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Analysis of Innovation Concepts in Slovenian Manufacturing Companies

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Competitive advantages of manufacturing companies are not only generated by R&D based product innovations, but also by technical and non-technical process innovations aiming to modernise manufacturing processes. This paper presents the use of selected innovation concepts in Slovenian manufacturing companies. Later we analyse the relationship of the use of selected technical and organisational innovation concepts and companies' performance indicators. The results show that R&D expenses and innovation concepts are not always correlated and that there is a difference in utilising innovation concepts between low, medium and high-tech industries. The data were obtained with The European Manufacturing Survey (EMS) that was conducted in 2009 within nine European countries. For the purpose of this paper the data of Slovenian manufacturing companies have been used.

Keywords: innovation, technical innovation, organisational innovation, company performance

0 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 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" [3].

Referring to many innovation researchers [4] to [6], innovation can be considered 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). Based on these considerations, there are four different types of innovations: technical product innovations, non-technical service innovations, technical process innovations, and non-technical process innovations, which are understood to be organizational innovations [7].

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 [8]. A technical innovation, therefore, can be an 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 [9] to [13].

The first three groups of innovation (technical product innovations, non-technical service innovations, technical process innovations) have been the subject of many studies. On the other hand, there have been little conceptual and methodological contributions to monitoring of organisational innovation so far [1].

This paper deals with analysis of technical and organisational innovation concepts in Slovenian manufacturing companies. We will present the use of selected innovation concepts in Slovenian manufacturing companies and their change in the last decade. Innovation in manufacturing companies is always related with the amount of money companies spend for R&D activities, so we will examine how the use of selected innovation concepts is related to R&D expenses. On the other hand, we will find out if the level of using technical innovation concept is interrelated with the use of level of organisational innovation concepts. Finally, we will form two groups of manufacturing companies based on the OECD classification for low, medium and high

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tech industries. The research question is the level of use of selected innovation concepts and the main reasons for implementing the innovation concept in question.

1 DESCRIPTION OF SELECTED INNOVATION CONCEPTS

First, two technical innovation concepts that are widely used in manufacturing companies around Europe, and were of great interest for our research are presented. **CAD/CAM** software provides the interface between the human user and the CNC machine. These machines are programmed with the required tool trajectory using a special command set called G-codes. These G-codes are a de facto standard in the CNC machine industry. G-code programs can be written manually for simple parts. However, in most cases CAM software is used to produce G-code programs directly from CAD models. A CAM package typically produces a G-code program in two stages. First, tool paths consisting of generic cutter locations (CLDATA) are generated. The CLDATA consists of a list of tool positions in the workpiece coordinate system. The cutter locations must then be converted into G-code programs using a post-processor specific to the NC machines that will produce the part. CAD/CAM process has four phases. First of all, the product should be designed taking into consideration its applications. After designing the product, assembly drawings and parts drawings of the product have to be made. These drawings are used for the reference purposes and more importantly for manufacturing the product on production shop floor. The drawings are also made by using CAD software. The production planning and scheduling of the designed product can be carried out by computers, which helps managing the manufacturing resources properly. The latter is the CAM part of the product cycle, while the last phase is manufacturing the product, where nowadays the use of CNC machines has become quite widespread. In CNC machines, the programming instructions for the manufacturing of the product that has been designed using the CAD software, are fed. The program gives appropriate instructions to the machine control to carry out the manufacturing of the product.

Automated handling devices can be 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. Non-automated, manual handling devices are called manipulators and are not an integral part of our definition. **Industrial robots** (IR) are a specific class of automated handling devices. An industrial robot is officially defined by ISO 8373:1994 as an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes. Typical applications of industrial robots include welding, painting, ironing, assembly, pick and place, palletizing, product inspection, and testing. In this paper, the term industrial robots or IR, always implicitly including automated handling devices in our understanding is used.

The origin of industrial robots can be found in reactor technology, where automated instead of manual handling devices have been used at an early stage within radioactive rooms. First industrial applications of IR in Europe have taken place in the early 1970s. From the mid 1980s to 2000 the adoption rate of industrial robots rose from about 3% to about 22%, still representing only a minority of industrial companies in Europe [14].

