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The use of innovative technology in production and its consequences

A German – Croatian cross-country comparison

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Abstract

It will be assumed that innovative process technologies are more intensively used by manufacturing companies from highly developed countries than from less developed ones. In this paper we will test this hypothesis by comparing manufacturing companies of Germany and Croatia.

We will present a cross-national comparison of the diffusion of selected technical process innovations such as Computer Aided Design and Manufacturing (CAD/CAM), Industrial Robots and Automated Handling Systems, Automated Machine Vision systems, Process Integrated Quality Control, etc. The presented results are based on the survey conducted in 2006 where 1280 German and 108 Croatian companies participated with a filled-in questionnaire. The results show that the intensity of use of the particular technology is less country specific and rather correlated with production features like complexity and batch size of the produced product.

Keywords: Innovative technology, Production, Germany, Croatia

1. Introduction

Globalization of markets, competitors and suppliers, increasing customer expectations, accelerating rates of technological change, and bourgeoning legislation are key challenges facing today's manufacturing companies. The acquisition of appropriate technologies to enable the development and manufacture of innovative products is of primary importance in gaining a competitive advantage (Gindey *et al.*, 2006, pp. 404). These technologies provide adopting firms with the potential to gain earlier entrance to market, respond more quickly to changed customer needs, and to offer higher quality products with improved consistency and reliability (Small, 2006, pp. 513).

In order to efficiently produce new and old products, companies need to have innovative technology. However, manufacturing technology is inevitably limited by financial constraints (Mann, 2002, pp. 86). One can then assume that a country like Croatia cannot as easily invest in innovative technologies as compared to more developed countries benefiting from economies of scale.

Lin *et al.* (2002, pp. 300) report that the acquisition of advanced manufacturing technologies has enabled Taiwanese companies to shift from traditional manufacturing to high-tech manufacturing and to survive in global competition.

So far we have only said that it is worthwhile investing in technology if one has the financial resources. What are those innovative technologies? In the next section we briefly introduce the innovative technology that we are investigating and explain the methodology used the cross-country comparison. We write from the Croatian standpoint and take German industry as a benchmark in order to see the differences in the use of innovative technologies and its consequences.

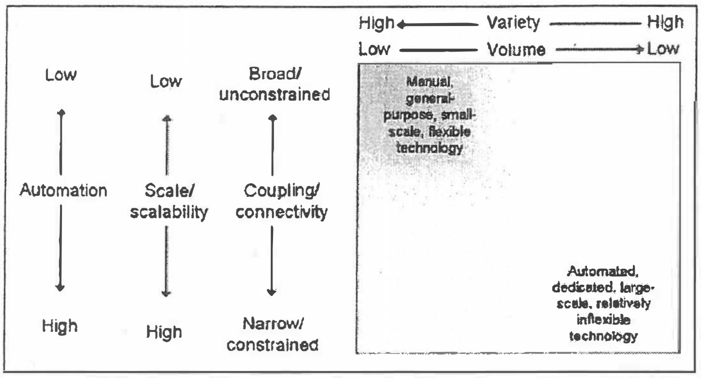
2. Manufacturing technology

What is considered as an innovative manufacturing technology? Such questions are usually posed in large-scale Delphi studies. In a recent Pan-European Delphi study (2004), several wide-use periods for following innovative manufacturing technologies were assessed; nano manufacturing (2020), manufacturing with living organisms (2018), micro-electromechanical systems (2013), rapid technologies (2015), use of intelligent controllers (2015), voice recognition in manufacturing (2017), cobots (2017), reconfigurable manufacturing systems (2015), process integration (2015) and high automation (2014). By the expert's prognosis, the first wider use of those technologies will start only after year 2013 with micro-electromechanical systems (MANVIS, 2005, pp.15). Advances in the mechanical sector, compared with the sectors mentioned above, are better in terms of time, coming into wider use by year 2010. Those advanced technologies are automatic CNC programming, virtual machine simulation, and NC software (MANVIS, 2005, pp.30).

A Delphi study conducted in the USA by TechCast.org (Halal, 2007, pp.384) lists following manufacturing concepts with the possible year of mainstream entrance: smart sensors (2011), mass customization (2013), nanotechnology (2018), smart robots (2020), and micro machines (2022).

