysed if high use of technology affects product complexity. If we compare product characteristics according to the share of the general use of TI concepts and share of high use of 10 most frequently used technologies, we can see that the average share of simple products with a high use of technologies increased by 3.9 %, the share of medium-complex products fell by 6.8 % the share of complex products increased by 2.9 % (Table 6).

Table 6 Product characteristic in relation to the high level of use of the 10 most used technologies

No.	Top 10 technologies	Share of high use [%]	Products: Simple [%]	Medium complex [%]	Complex [%]
1	technology for the processing of alloys	64.3	0.0	66.7	33.3
2	technology for generating power	55.0	9.0	45.5	45.5
3	virtual reality in product design	46.9	6.7	40.0	53.3
4	automated warehouse management	46.7	0.0	33.3	66.7
5	computer data exchange with suppliers	45.5	10.5	57.9	31.6
6	industrial robots	40.8	5.0	65.0	30.0
7	IT systems for management ideas	30.4	0.0	42.9	57.1
8	control systems to stop at light load	30.0	16.7	33.3	50.0
9	recapitulation of kinetic and process	17.9	33.3	66.7	0.0
10	virtual reality in production	5.3	0.0	100.0	0.0

We have to point out that this data can be a bit misleading as the sample of companies for some technologies becomes quite low. Therefore, we are commenting some of the technologies separately. High use of mostly widely used technologies (industrial robots and computer data exchange with suppliers) does not change the distribution of product complexity. It is different for the third most widely used technology – virtual reality in product design – where with the high use of this software the share of complex products increases to over 50 % of companies. This might lead to conclusion that the companies that use computer software for product design to its full potential are more capable to design and manufacture complex.

Similarly, we analysed the products complexity in 10 most widely used OI concepts. Table 7 shows the product characteristics based on the share of overall use of selected OI concepts. We can see that the average share of complex products has increased to 41.5 %, the share of medium-complex products is still around 51 %, while the share of simple products decreased to 7 %.

With all ten selected OI concepts the share of complex products is higher than average - 36 %. This could mean that the companies that have implemented proposed OI concepts are more prepared and capable to manufacture complex products. On the other hand investing in new OI concepts could also mean that these manufacturing companies are trying to exclude manufacturing of simple products and focus more on products with higher value added.

If the OI concepts are classified according to the share of high use, we can observe that the order of concepts has been mixed up (Table 8). If we compare product complexity according to the share of general use of OI and share of high use of the 10 most used OI, we can see that the average share of simple products with the high share of use of OI has decreased by 3.4 %, the share of medium-complex products has decreased by 6.2 %, while the share of complex products increased by 9.5 %. Based on that we can conclude that the high use of selected OI concepts has even stronger impact on the ability for companies to manufacture complex products. Looking at specific OI concepts we can point out several things. OI concepts program of staff development and training to enhance creativity have the lowest share of high use, but on the other hand, we can see that the share of complex products in companies with the high use of these two OI concepts is extremely high.

Table 7 Product characteristic in relation to the level of use of the 10 most used organisational concepts

No.	Top 10 organisational concepts	Share of use in companies [%]	Products		
			Simple [%]	Medium complex [%]	Complex [%]
1	teamwork in production and assembly	78.7	10.4	46.3	43.3
2	standardized work instructions	77.5	10.3	52.9	36.8
3	ISO 9000 and other	77.5	9.2	52.3	38.5
4	5S	52.8	10.6	44.7	44.7
5	training to enhance creativity	52.8	9.1	50.0	40.9
6	TPM	49.4	6.8	50.0	43.2
7	continuous improvement of processes	43.8	0.0	64.1	35.9
8	TQM	40.5	5.6	52.7	41.7
9	integration tasks	40.5	5.6	41.6	52.8
10	program of staff development	39.3	5.7	57.1	37.2

Table 8 Product characteristic in relation to the high level of use of the 10 most used organisational concepts

No.	Top 10 organisational concepts	Share of high use [%]	Products		
			Simple [%]	Medium complex [%]	Complex [%]
1	ISO 9000 and other	66.7	8.7	52.2	39.1
2	standardized work instructions	46.4	9.4	59.3	31.3
3	5S	40.4	10.5	47.4	42.1
4	integration tasks	38.9	0.0	35.7	64.3
5	teamwork in production and assembly	38.6	11.1	40.7	48.2
6	continuous improvement of processes	38.5	0.0	53.3	46.7
7	TQM	36.1	0.0	61.5	38.5
8	TPM	25.0	0.0	45.5	54.5
9	program of staff development	22.9	0.0	37.5	62.5
10	training to enhance creativity	12.8	0.0	16.7	83.3

We can observe something similar for integration of tasks. This means that implementation of HRM concepts and specific forms of organising people in production (teamwork and integration of work) have a huge impact on companies' abilities to manufacture complex products. We can also see that within high use of six selected OI concepts companies do not produce simple products. This goes in line with the conclusion of general use of OI concepts.

