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Improvement of production process capability — a case study of two furniture companies

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ABSTRACT

The article aims to assess the improvement of the process capability by implementing the Six Sigma methodology in furniture enterprises with different levels of the quality management system (QMS) and ownership. The implementation of the Six Sigma methodology according to the DMAIC steps, also analysis, evaluation, and comparison of the implementation results were performed to improve the process performance. The implementation of the Six Sigma methodology was carried out in an international enterprise with foreign capital and a certified Quality Management System (QMS) and in a domestic enterprise with purely domestic capital without an established Quality Management System. The implementation results confirmed the positive development in the key indicators of critical processes, namely, in the reduction of DPMO, the increase of efficiency and the level of Sigma Process, and the values of process capability indices. The positive effects were more pronounced in the international enterprise compared to the domestic. The application of the Six Sigma methodology brings better results in manufacturing companies with international management skills and implemented certified QMS. These two aspects can be key success factors by managing and improving process capability. The practical contribution of the paper can be seen in the proposal of suitable methods and tools by implementing Six Sigma conception in furniture manufacturing regardless of the ownership or level of quality management systems.

KEY WORDS

process performance, quality, process capability indices, Six Sigma methodology, furniture enterprises, domestic capital, foreign capital

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Introduction

Changes in the economic and political situation in Slovakia reflect not only in the ownership of enterprises but also, subsequently, in their management through performance and process quality. Due to the increasing pressure on the quality of products and services, enterprises are moving from traditional quality management methods to new approaches. A specific study of the application of the Six Sigma methodology to ensure and increase the quality of

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selected production processes in furniture enterprises with different ownership and degree of a quality management system is an example of differences in process management, which aims to improve quality and performance of furniture enterprises in the wood processing industry. The Slovak economy is highly dependent on foreign capital, which increases the productivity of the economy. In Slovakia, up to 40 % of value added is produced by companies with foreign capital, bringing new trends in business management. In the Slovak Republic, 9591 companies are controlled by entrepreneurs from the neighbouring Czech Republic with their own share of over EUR 2.366 billion. This number of companies is the largest in Slovakia. In terms of capital controlled in Slovakia by foreign owners, the Netherlands leads with a share amounting to more than EUR 5.174 billion (www.etrend.sk).

As for the wood processing industry, the largest companies in Slovakia include Ikea Industry Slovakia, Swedwood Slovakia, Mondi SCP, Essity Slovakia, s.r.o., Metsa Tissue Slovakia, Bukocel, Kronospan, SHP Harmanec, Ekoltech, Rettenmeier Tatra Timber, Doka drevo, Decodom, and Bukóza Export-Import (www.etrend.sk). According to statistical data and own research results, 51 % of furniture companies in Slovakia are domestically owned.

Following the results of the research on a sample of 188 enterprises, the ownership of Slovak wood processing enterprises is shown in Fig. 1. Enterprises of the wood processing industry are divided into wood, furniture and pulp and paper categories.

In quality assurance and performance improvement of processes, an important role is given to sound decisions based on a situation analysis using appropriate tools and methods of operational management and quality improvement. The Six Sigma methodology is used to ensure and improve the quality of processes, increase the capability of business processes, and focus on the customer. Its implementation resulted in substantial cost savings, especially in the engineering, automotive and electrical engineering industries and services. Based on STN EN ISO 9001:2015, the quality management system (QMS) is the starting point for the use of concepts, methods, tools, and techniques in companies with different specialisations, including furniture enterprises. If systematic methods of process management, statistical analyses, data from measurements of operational performance and subsequent process improvement are used, the occurrence of zero defects is also assumed.

According to the available information, the Six Sigma methodology is not used in the furniture industry of the Slovak Republic to ensure and continuously improve the quality of processes. Based on results from the application of the Six Sigma methodology in other industries, there is space for searching its possible effects under specific conditions of furniture manufacturing. Moreover, it is worthwhile to find out if implemented QMS and international management in a company result in better effects.

This paper aims to present and compare the impacts of using the Six Sigma methodology on the performance of processes in furniture enterprises with different types of ownership and levels of a quality management system. Process performance analysis in terms of process capability forms the basis for selecting the appropriate combination of methods and tools within the Six Sigma methodology. Comparing the level of process capability before and after implementing selected Six Sigma methods made it possible to identify the impacts of this concept on the performance of processes in two types of companies, international and domestic, operating at the national level.

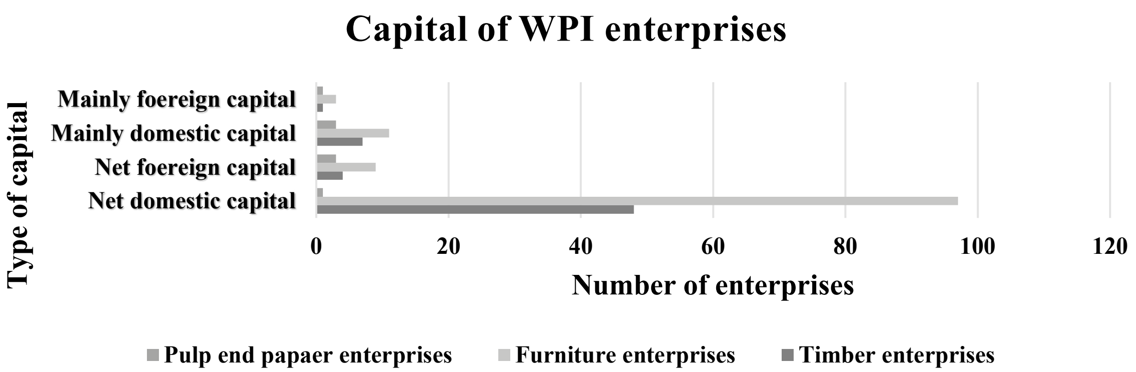

Fig. 1. Capital of WPI enterprises

Source: elaborated by the author.