Different process technologies will be appropriate for different parts of the volume-variety continuum. High-variety, low-volume processes usually require technology that is general purpose because it can perform a wide range of activities that high-variety production demands. High-volume, low-variety processes can use technology that is dedicated to a narrow range of processing requirements. Within the spectrum, from general purpose to dedicated process technologies, three dimensions in particular tend to vary with volume and variety. The first dimension of *automation* is the extent to which the process technology carries out activities and makes decisions for itself. The second, the *degree of scalability,* is the capacity of the technology to process work that is scale. The third, *degree of coupling/connectivity,* is the extent to which the technology is integrated with other technologies (Slack et al., 2007, pp. 239). These technologies and their characteristics are shown on Figure 1.

Figure 1: Different process technologies are appropriate for different volume–variety combinations



Source:

Slack N., Chambers S., Johnston R., (2007), Operations management, *FT Prentice Hall*, pp. 239

This paper focuses on the comparative analyses of the diffusion rates of selected technical concepts used in the discrete manufacturing industry. In particular, the following technical concepts were selected for analysis: Computer Aided Design (CAD), virtual reality and 3D simulations, Computer Aided Manufacturing (CAM), integration of CAD/CAM, materials handling systems and industrial robots, automated machine vision systems, process-integrated quality control, Enterprise Resource Planning systems (ERP),and supply chain management software (SCA).

CAD is an electronic system for designing new parts and products or for altering existing ones. It replaces drafting traditionally done by hand. At the heart of CAD is a powerful desktop computer and graphics software that allows the designer to manipulate geometric shapes. The designer can view drawings from various angles and simulate forces to test the qualities and strengh of the part. The drawings are easily printed, stored and retrieved, and can classify data (Krajewski and Ritzman, 2005, K2).

Computer integrated manufacturing (CIM) is an umbrella term for the total integration of product design and engineering, process planning, and manufacturing by means of a complex computer system. These systems usually integrate all phases of manufacturing, from the initial customer order to final shipments.

CAM systems are the parts of CIM that deal directly with manufacturing. These systems are used to design production processes and to control machine tools and material flow through programmable automation.

Thus the CAD/CAM integration system integrates the design and manufacturing function by translating final design specifications into detailed machine instructions for manufacturing an item. Such a system allows engineers to see how various design parts interact with each other without having to build a prototype (Krajewski and Ritzman, 2005, K3).

Industrial robots are versatile, computer-controlled machines programmed to perform various tasks. Most are stationary and mounted to the floor with an arm that can reach into difficult locations. Robots are also used for materials handling, spot welding, spray painting, assembly, inspection and testing. Second generation robots are equipped with sensors and have lead to new areas of usage such as picking fruits from trees. The cost of a robot depends on its size and its function (Krajewski and Ritzman, 2005, K5).

Materials handling systems are used for the processes of moving, packaging and storing a product. These processes cost time and add no value to the product. However, materials handling automation is expensive and is justifiable only for high-volume processes with high repeatability where handling can be automated (Krajewski and Ritzman, 2005, K5).

Automated machine vision systems have sensors, usually analog, that collect data to be read (for example every second) by an analog device that translates the data into digital signals. The digital data are then transmitted to a computer, printer, statistical process charts, and warning lights or horns,. This technology is mostly used for inspection, usually involves cameras, and is also referred to as process-integrated quality control (Heizer and Render, 2006, pp. 273).

Virtual reality and 3D simulations are used for rapid prototype testing and simulation of production process design. It is usually a software package that tests various process designs before the actual construction of the plant.

ERP systems are large software programs used for planning and coordinating all resources throughout the entire enterprise. They allow data sharing and communication within and outside the firm, enabling collaborative decision-making (Reid and Sanders, 2005, pp. 79).

Supply chain management software is usually an extension to ERP systems that enable collaboration with supply chain partners. This necessitates EDI connections with supply chain partners (Webster, 2008, pp. 89).

In this paper we will present a cross-national comparison of the diffusion rates in Croatia and Germany for the technical concepts mentioned above.

3. Methodology

The results presented in this paper are based on the data from the EMIS, run in two years intervals since 1995 by the Institute for Systems and Innovation Research (ISI) in Karlsruhe, Germany. The current results refer to the EMIS survey conducted 2006. Although the EMIS survey covers the whole manufacturing industry (NACEs 15-36), for the purpose of comparison, we selected only the sample of discrete manufacturing industries (NACEs 25, 27-36). These industries are similar in production process types, which enables us a more thorough analysis of differences.