As mentioned above, organisational innovation concepts did not receive as much attention in the literature as other concepts. Existing literature on organisational innovation is diverse and scattered. There is no consensus on a definition of the term "organisational innovation", which remains ambiguous [15]. [16] defines it as the use of new managerial and working concepts and practices. When speaking about organisational innovation, Damanpour and Evan [5] consider them to be responses to environmental change or means of bringing change to an organisation. Organisations can cope with environmental changes and uncertainties not only by applying new technologies, but also by successfully integrating technical or administrative changes into their organisational structure thereby improving the level of achievement of their goals [17]. Innovations at the organisational level may involve implementation of a new technical idea or a new administrative idea. The adoption of a new idea in an organisation, regardless of the time of its adoption in the related organisation population, is expected to result in an organisational change that might affect the performance of that organisation. Therefore, an idea is considered new in relation to the adopting organisation, not in relation to its organisational population [16].

Armbruster et al. [7] prepared a classification of organisational innovation. There are several ways of differentiating organisational innovation. The first possibility is into structural organisational innovations and procedural organisational innovations. Structural organisational innovations influence, change and improve responsibilities, accountability, command lines and information flows as well as the number of hierarchical levels, the divisional structure of functions (R&D, production, human resources, financing, etc.), or the separation between line and support functions. Procedural organisational innovations affect a company's processes and operations. Thus, these innovations change or implement new procedures and processes within the company, such as simultaneous engineering or zero buffer rules. Organisational innovation can be further differentiated along an intra-organisational and inter-organisational dimension. While intra-organisational innovations occur within an organisation or a company, inter-organisational innovations include new organisational structures or procedures beyond a company's boundaries. These comprise new organisational structures in an organisation's environment, such as R&D cooperation with customers, just-in-time processes with suppliers or customers, supply chain management practices with suppliers or customer quality audits. Intra-organisational innovations may concern particular departments or functions or may affect the overall structure and strategy of the company as a whole. Examples of intra-organisational innovations include the implementation of teamwork, quality circles, continuous improvement processes, certification of a company under ISO 9000, simultaneous (concurrent) engineering, zero-buffer principles, environmental audits and cross-functional teams [7].

Lean production comprises an integrated variety of new organizational concepts such as teamwork, job enrichment and enlargement, decentralization of planning, operating and controlling functions, manufacturing cells, quality circles, continuous improvements (kanban), simultaneous engineering and just-in-time delivery, which was found to be the main cause of the superiority of the Japanese car industry at this time [18] to [23].

		Focus of organisational innovation	
		Intra-organisational	**Inter-organisational**
Type of organisational innovation	**Structural innovation**	• Cross-functional teams • Decentralisation of planning, operating and controlling functions • Manufacturing cells or segments • Reduction of hierarchical levels, etc.	• Cooperation / networks / alliances (R&D, production, service, sales), • Make or buy / outsourcing • Offshoring / relocation, etc.
	Procedural innovation	• Teamwork in production • Job enrichment / job enlargement • Simultaneous engineering / concurrent engineering • Continuous improvement process / Kaizen • Quality circles • Quality audits / certification (ISO) • Environmental audits (ISO) • Zero-buffer principles (KANBAN) • Preventive maintenance, etc.	• "Just-in-time" (to customers, with suppliers) • Single / dual sourcing • Supply chain management • Customer quality audits, etc.

Fig. 1. *An item-oriented typology of organisational innovations [7]*

One of the organisational innovation concepts that we will look into is a teamwork in production. Since the 1990s **teamwork** has been intensely discussed as an important element of a lean factory. It is argued that, contrary to the tayloristic way of production, the implementation of teamwork into the production process increases product and process flexibility along with productivity [18]. Teamworkers have a high variety of skills allowing for job rotation within the team, so that they can fill in for one another. The enlargement of skills and responsibilities as well as the cooperation with other workers is supposed to have a positive impact on workers' job satisfaction and task commitment, which in turn positively supports the team's productivity [14].

The other interesting concept is zero buffer principle or "kanban"; a concept related to lean and just-in-time (JIT) production. Kanban is a signalling system to trigger action. As its name suggests, kanban historically uses cards to signal the need for an item. Kanban became an effective tool to support the running of the production system as a whole. In addition, it proved to be an excellent way for promoting improvements because reducing the number of kanban in circulation highlighted problem areas. We focused on inventory management. Kanban is used as a demand signal which immediately propagates through the supply chain. This can be used to ensure that intermediate stocks held in the supply chain are better managed, and usually smaller.