1. Literature review

Motorola developed Six Sigma to improve product quality, where high component counts often resulted in a correspondingly high probability of defective final products (Arnheiter & Malexeff, 2005). Six Sigma improves productivity through process variation reduction.

Six Sigma is defined as a business strategy that increases and reduces the factors of defects and failures, increases productivity, reduces cycle time and productions costs. Six Sigma is a statistical method used for reducing variations in any process, as Näslund (2008) and Chakravorty et al. (2012) suggest. Drohomeretski et al. (2013), Shah et al. (2008), Manville et al. (2012), Lee and Wei (2009), and Näslund (2008) subjoin reducing costs in manufacturing and services, making savings in the bottom line, increasing customer satisfaction measuring defects, improving product quality (Pabedinskaitė & Vitkauskas, 2009), and reducing defects to 3.4 parts per millions of opportunities in the organisation. Six Sigma is a methodology that highlights the variation in the manufacturing process and helps to reduce them through their statistical tools and techniques (Vinodh & Swarnakar, 2015). Six Sigma is a data-driven process improvement methodology used to achieve stable and predictable process results by reducing process variations and defects (Laureani & Antony, 2017). Six Sigma statistical methods provide a structured approach for identifying the root causes of production defects (Schroeder et al., 2008). According to Kadri (2013), Six Sigma processes show a proven approach for businesses and organisations to improve their performance, and that sustainability programmes need this operational approach and discipline. Six Sigma helps a business leader to design a sustainable programme for value creation. Sachin and Dileeplal (2017), Kumar et al. (2011), and Chandrea et al. (2014) state that Six Sigma methods can be implemented by two different strategies, i.e., Define, Measure, Analyse, Implement, Control (DMAIC) and Define, Measure, Analyse, Define, Validate (DMADV). DMADV deals with new product development, while DMAIC is used to bring improvements in existing products or processes. Steps of the DMAIC procedure endeavour to adopt a smarter way of doing things so as to minimise the occurrence of errors. It emphasises doing things right the first time, rather than spending effort on correcting errors (Okpala, 2012).

Process capability refers to the evaluation of how well a process meets specifications or the ability of the process to produce parts that conform to engineering specifications. Process control refers to the evaluation of process stability over time or the ability of the process to maintain a state of good statistical control. According to Yerriswamy et al. (2014), process capability can be evaluated through the computations of various process capability ratios and indices.

According to several researchers, such as Wang et al. (2017), Gong et al. (2017) and Chen et al. (2019), the process capability index PCI can be used as a Six Sigma evaluation tool and successfully applied in various industries. Process capability indices are intended to provide a single number assessment of the ability of a process to meet specification limits on quality characteristics of interest. Thus, it identifies the opportunities for improving quality and productivity. Cp and Cpk capability indices allow an assessment of the process's critical capability in terms of compliance with a set or expected limits and average value according to Al-Agha et al. (2015) and Simanová (2015). Chen et al. (2003), Ray and Das (2011), and Gejdoš (2006, 2014) consider the Cp and Cpk indices to be the most used basic indicators of competence in the manufacturing industry.

The research results on the use of the Six Sigma methodology, which is currently known worldwide, show the successes and failures of implementation. Currently, many companies in Europe and America show economic benefits after implementing the Six Sigma concept. Motorola is widely believed to be the first company to announce success in implementing Six Sigma. While Japanese companies experienced benefits earlier, American companies were the first to disseminate their results, leading to rapid takeovers by other companies (Montgomery, 2016; Madhani, 2017).

Following the successful implementation of Six Sigma, other industries have followed, such as Toyota, IBM, AlliedSignal, General Electric, Xerox, Kodak, Ford, General Motors, BMW, Hilti, Shell, Honeywell, Chrysler etc. (Khumar, 2006). Other companies that have shown success in implementing Six Sigma are listed by Kwak and Anbari (2006). The Six Sigma methodology is also used by some Slovak companies, e.g., Telecom, U.S. Steel, Kooperatíva insurance company, Jungheinrich, VST Oceľ, Kosice, Nemak Žiar nad Hronom, ZTS Strojárne Námestovo, Prima banka (www.fbe.sk).