1280 German and 59 Croatian discrete manufacturing companies participated in the survey with a fill-in questionnaire. A thorough analysis was done for checking the representativeness according to the methodology presented by Telhaj *et al.* (2004). The results were positive. Both the German and Croatian realized samples represent a cross-section of the discrete manufacturing industries in those countries.

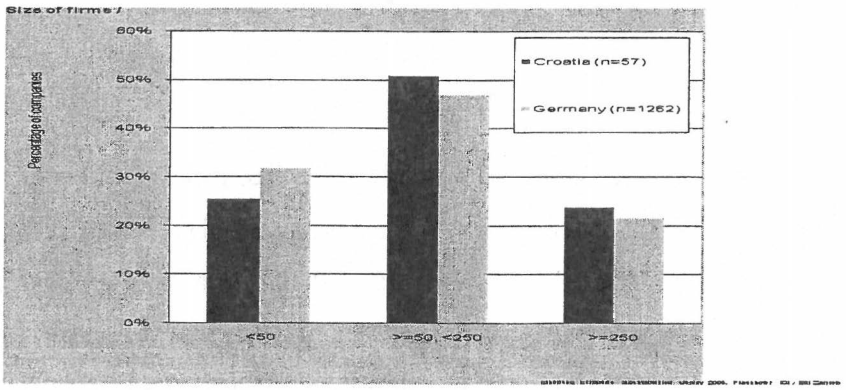
First we will present descriptive data that compares the two samples. We use descriptive statistics to show the main production characteristics of Croatian and German samples. We follow with hypothesis testing. The first hypothesis is that the Croatian and German samples do not differ in respect to the usage of technology. We will use Person's Chi-Quadrate test for testing proportions. The reason for positing this bold hypothesis is that Croatian companies would not survive in competitive environments if they had not adopted the latest technology.

Then we will look into the question of technology diffusion. More precisely, we will compare the year technology adoption in Germany and Croatia. We will test the differences of the mean year of adoption. It will become obvious that for some technologies, Croatian companies lag several years behind their German counterparts.

4. Results

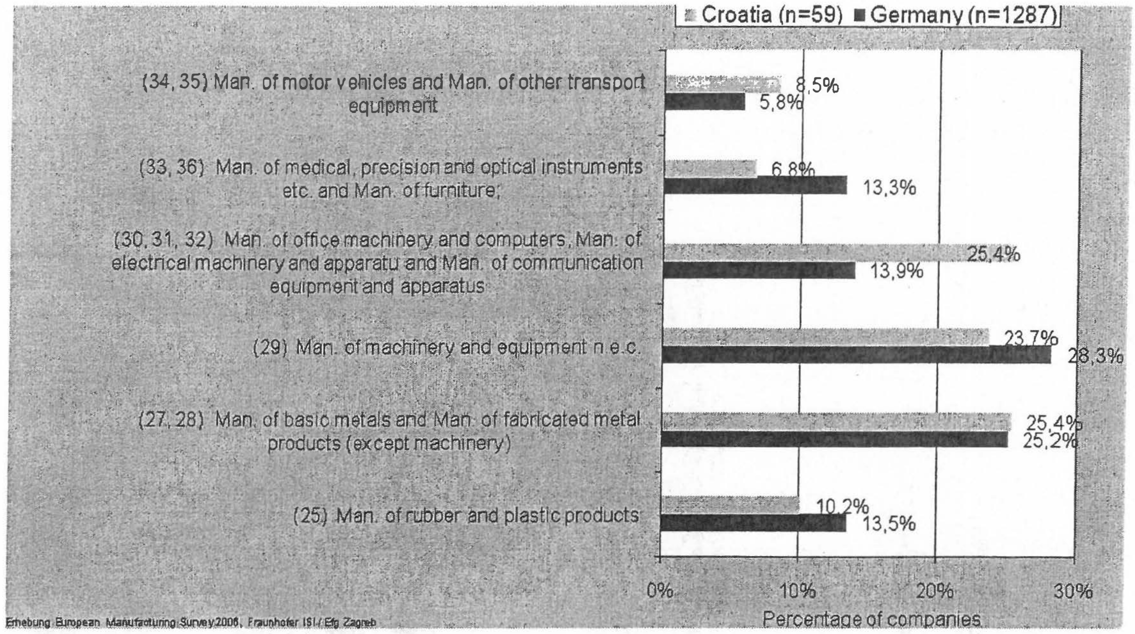
The first step in our analysis will be to check if the national samples can be compared to each other or if weighted averages are need. For this reason, the following criteria were compared: the structure of the discrete manufacturing sector, the dispersion of company size as well as the companies structure according some product and production features. The first descriptive results show that the frequencies of both samples according to the selected criteria are alike.