2 RESEARCH METHODOLOGY

Presented data on technical and organisational issues is the result of European Manufacturing Survey (EMS). EMS was first conducted in 2003/2004 as a pilot survey in nine European countries: Austria, Croatia, France, Germany, Great Britain, Italy, Slovenia, Switzerland and Turkey. In total, 2249 companies answered questions concerning manufacturing strategies, the application of innovative organisational and technological concepts in production and questions of personnel deployment and qualification. In addition, data on performance indicators such as productivity, flexibility, quality and returns was collected. The responding companies present a cross-section of the main manufacturing industries, such as producers of rubber and plastics, producers of metal works, mechanical engineering, electrical engineering and textile. In the year 2006 a new survey was conducted in some other European countries when Greece, Netherlands and Spain joined the project. The third round was performed in 2009 and 2010. We received around 4000 responses from European manufacturing companies. The Slovenian sample consists of 67 responses with a 10.1% response rate.

Descriptive statistics is used to depict the state of the use of organisational and technical innovation concepts in Slovenian manufacturing companies. Later we use several correlation coefficients and statistical tests to analyse the relationship between the level of using selected innovation concepts and companies' performance indicators.

3 THE USE OF INNOVATION CONCEPTS

First, the level of use of specific technical and organisational innovation concepts in Slovenian manufacturing companies is presented. Our research included 13 technical innovation concepts and 15 organisational innovation concepts. We asked companies if they use specific innovation concepts. The first results depict the percentage of manufacturing companies that use specific innovation concepts.

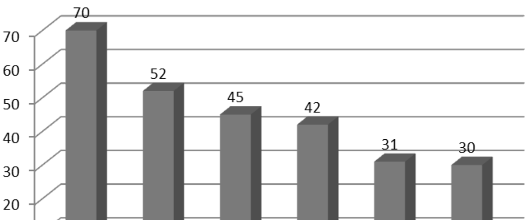

Fig. 2. *The use of technical innovation in percentage of companies*

Fig. 2 presents six technical innovation concepts that are most widely used in Slovenian manufacturing companies. It can be seen that the most widely used concept is classical integration of CAD-CAM technologies. Industrial robots are used in more than half of manufacturing companies. Other relatively widely used concepts are process integrated quality control (PIQC), digital exchange of operation scheduling data with supply chain management systems of suppliers/customers (SCM), Manufacturing Execution System as an integration of PPS/ERP with production data logging (MES) and virtual reality and/or simulation in product development and/or manufacturing (VR).

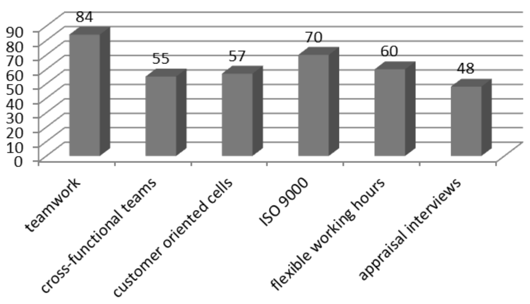

Fig. 3. *The use of organisational innovation in percentage of companies*

Fig. 3 presents the use of six most used organisational innovation concepts in Slovenian manufacturing companies. Teamwork in production and ISO 9000 quality management systems are the two most widely used concepts. Other concepts are used in approximately half of manufacturing companies. We were also interested in the zero buffer principle. The research has showed that these concepts are used by every fourth manufacturing company.