Project success is determined by such factors as the connection of Six Sigma projects to the business goals of the enterprise, key performance indicators, quality costs, involvement of senior management with sufficient influence, security of resources, access to reliable data, project completion within a specified time limit, use of statistical tools and information technology, human resources. According to Kwak and Anbari (2006), Vest and Gamm (2009), and Chow and Moseley (2017), these factors are local, may not apply to all companies and their implementation without adaptation to the environment may be another factor in failure. Similarly, Antony et al. (2007) and Raman et al. (2017) mainly mention the economic benefits for companies derived from the Six Sigma implementation. Garcia-Alcaraz et al. (2017), for example, performed an analysis to combine human factors with operational benefits, such as labour productivity, product rejection levels, and client complaints, where economic benefits were also achieved. It can be stated that the implementation of the Six Sigma concept is strongly influenced by the level of human resources.

The failures and causes of a Six Sigma failure have been reported in the work of several authors. The reasons for failure include inadequate understanding of the concept and scope of the methodology, insufficient education and training, poor management strategies and a lack of supporting organisational structures (Chakravorty 2009; Nourelfath et al., 2016). Kumar et al. (2014) found that the absence of activities related to the lead manager, as well as the subsequent misunderstanding of the Six Sigma project by other team members, was the main cause of the failure. Further reports and analyses regarding critical success factors for Six Sigma are offered by Mustafa and Jamaluddin (2017), Ribeiro de Jesus et al. (2016), Alhuraish et al. (2017), Marzagão and Carvalho (2016), Psomas (2016), and Lande et al. (2016).

2. Research methods

The input information for the research, the determination of its objectives, and the implementation process were obtained by summarising the findings from available publications, mostly by foreign authors, listed in Section 1. The research methodology is based on general methodology by primary research, and it was adjusted to the combination of primary quantitative research and the applied research by case studies. The framework of our research is shown in Fig. 2.

Primary research in furniture manufacturing enterprises was conducted to determine the extent of the use of the Six Sigma methodology, and concepts, methods and tools for managing the performance of business processes and improving their quality. Relevant data were obtained through an online research questionnaire. The questionnaire included four general questions, such as enterprise size by an average number of employees, focus, business ownership, return on equity, and eight questions focusing on areas such as process types, performance management, process capability, quality management system certification, as well as the use of selected concepts and methods of process performance management.

A total of 479 furniture enterprises were contacted, and 188 questionnaires were returned, representing 39.25 % of the total number of enterprises

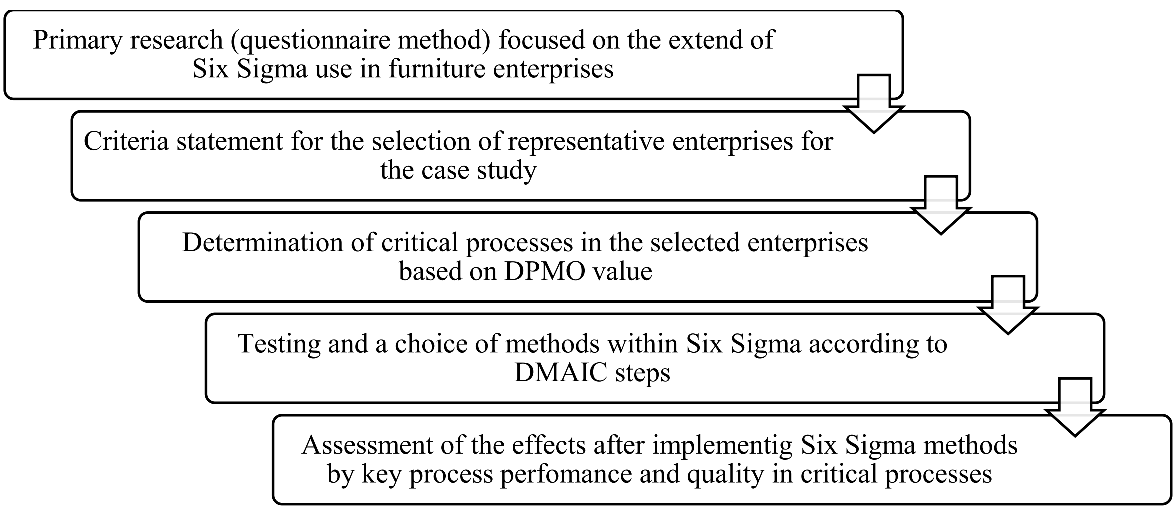

Fig. 2. Research framework

Tab. 1. Overview of factors of selected enterprises for the implementation of Six Sigma

ENTERPRISE	International	Domestic
TYPE OF CAPITAL	Purely foreign	Purely domestic
MARKET ACTIVITY	Longer than 10 years	Longer than 10 years
FOCUS OF THE MAIN ACTIVITY	Furniture production	Furniture production
CERTIFICATION QMS	ISO 9001, ISO 14001, OHSAS 18001	None

contacted. According to the calculation of the sample size using the equation of the Raosoft application, this is a statistically significant sample at a 92 % confidence level and a 5 % margin of error. The results were processed in the Statistic program, and descriptive statistics modules were used.

Based on the results of the primary research, the criteria for the selection of representative enterprises were set out in Table 1 for the implementation of the second part of the research focused on the implementation of the Six Sigma concept in selected enterprises.

Relevant data for the calculation of critical indicators of furniture production processes were obtained from the databases of the surveyed enterprises and by own measurement of process characteristics.

A critical process and a specific process problem were identified by the defect analysis in the process. Defects were divided into material and technological. Calculations of the DPMO value were used as well as the process efficiency as total output revenue and a level of Six Sigma. DPMO (Defects per Million Opportunities) denominates the number of defects that occur per one million opportunities at the development or manufacturing of a product and can be calculated by the formula 1.