Figure 1: The structure f the companies size for Croatia and Gemany



Source: European Manufacturing Innovations Survey 2006, Fraunhofer ISI Karlsruhe/ Faculty of Economisc, Zagreb

Figure 2: The structure of discrete manufacturing sector for Croatia and Germany (NACE 25, 27- 36)



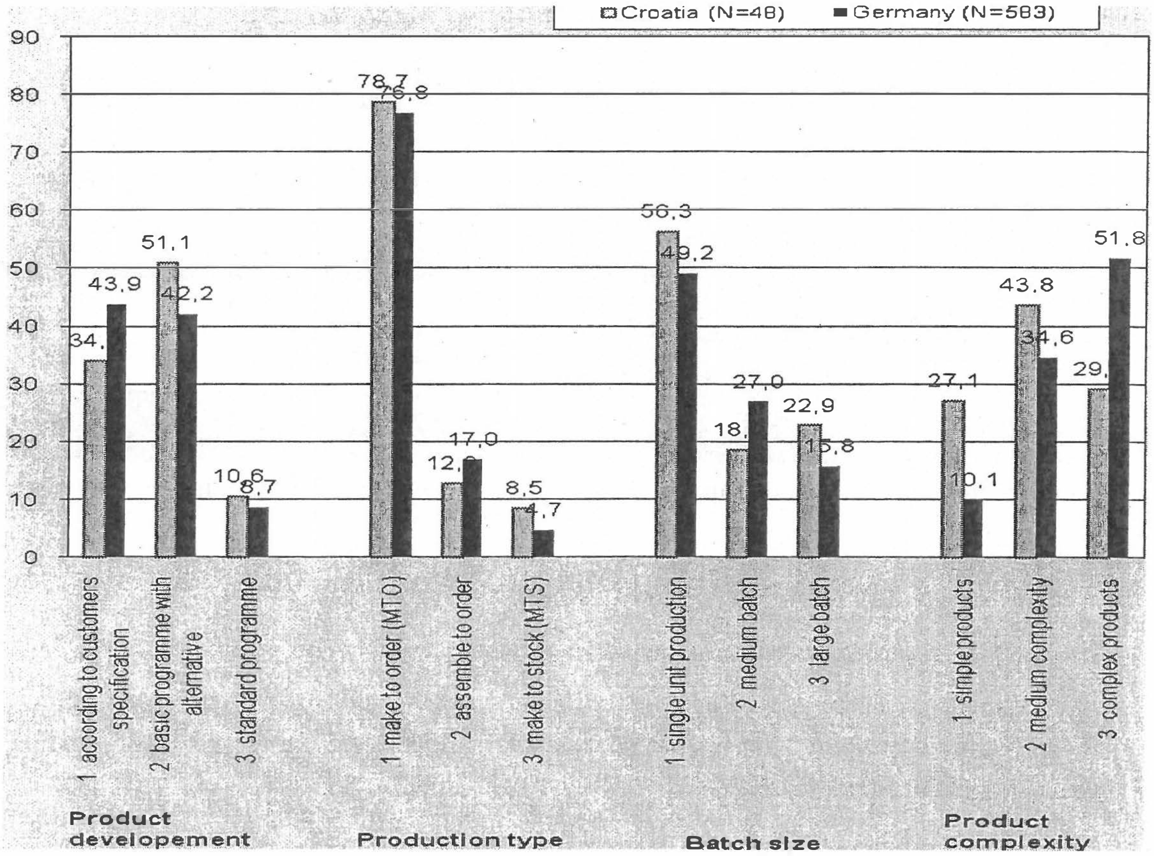
Source: European Manufacturing Innovations Survey 2006, Fraunhofer ISI Karlsruhe/ Faculty of Economisc, Zagreb

The samples' structure according to the production characteristics are depicted in Figure 3. It shows the distribution of the way the products are developed, the production type, the batch size, and product complexity.