EMS 2009 is the third survey conducted in the last decade. Through the years we have observed the level of use of specific innovation concepts and its changes. We have selected two technical (CAD-CAM integration and industrial robots) and two organisational (zero buffer principle and teamwork in production) innovation concepts. It can be see that the use of both technical innovation concepts has been rising through the years. In 2003 only half of manufacturing companies used CAD-CAM integration. In little over five years this number has risen to an extent that three out of four companies now use this concept. The change is even bigger with industrial robots. The percentage of companies that use industrial robots and handling systems in manufacturing and assembly has doubled from 2003. This clearly proves that Slovenian manufacturing companies heavily invested in manufacturing equipment and technology in the last decade. Teamwork in production has been at a high level throughout the years. A little more interesting is the use of zero buffer principles, whether it is kanban or the JIT principle. The use of these concepts reached its peak in 2006, where a third of companies used one of these concepts. However, in the last three years the level dropped down to one fourth of companies. This could mean different things. Slovenian manufacturing companies are not aware of the problems associated with inventory management and they do not pay enough attention to process reengineering issues within their companies or in the whole supply chain. Another explanation could be that as the majority of Slovenian manufacturing companies are suppliers to different industries they cannot afford to have problems with supplying their goods. This fact forces them to keep inventory level higher with no possibility to reduce it to a minimum (zero) level.

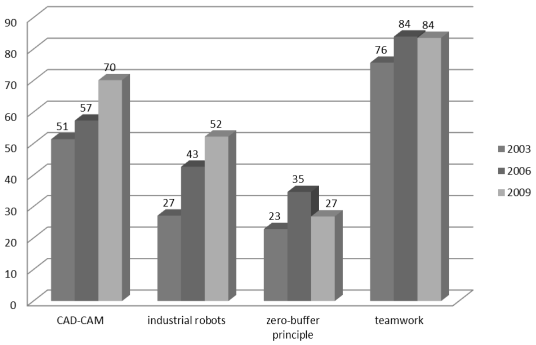

Fig. 4. *The use of innovation concepts from 2003 until 2009 in Slovenian manufacturing companies in percentage of companies*

4 ANALYSIS AND DISCUSSION OF INNOVATION CONCEPTS

As mentioned above, the innovation activity is related to the amount of money companies spend on R&D activities. We measured R&D expenses as a share of companies' annual turnover. Based on previous research, we assumed that the number of technical and organisational innovation concepts used, is directly correlated with the amount of R&D expenses. Therefore, we calculated correlation coefficients for two situations. First, we wanted to establish if the total number of technical innovation used is related with the amount of

R&D expenses. We used the Pearson's correlation coefficient calculation. From 67 responses we included 60 with a complete data on innovation concepts used and amount of R&D expenses. Table 1 presents the results.

Table 1. *Correlation between technical innovation and R&D expenses*

		R&D expenses
Number of technical innovation	Pearson Correlation	*.280
	Sig. (2-tailed)	.030
	N	60

*. Correlation is significant at the 0.05 level (2-tailed).

As predicted, there is a positive correlation between the number of technical innovation concepts used and R&D expenses, but it is slightly lower than expected. Nevertheless, it can be assumed that R&D expenses are associated with investment in equipment and R&D activities in companies and higher the R&D expenses are more technical innovation concepts are implemented.

Similarly, we assumed that the number of organisational innovation concepts is also positively correlated with R&D expenses. Again, 60 companies were included in the test with the following results:

Table 2. *Correlation between organisational innovation and R&D expenses*

		R&D expenses
Number of organisati. innovation	Pearson Correlation	.110
	Sig. (2-tailed)	.404
	N	60

It can be seen that there is no correlation between the number of organisational concepts used and R&D expenses. The significance value is over 0.05 (0.404), which means there is no significant relationship between the number of organisational concepts used and R&D expenses. The results prove that implementation of organisational innovation concepts does not necessarily influence the amount of R&D expenses in the company. It seems that organisational concepts cost a lot less than investments in technical innovation or they are not directly seen as innovation drivers. Furthermore, we found that many companies that do not spend any money on R&D activities or they spend a very small percentage of total turnover still implement a high number of organisational innovation concepts.

We performed another test to find out how the number of technical innovation concepts is related to the number of organisational innovation concepts. Based on previous two correlations we allowed positive and negative correlation for this test. The results are in Table 3.

Table 3. *Correlation between technical innovation and organisational innovation*

		No. of org. in.
Number of technical innovation	Pearson Correlation	**.541
	Sig. (2-tailed)	.000
	N	60

**. Correlation is significant at the 0.01 level (2-tailed).

It can be seen that there is a quite significant positive relationship between the number of technical and organisational concepts used (significance value is under 0.01). It can be concluded that the use of technical innovation concepts usually requires the use of organisational innovation concepts in order to utilise them at a higher level.