Modules of Descriptive statistics and Industrial statistics and Sigma process analysis was used for the calculations (Statistica CZ).

When implementing the Six Sigma methodology in enterprises with different types of ownership and QMS certification level, several methods were selected in the individual phases of DMAIC as described below.

The Define Phase was characterised by detecting VoC (Voice of Customers) and specific customer requirements using the CTQ (Critical to Quality) method. The Quality Function Deployment (QFD) method displays the transformation of customer requirements into a product. Non-conformance record tables and Six Sigma industry statistics modules for calculating and comparing Defects per Million Opportunities (DPMO) indicators, process efficiency levels, and Sigma process levels identify critical processes. The Pareto diagram determines the priority cause affecting process performance. The project charter is used as a plan to address performance and process improvement.

In the Measure Phase, key parameters of the critical process were defined using the measurement plan according to Pande et al. (2002). Due to the possibility of comparing the performance of critical processes of individual enterprises before corrective measures and after their implementation, the calculations of the capability indices C_p and C_{pk} were chosen. These were performed through industrial statistics and Sigma process analysis, graphical representation via histograms and control charts, and provided a suitable platform for the final comparison of results.

The essence of the Analyse Phase consisted of analyses of discrepancies, DPMO values, values of the efficiency level of furniture production processes, Sigma process levels, measurement results and problem identification, as well as Ishikawa diagram for decomposition of first degree causes into second and third-degree causes, affinity diagram for finding causes in a broader context. An analysis of possible errors and their consequences used FMEA (Failure Mode and Effect Analysis) and the Brainstorming method as a highly operative method based on the principle of collective discussion.

The Improve Phase is characterised by a response plan with proposals for corrective measures to eliminate the causes of problems affecting the performance of critical processes. The verification of corrective action results was considered an integral part of this DMAIC step and was implemented through methods of analysis and synthesis, industry statistics & Sigma process analysis, statistical modules for process analysis, histograms and control charts.

In the Control Phase, in addition to primary information from non-compliance records, DPMO indicators, process efficiency levels, Sigma levels, an

$$DPMO = \frac{number\ of\ defect\ products}{\text{total number of products}*\text{number of opportunities per defect}} * 10^6 \qquad (1)$$

affinity diagram were selected to identify logical and causal relationships in solving quality and performance problems from a broader perspective. For monitoring and comparing critical process indicators, the intention was to use the methods of the previous DMAIC steps, such as process capability indices (C_p, C_{pk}), VOC, CTQ, QFD, methods and tools, such as the affinity diagram, Ishikawa diagram and discrepancy records tables.

3. Research results

The primary quantitative research was focused on finding out the use of concepts, methods and tools in performance management and quality management in furniture enterprises. Fig. 3 shows an overview of selected concepts, methods and tools used to increase performance and improve the quality of processes in Slovak furniture enterprises, including two representative enterprises chosen for our case study.

Out of 188 furniture enterprises, most (38.30 %) enterprises used the Brainstorming method. In contrast, only 2.13 % of enterprises used the Six Sigma methodology, and 3.19 % used the Lean Six Sigma method. The analysis showed that 15.43 % – 22.24 % of enterprises used concepts and methods, such as process controlling, TQM and Kaizen. Less than 11.00 % of enterprises used individual concepts, methods and tools, such as Kanban, Poka-Yoke, Method 5S, traditional and new quality management methods, process capability indices and Statistical process control (SPC). Some (11.17 %) furniture enterprises did not use any concepts, methods and tools. The above research results show reserves in the furniture industry for the use of modern concepts and methods of performance and quality management. These conclusions confirmed the intention of the author to focus on comparing the implementation of the Six Sigma methodology for ensuring and increasing the quality of production processes in furniture enterprises with different degrees of a quality management system and with different types of ownership.

When selecting enterprises to implement the Six Sigma methodology, the research focused on the factors listed in Table 1: different types of capital and certification QMS, the same focus and length of market activities.

An enterprise with foreign capital was selected to implement an integrated management system having precisely defined procedures, guidelines and standards with described responsibilities, the frequency for ensuring quality control of input materials, work-in-progress and finished products, and detecting quality deviations. Processes were defined, and a low-level structure of processes was created, the connections between processes in the enterprise documentation were monitored, the quality of processes was monitored through the evaluation of the number of discrepancies and the costs of discrepancies. The enterprise with net domestic capital only had a manual for the description of processes and a classical technological procedure to produce furniture. From the quality control viewpoint, it had no developed quality