Regarding the way the companies develop their products; the samples of both countries reveal that products are developed either according to customer specifications or as a standard basic programme into which customer specific options are implemented. To be able to quickly fulfill the specific product-development needs of each customer, companies need high product- development competence in house. This ensures long-term competitive advantage.

Make to order (MTO) production types dominate in both national samples (S. Figure 3.). This type of production necessitates a highly-qualified workforce with the ability to make quick changeovers for a new batch. Furthermore, it must employ flexible equipment, short setup times and sophisticated logistical solutions for relationships with suppliers. In both samples, small batches (1-20 pieces a month) dominate. High-complexity production is more widely observed in the German sample. The manufacturing of products of middle (multi-part products) or high-complexity (sophisticated machines or plants) requires highly-qualified shop-floor employees with specific mechanical and electrical knowledge. Exactly because of its complexity, this type of production is very hard to copy and represents a long-term competitive advantage for the companies. Croatian companies dominate in production of medium complexity products such as simple multi-part mechanical or electrical machines and devises.

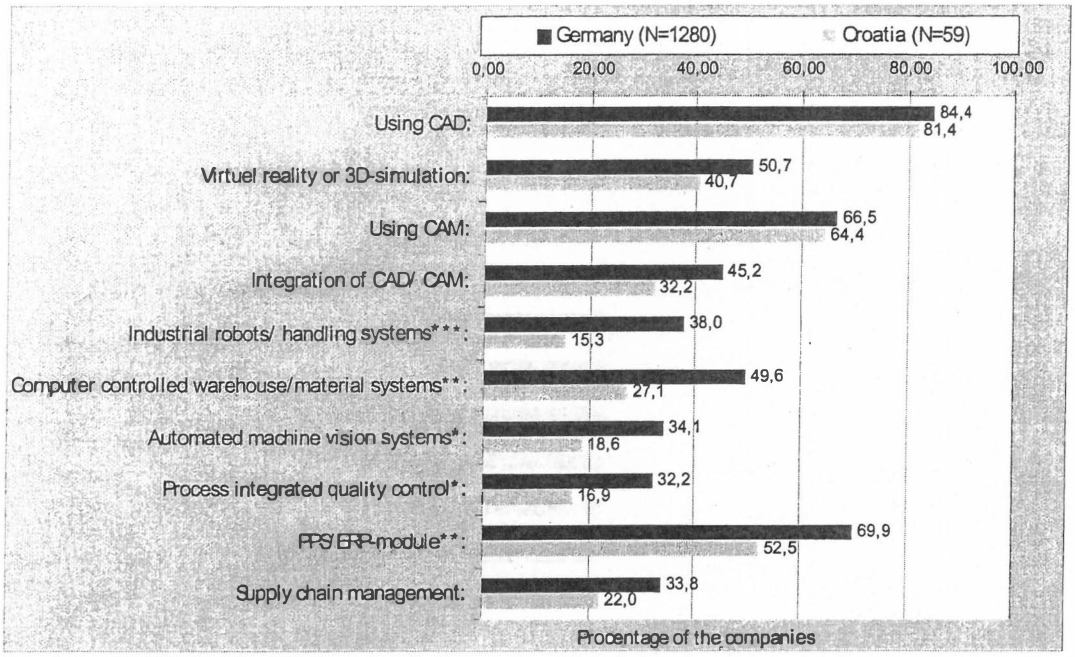
Figure 3: Compared industries according to product and production features (NACE 25, 27- 36)



Source: European Manufacturing Innovations Survey 2006, Fraunhofer ISI Karlsruhe/ Faculty of Economics, Zagreb

It can be concluded that, in spite of some stated differences, the production and product features of Croatian and German discrete manufacturing industries are comparable to each other. Moreover, we also assume that comparable production structure implies the use of the selected technological concepts to a similar extent.