Table 9 presents where companies get impulse for innovation from. We analysed the internal and external resources according to the three areas of innovation (new products, new technical production process and the new organisational concepts). Internal sources for innovation impulse are R&D department, production, sales department (contact with customers) and CEO. External sources for innovation impulse are customer-users, suppliers, research institutions and universities, conference-fairs.

If we focus on internal resources, we see that most impulses for innovation in the field of new product development come from sales (62.9 %) and the least from the production (7.9 %).Most impulses in the field of technical production process come from production (82 %) and the least from sales department (2.3 %). In the field of new OI concepts more than 60 % of the ideas come from CEO and the least from sales (10.1 %). The share of R&D does not exceed 50 % for any of three analysed areas.

If we look at external sources, we see that in the field of new product development, the highest share of ideas for innovation comes from customers (61.8 %) and least from research institutions and universities (6.7 %). In the field of new technical production process, the highest share of impulse for innovation comes from the suppliers (23.6 %), and the least from research institutions. In the area of innovation of new OI concepts, the largest share of ideas for innovation companies pick at conferences and trade shows (15.7 %). We can see that external sources are quite scarce for new technical production processes and OI concepts.

Table 10 depicts the impact of resources to innovate on the complexity of the products. We have chosen four internal resources (R&D, production, sales, CEO) and four external sources (customer-users, suppliers, research institute, conference-fairs). If we focus on internal resources, we can see that R&D, as an internal source, gives the highest share of impulse for medium complex products (60.6 %). The largest share of ideas for complex products comes from CEO`s (40.6 %). Looking at external sources, we see that the largest share of impulses for complex products comes from conferences and fairs (37 %). The largest share of impulses for medium complex products comes from research institutes and universities. To sum up, we did not find any significant relationship between product complexity and the impulses for product innovation. The only exceptions are perhaps research institutes and universities, and conferences and fairs, where companies do not look for ideas for simple products.

Table 9 Sources of innovation

Internal sources				
Field of innovations	R&D [%]	Production [%]	Sales department [%]	CEO [%]
New products	43.8	7.9	62.9	18.0
New technical production process	46.1	82.0	2.3	16.9
The new organizational concepts	14.6	24.7	10.1	61.8
External sources				
Field of innovations	Buyer/user [%]	Suppliers [%]	Research institutions [%]	Conferences, fairs [%]
New products	61.8	10.1	6.7	11.2
New technical production process	14.6	23.6	5.6	18.0
The new organizational concepts	7.9	4.5	9.0	15.7

Table 10 Impact of resources to innovate on the complexity of the product

	Complexity of products				Complexity of products		
Internal sources	Simple [%]	Medium complex [%]	Complex [%]	External soucses	Simple [%]	Medium complex [%]	Complex [%]
R&D	5.3	60.6	34.0	Buyer/user	12.3	54.4	33.3
Production	10.9	51.8	37.3	supplier	11.1	64.4	24.4
Sales department	10.8	52.9	36.3	Research, university	0.0	70.0	30.0
Top management	9.4	50.0	40.6	Conferences, fairs	0.0	63.0	37.0

5. Conclusion

The paper deals with issues relating to the prevalence and use of TI and OI concepts in Slovenian manufacturing industry, product complexity and sources of innovation. The purpose of the paper is to determine the use of TI and OI concepts of manufacturing companies and to analyse how they affect the characteristics of the product. According to the researchers Camisón and Villar-López this area is not studied enough [7], so the present paper contributes to research in this area. The results show that companies that have introduced specific technologies are continuously upgrading their performance. Unfortunately, majority of companies admits that they are not fully utilising these technologies up to their potential. Something similar can be observed for the high use of OI concepts. This means that manufacturing companies have a lot of room to improve their performance. Analysis of the impact of use of technical and OI concepts showed that general and high use of 10 most used innovation concepts has a positive impact on increasing complexity of products. We can observe that by increasing the number of introduced TI and OI concepts the share of simple products is decreasing, while the share of complex products is increasing. The high use of selected OI concepts has even stronger impact on the ability for companies to manufacture complex products. It is also a fact that with higher number of TI and OI concepts implemented the share of companies that have introduced new product to the market in the past three years also increases.

Our research results are unique since we found no studies that examine the relationship between the use of specific TI and OI concepts, product complexity and the ability to introduce new products to the market. Future research in this area will focus on finding correlations between innovation sources and product complexity. With new findings companies would have more data how to improve their chance for success.

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