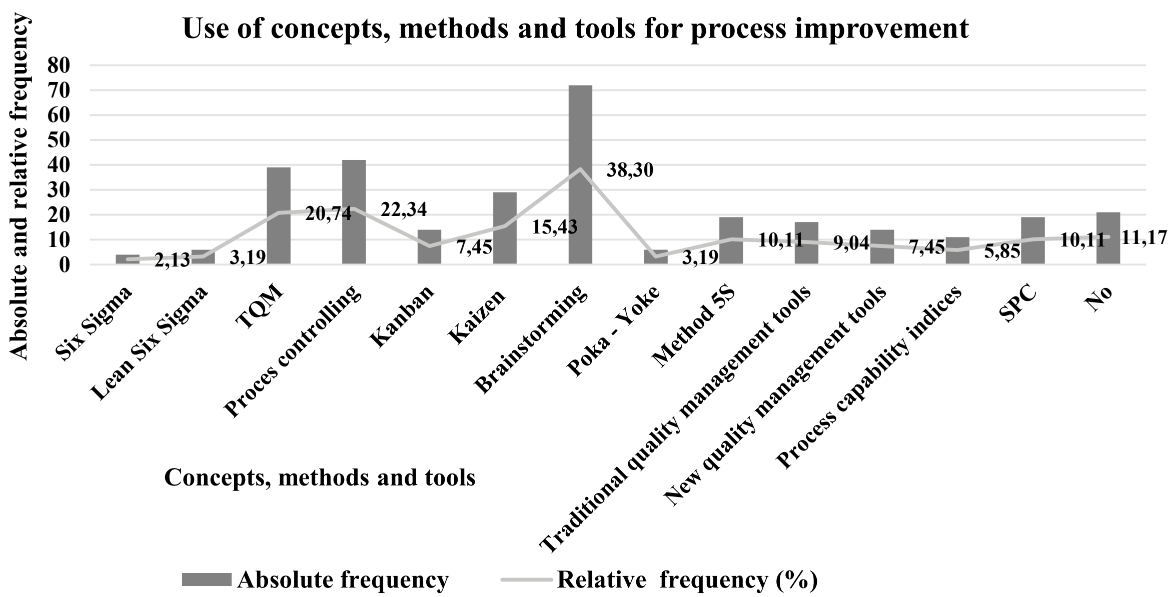

Fig. 3. Use of concepts, methods and tools for process improvement

management system. The enterprise had a high-level structure of processes, did not use methods for process management or indicators to measure process performance.

The implementation of the Six Sigma methodology started with the analysis disagreement of furniture production processes in two different enterprises from the viewpoint of ownership and QMS certification. Calculations of the DPMO values, efficiency levels and Sigma levels of furniture parts production processes were used for the purpose of comparing the results of process outputs and determining the critical process.

In the enterprise with foreign capital and with a certified QMS, the processes of formatting, glueing side surfaces, pressing, drilling holes, surface treatment, joining and handling were considered. The pressing was determined as the critical process due to the lowest process capability (the lowest value of the Six Sigma level). To determine the capability of the pressing process before and after the implementation of corrective measures to improve the efficiency and quality of the process, the adhesive deposits were measured in g/m2.

In the enterprise with domestic capital and without a certified QMS, the processes of formatting, pressing, glueing of side surfaces, grinding, and surface treatment were evaluated. Drilling was detected as a critical process due to the lowest value of Six Sigma. To determine the capability of the grinding process before and after corrective measures to improve the performance and quality of the process, the thicknesses of the furniture parts were measured (in mm).

The basic characteristics of critical processes in both enterprises were measured over a period of one month and provided a database of basic data for the calculation of C_p and C_{pk} indices, their comparison within the enterprise, as well as between selected enterprises.

The comb shape of the histograms in Figs. 4 and 5 indicates that the variability of both processes is high and is not caused by natural variability in the process. The values of the capability indices are low in both processes. In the pressing process, the total coefficient C_p has a value of 0.42 and the total coefficient C_{pk} = 0.36. In the grinding process, C_p is 0.59 and C_{pk} is 0.48. The values of both indices in the pressing and grinding processes are less than one; therefore, based on the summary results, the pressing and grinding processes are not capable. Furthermore, the indices $C_p > C_{pk}$, which means that the processes are not cantered in the middle of the tolerance interval and react to the deviation of the actual mean value of the process μ from the centre of the tolerance interval. Based on the above facts, processes contain definable, systematic causes. The comparison of the capability of processes through capability indices before measures showed that the indices were a suitable basis for comparison and that the capability of critical processes at this stage was not affected by the type of capital or QMS certification level. A higher priority was given to the comparison of capability indices after the implementation of corrective measures to improve the performance and quality of processes.

The selection of methods and tools for the implementation of the Six Sigma methodology was carried out, aiming to coach individual team members who participated in the project in both companies without special training and increased training costs. The concepts, methods and tools used according to the DMAIC steps for international and domestic enterprises, considering their specifics, are listed in Table 2.

The implementation of concepts, methods and tools within the Six Sigma methodology and according to the DMAIC steps involved outlining essential