Figure 4: Percentage of companies using the technology (NACE 25, 27- 36)

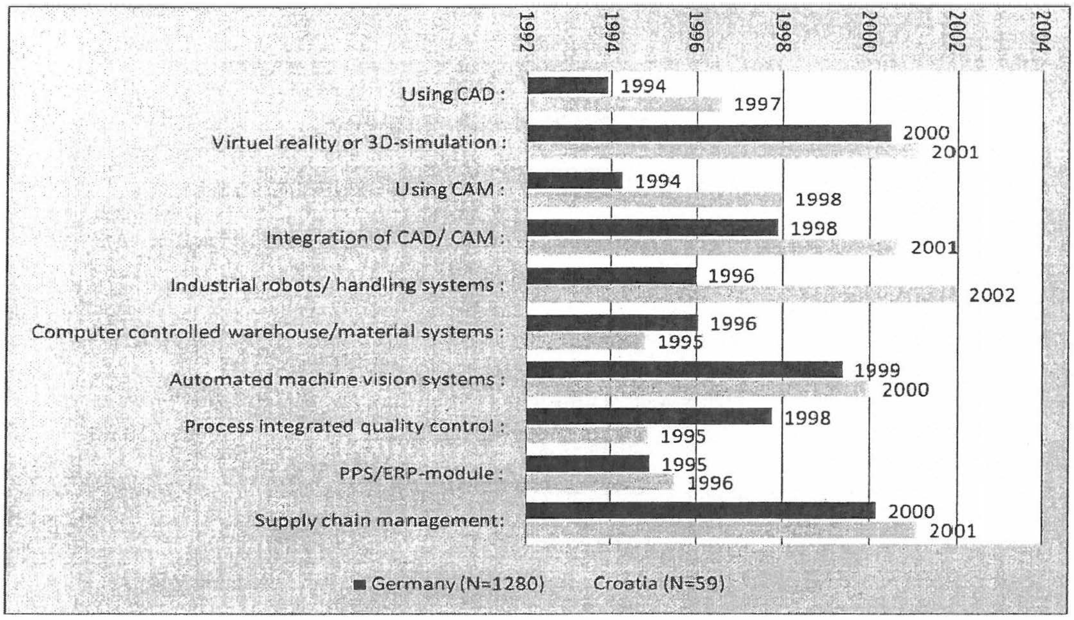


*** p< 0,0001; ** p< 0,01; * p< 0,05

Source: European Manufacturing Innovations Survey 2006, Fraunhofer ISI Karlsruhe/ Faculty of Economisc, Zagreb

As shown in Figure 4., the differences in the researched technologies level of usage are not significant. Design concepts such as CAD, virtual reality, 3D-simulation, CAM and the Integration of CAD and CAM, are all directly used to increase the performance of technology, as well as the efficiency of supply chain management. On the other hand, there are significant differences regarding the use of industrial robots and handling systems, computer controlled warehouses, automated machine vision systems and process integrated quality control. These are tools for increasing speed and flexibility, as well as securing the quality of the production process.

Figure 5: The average year of first introduction of technology (NACE 25, 27- 36)



Source: European Manufacturing Innovations Survey 2006, Fraunhofer ISI Karlsruhe/ Faculty of Economics, Zagreb