OECD classifies manufacturing industries into four categories: low-tech, medium-low-tech, medium-high-tech and high-tech. We split our sample into two groups, one being low and medium-low tech industries (LMT, including NACE-2003 17 to 19, 25 and 28) and medium-high and high-tech industries (MHT, including NACE-2003 29 to 32, 34 and 35). We wished to find out if these two groups differ in the use of specific innovation concepts. Table 4 presents the percentage of the use of selected technical innovation concepts.

Table 4. *The use of technical innovation concepts in LMT and MHT industries*

	CAD	robots	PIQC	SCM	MES	VR
LMT	62	41	41	49	26	26
MHT	82	68	50	32	39	36

It can be observed that the use of technical innovation concepts is higher in MHT industries. Obviously, they spend more money for R&D activities (2.86% of annual turnover in MHT and 2.21 in LMT) and these expenses, as already proven, are positively related to the use of these concepts. One of the exceptions is a digital exchange of operation scheduling data with supply chain management systems of suppliers/customers (SCM) that is widely used in LMT companies. It seems that these companies are mostly suppliers and are tightly connected to their buyers and heavily depend on their schedules. It should also be pointed out that the use of new material is three times higher in MHT than in LMT companies.

Table 5 present results for the use of organisational innovation concepts in LMT and MHT industries.

Table 5. *The use of organisational innovation concepts in LMT and MHT industries*

	team work	cross teams	custom. cells	ISO 9000	flex. hours	inter-views
LMT	82	51	46	72	59	46
MHT	86	61	71	68	61	50

The results show that organisational innovation concepts are more equally represented in both industries. A big exception is the use of customer or product-focussed lines/cells in the factory (instead of task-/operation-structured shop floor). It is clear that MHT companies are more customer-oriented than LMT ones. Zero buffer principles and total costs of ownership (assessment of investment and activities reflecting all costs of their entire product life cycle) as well as financial participation by employees eligible for all employee groups (e.g. profit sharing schemes, share (options) plans, etc.) are substantially higher in MHT companies.

Finally, we asked companies about the level of use of specific innovation concepts. In other words, we were enquiring about the extent of use potential as an actual utilisation compared to the most reasonable potential utilisation in your factory: “low” for an initial attempt to utilise, “medium” for partly utilised and “high” for extensive utilisation. At the same time, we asked about the main aim of innovation concept utilisation: an increase in quality (precision), increase in productivity, increase in flexibility or product innovation. For this purpose, we selected two most widely popular concepts: CAD-CAM integration and teamwork in production. Table 6 presents the results for companies in LMT and MHT industries. Values for utilisation level are 1, 2 and 3 (high utilisation), the table presents the average value of utilisation level. Other values present the percentage of companies that use CAD-CAM or teamwork for specific aim of innovation concept utilisation.

The utilisation level of both innovation concepts is very similar in both industries and it is very high. The companies that implemented them state that they are exploiting their potential fully. It is more interesting to observe the aim of utilisation. MTH companies implemented both concepts to improve quality and to increase flexibility, where LMT companies use them mainly to increase productivity (with the aim of decreasing production costs). The product innovation aim has quite lower values, which could again draw us to a conclusion that many innovation concepts are not really innovation-oriented.

Table 6. *The use of CAD-CAM and teamwork in LMT and MHT industries*

CAD-CAM	utilis. level	quality	produc tivity	flexi-bility	prod. innova.
LMT	2.58	58	50	21	25
MHT	2.70	65	39	35	17
weam work	utilis. level	quality	produc tivity	flexi-bility	prod. innova.
LMT	2.44	38	69	31	19
MHT	2.26	48	65	35	22

5 CONCLUSION

This paper deals with several issues, concerned with innovation patterns in Slovenian manufacturing companies. Its primary aim was to depict the state-of-the art of technical and organisational innovation concepts used. It has proved that the scope and the level of innovation concepts utilisation are not always correlated with R&D expenses. On the other hand, the use of one type of innovation concepts in most cases requires the utilisation of the other type as well. The paper has also showed that there is a difference in innovation concepts utilisation regarding the industry type based on distinction into low-, medium- and high-tech industries and provides new directions for future research.

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