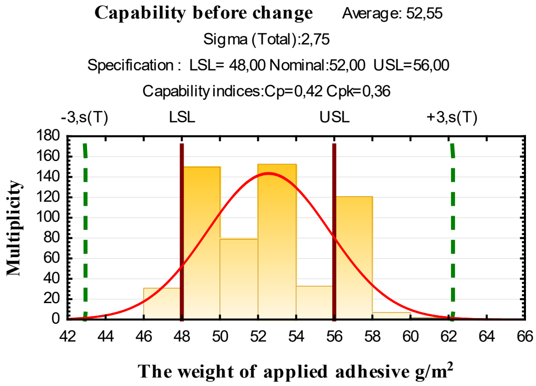

Fig. 4. Capability of the pressing process before changing

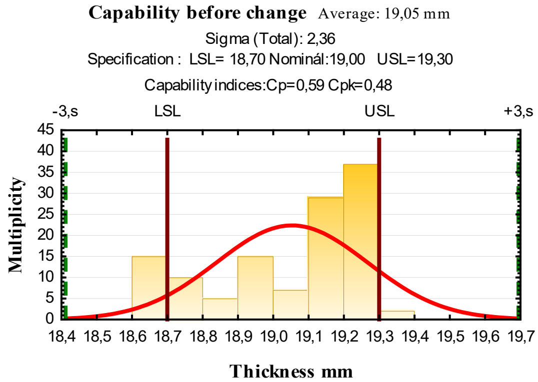

Fig. 5. Capability of the grinding process before changing

Tab. 2. Description of concepts, methods and tools for the implementation of Six Sigma in furniture enterprises with different types of ownership and certified QMS

Concepts, methods and tools	Description
Tables for recording disagreements	Excel is a suitable tool for creating tables for various purposes. A tool should be independent of the ownership type and the level of certification
Voice of Customers (VoC)	The VoC method is suitable for determining customer requirements regardless of the ownership type and QMS certification
Critical to quality (CTQ)	The CTQ method for determining critical quality parameters and deviations that the customer is able to accept. The use of this method is possible in enterprises with different ownership types and with different degrees of QMS certification
DPMO, efficiency level, Sigma level, line graphs, Pareto diagram, tables, STATISTICA program	Histograms to show the frequency of errors, the Pareto diagram to show the effect of the error on the process, line graphs, tables, and the STATISTICA program for calculating the values of efficiency level and the Sigma level are tools usable in both enterprises regardless of the level of the QMS implementation
DMAIC	An appropriate methodology for both enterprises, regardless of the level of QMS implementation and the ownership type
SIPOC map (Supplier, Input, Process, Output, and Customer	SIPOC map is a simple tool for mapping business processes. The pressing process in an international enterprise is characterised by a wider number of operations, line synchronisation, established standards certified by QMS; therefore, this method is more suitable for this enterprise. From the viewpoint of the furniture production process in the domestic enterprise, it will first be necessary to create process maps of existing processes
Project charter	A suitable tool for a basic description of the project, setting goals, deadlines and responsibilities for both enterprises, regardless of the ownership type and the level of certified QMS
Process diagram	The Pareto diagram identifies and prioritises problems. It is a simple and clear tool for managerial decision-making in both enterprises, regardless of the level of QMS certification and the ownership type
Measurement plan according to Pande - Neuman - Cavanah (2002)	This measurement plan is suitable for both types of enterprises with the adaptation of the individual steps of the plan to the technological conditions and the scope of production in the enterprise
Descriptive statistics. Capability indices C_p a C_{pk}, histograms	The use of the STATISTICA program for both enterprises is, from the viewpoint of the use of Six Sigma methods and tools, a necessary aid in identifying critical processes based on capability indice
Ishikawa diagram	The Ishikawa diagram, a suitable tool for decomposing the causes of disagreements, can be used in both enterprises with different types of ownership and QMS certification levels, with certain variations considering the specifics of the processes
Reaction plan	In practice, this tool is very effective and similar to a control diagram. It is suitable for a specific textual and graphical description of a process or operation with the setting of process characteristics. The reaction plan can also serve as a type of standard in the production process. Suitable for both types of enterprises
Quality Function Deployment (QFD)	The differences and sophistication in the construction of the Quality House depend on determining the importance of the requirements and the determination of the product properties in the enterprises, as well as on their technical and qualification equipment. The tool can be used in both types of enterprises with interest in the transformation of customer needs into product quality. Its use depends on the level of management, and the use of VoC and CTQ methods, which in an enterprise with domestic capital and without a certified QMS, is demanding but not impracticable
Pareto diagram	A Pareto diagram is a suitable tool for illustrating the effect of the error on process output. It is applicable in both enterprises regardless of the type of ownership and the level of certified QMS
Brainstorming	This method is very effective, creative, and usable for solving problems in various types of enterprises, regardless of the level of QMS and the ownership type
Affinity diagram	The diagram is suitable for identifying logical and causal connections. Its creation had to be adapted to the specific conditions of enterprises with different ownership types and levels of the QSM certification
Diagram of hierarchical and personnel provision of projects	A graphical method of personnel occupancy in Six Sigma projects and its synchronisation with managerial functions. It must be adapted to organisational and competence structure according to an ownership type and level of QMS
Control diagrams	The graphical method is suitable for both types of enterprises for analysis and synthesis of obtained measurement results of process characteristics, the use of industrial statistics & Sigma process analysis, and statistical modules for process analysis and creation of control diagrams

activities for increasing the performance of processes in terms of quality and recommended methods for the implementation of concepts, methods and tools within the Six Sigma methodology and according to the DMAIC steps, essential activities for increasing the performance of processes in terms of quality and recommended methods for its assurance.

The priority of the implementation of the Six Sigma concept, specifically the Improvement Phase, was to take such measures as would ensure an increase in the capability of critical pressing and grinding processes in two selected furniture enterprises. Figs. 6 and 7 show the changes in the shape of the histograms and the concentration of the basic characteristics of the critical processes between the tolerance limits of the pressing and grinding processes.