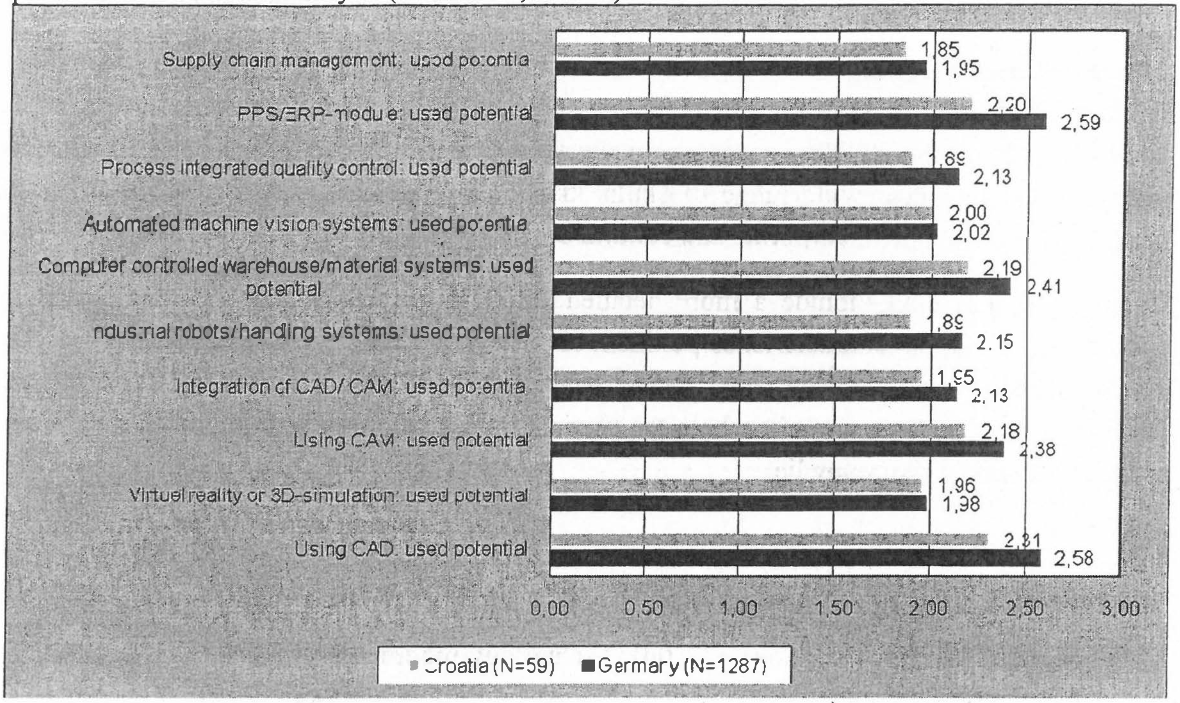
Croatian companies are on average two years behind German companies in adopting new technologies (S. Figure 5). Since it takes time for technology to be developed and used to its full extent, one can conclude that Croatian companies must continue integrating innovative technology in higher levels then they are now.

When analyzing Croatian companies' self-assessed extent of technology use, it can be deduced that their levels of technology usage are not as high as in Germany. (S. Figure 6) Therefore it is clear that Croatian companies must work more on taking advantage of modern technology.

Today's manufacturing process is not solely concerned with transforming raw material into products on the factory floor. Rather, the process is becoming more holistic, integrating a wide range of skills, knowledge and competences that need to be functionally managed, despite corporate and cultural borders (Jung-Erceg et al. pp. 38). This shows that Croatian companies must focus their attention on taking advantage of the benefits of modern technology.

In figure 6. we see that the level of Croatian technology usage is lower than in Germany.

Figure 6: The self-assesed level of technology using compared to the most reasonable potential use for the factory*[1] (NACE 25, 27- 36)



Source: European Manufacturing Innovations Survey 2006, Fraunhofer ISI Karlsruhe/ Faculty of Economics, Zagreb

5. Conclusion

Thanks to our cross country analysis we found some significant, but not in all cases relevant differences in the use of innovative technologies between Croatia and Germany. Thus, innovative technology use in manufacturing firms is not primarily country specific. We found the structure within the discrete manufacturing industry sectors to be alike in both countries. The production characteristics are almost identical in Croatia and Germany, with the exception that Germany focuses more on complex products. Croatia on the other hand dominates with medium complexity products. High complexity production needs a highly competent workforce and through this "know how" is able to create a competitive advantage.

There is no significant difference between the intensity of use of CAD or CAM, nor between their integrated uses. By analyzing the adoption time frame of these technologies, one can identify that Croatian companies lag on average two years behind Germany. One possible explanation for this could be that as time passes and technology becomes cheaper Croatian

[1] Number 3 indicates high usage, number 2 medium usages and 1 indicates low level usage.

companies can afford it more easily. However, the consequence is that Croatian companies do not fully adopt innovative technology until two years after their Germany counterparts.

Levels of manufacturing technology use are lower in Croatia then in Germany. We believe that this difference is due to the fact that even sophisticated technology necessitates a rather advanced "know how". Thus, companies have to adopt a holistic view in their production process that includes a wide range of skills, knowledge and competences that need to be managed over functional, corporate and cultural borders (Jung-Erceg *et al.* pp. 38).

Future research might include a more detailed analysis of performance factors and other significant production characteristics pertinent to specific technology. Further research could perhaps allow one to identify how specific technology may influence certain performance indicators, and most importantly where the barriers in Croatia's realization of full high-level research technology use may lie.

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