Table 3 demonstrates the comparison of key performance and quality indicators of processes, such as the DPMO of the critical processes, efficiency and Sigma process levels, Cp capability indices and Cpk critical capability indices, the number of non-conforming products, cost of non-conforming products in an international foreign capital company and a domestic company with purely domestic capital.

The knowledge from the implementation of individual concepts, methods, and tools of the Six Sigma concept according to DMAIC steps showed that in both selected enterprises with different levels of QMS certification and different ownership, the same methods could be applied to improve process performance and quality. The results shown in Table 3 demonstrate that the concepts, methods, and tools implemented within the Six Sigma methodology used to improve the quality and performance of critical furniture manufacturing processes can be considered effective and efficient in foreign and domestic enterprises. This fact was also confirmed by the verification results of the Six Sigma concept implementation according to the DMAIC steps in critical pressing and grinding processes based on comparable indicators of their performance. In an enterprise with foreign capital and certified QMS, pressing was defined as a critical process with DPMO values before the improvement amounting to 107 536.58, efficiency level value of 89.25 and Sigma level of 2.75 and with DPMO values after the improvement equal to 53 325.46, efficiency level value of 94.67 and Sigma level of 3.11. The grinding process was defined as a critical process in an enterprise with domestic capital and without a certified SMK with DPMO values before the improvement amounting to 197 629.13, efficiency levels of 80.24 and Sigma levels of 2.36, and with DPMO values after the

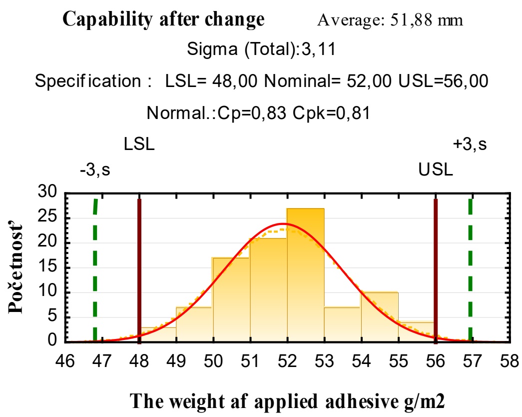

Fig. 6. Capability of the pressing process after the change

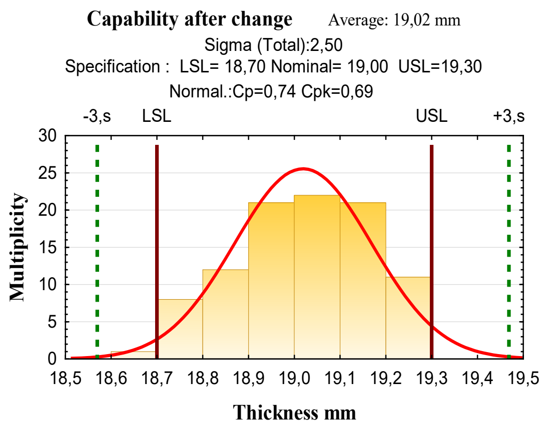

Fig. 7. Capability of the grinding process after the change

Tab. 3. Results before and after the change in two furniture manufacturing companies

Key metrics	Enterprise with foreign capital		Enterprise with domestic capital	
	Before	After	Before	After
DPMO critical process	107 536.58	53 325.46	197 629,13	134 753,36
Sigma level	**2.75**	**3.11**	2,36	2,50
Effectiveness %	89.25	94.67	80,24	84,13
Capability index C_p	**0.42**	**0.83**	**0.59**	**0.74**
Capability index C_{pk}	0.36	0.81	0.48	0.69
Non-conforming products in pcs	6 879	5 324	724	629
Cost of nonconformities € (in a month)	**37 653.25**	**29 985.75**	4 923.50	4 277.20

improvement equal to 134 753.36, efficiency levels of 84.13 and Sigma level 2.5.

4. Discussion of the results

On a specific example regarding the implementation of methods and tools, improvements were recorded in key indicators for both types of enterprises, while the DPMO value of the critical process of the enterprise with foreign capital had a higher difference (by 13.09 %) before and after the implementation, and an efficiency level (by 6.07 %). The DPMO value of the critical process of the enterprise with domestic capital saw an improvement of 5.93 % and an efficiency level of 4.85 %. Even though the values of capability indices increased by more than 50 % in the international enterprise and by more than 25 % in the domestic enterprise, which was positive, these coefficients were still less than one. The number of non-compliant products and the amount of costs were lower in the observed period of one month after the corrective measures within the Six Sigma methodology by 22.6 % in an international enterprise and by 13.12 % in a domestic enterprise. Based on the above, an enterprise with foreign capital and a certified QMS had significantly higher results than an enterprise with domestic capital and without a certified QMS. Although significant differences were found in the DPMO values, efficiency levels, and Sigma levels in the critical processes of both enterprises, the implementation of the Six Sigma concept was successful in both selected enterprises. A further inquiry into a more comprehensive understanding of this success led to the conclusion that an enterprise with certified QMS and foreign capital applied the Six Sigma concept more rationally and sophisticatedly in terms of information systems, organisational structure, corporate culture, and also in the understanding of the concept by enterprise managers of various levels and employees. Although these implementation results of the Six Sigma concept reflect positive developments, critical furniture manufacturing processes have not been fully capable and still produce non-conforming products. A visible improvement of the processes occurred in the observance of tolerance limits once reaction plans were introduced into the processes with the definition of tolerance, technological and setting intervals. Based on Inal Tamer et al. (2018), Smętkowska and Mrugalska (2018), the Six Sigma concept improves the quality and performance of processes. These observations were also confirmed by the analyses results regarding the evaluation of furniture production processes in one international and one domestic enterprise. The application of new concepts, methods, and tools to ensure improved performance and quality of processes was more easily implemented in an enterprise with foreign capital, which had a certified QMS, production standards, and an established system for measuring, controlling and analysing key process characteristics.

The application of the Six Sigma methodology is closely linked to the qualification structure of human resources at various levels of management, as well as to the qualification structure of human resources directly involved in the production process. The success of the application of the Six Sigma methodology would not have been achieved without the support of the company's management, managers, and the cooperation of technicians, operators, and equipment operators. According to Bruno (2011) and Desai et al. (2012), the application of the Six Sigma methodology also differs from the size of the enterprises. The choice of appropriate methods and tools for the Six Sigma implementation also depends on the type and specifics of a production process. Regarding the technology of furniture manufacturing and a prevailing serial or custom type of production, applicable methods and tools must be chosen. This case study tested several existing methods. However, some of them proved to be inappropriate as they did not bring the desired effect. The enterprise without a certified QMS and lower process maturity had to consider the ability and readiness of employees to perform activities of proposed methods and tools. Finally, the chosen methods and tools were applied in both enterprises where the QMS level and process maturity were different, but the desired positive effects were reached.

The methods and tools used in the implementation of the Six Sigma methodology can be recommended with their adaptation to the form of capital, size of the enterprise, capacities, hierarchical process management, the implementation degree of the quality management system, as well as the educational level of employees.

The paper contributed to the development of knowledge in the implementation of the Six Sigma model under specific conditions of furniture manufacturing. The findings confirmed positive effects and a greater improvement of process capability in the environment of a certified and standardised QMS and in an enterprise with international activities. Internationally managed enterprises have a high process management maturity, more qualified and better-educated employees. These factors create better starting points by implementing modern conceptions of process management, such as the Six Sigma methodology. Foreign capital brings different corporate culture to furniture enterprises, a higher degree of quality assurance through certified quality management systems, the use of methods and tools to improve process performance. The application of methods and tools to improve the process capability in furniture production provides enterprises with the opportunity to choose appropriate methods and approaches within the DMAIC steps.

Conclusions

Aiming to improve the competitiveness of enterprises, it is important to focus on such attributes as the increase in the performance and quality of processes, the level of assurance and improvement of the quality of products and services, and the satisfaction of customer needs. The implementation and certification of the Quality Management System are currently among the prioritised business strategies, but enterprise readiness is insufficient in many respects. Based on the experience implementing Six Sigma projects in international and domestic furniture enterprises with different levels of the Quality Management System, the methodology should be implemented in furniture manufacturing processes of enterprises with different ownership types as it improves quality and increases the performance of enterprises in terms of specific indicators. However, better results have been achieved in an international enterprise, which can be attributed to several causal factors, such as a high level of corporate culture, intuitive decision-making replaced by data-based decision-making, which is associated with a consistent record of basic process characteristics, the level of technical and technological standards. Besides, the implementation involved more sophisticated technical, technological and information systems, a thoroughly reworked organisational structure with the process of escalation and problem solving, and an understanding of the Six Sigma methodology, which is promoted by top-down management and developed mainly at the middle management.

The wood processing industry, except for furniture manufacturing, has promising prospects with progress and growth of competitiveness depending on the type of ownership, the level of the established Quality Management System, and the use of new methods of performance management and process quality assurance. Enterprises with foreign capital and an established and certified quality management system have a competitive advantage. Their progress is accompanied by managing constant changes in processes depending on increasing customer requirements. Companies that do not have a quality management system in place to maintain their market position are striving to streamline process quality management, which is impossible without effective new approaches.

Based on the implementation findings, home-owned enterprises that seek to increase the efficiency and quality of their processes could be recommended to increase the level of corporate culture, focus on streamlining the organisational structure and the employee qualification structure. The successful introduction of the QMS certification and the associated technical and technological standards, information systems, more sophisticated data collection on processes and product characteristics mainly depends on the understanding of management at various levels of process management. The level of management guarantees the successful implementation of new concepts and methods for managing the performance and quality of processes.

The proposed methods and tools for implementing the Six Sigma methodology presented in this paper are suitable and applicable in conditions of furniture manufacturing. Their complexity in the application is manageable even in smaller companies without an established QMS by respecting DMAIC steps.

The positive results from the implementation of the Six Sigma concept according to the DMAIC steps are the inputs for further research in increasing the performance and quality of processes using new concepts and methods not only in the furniture industry but also in the woodworking industry as a whole. The future research will be directed to modern process improvement methods and not only process capability but also their application in the specifics of different wood handling processes. The study focusing on the effects of implementing the Lean Six Sigma methods would also contribute to experience and knowledge in the improvement of process capability.

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