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# Improving the Performance and Quality of Processes by Applying and Implementing Six Sigma Methodology in Furniture Manufacturing Process

## Poboljšanje izvedbe i kvalitete procesa proizvodnje namještaja primjenom metodologije *Six Sigma*

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**ABSTRACT** • *The main aim of this paper is to illustrate the application of selected methods and procedures in the implementation of the Six Sigma Methodology in the furniture manufacturing processes, specifically in the wood veneer pressing, to verify the application and to evaluate the benefits of using selected methods and procedures through a series of step DMAIC process improvement. The application of selected methods and tools within the Six Sigma Methodology, such as DPMO, efficiency and sigma levels, project charter, histogram of mistakes caused by the application of the adhesive, the SIPOC plot mapping process, reaction plans, Ishikawa diagram and control diagrams bring the system and clarity of measurable results into project management for process improvement and process change. The benefits of their use are the cost savings and performance improvement processes.*

***Keywords:*** *process, quality, Six Sigma Methodology, DMAIC, statistical regulation, process performance, furniture manufacturing*

**SAŽETAK** • *Glavni je cilj ovog rada prikazati provedbu odabranih metoda i postupaka pri primjeni Six Sigma metodologije u proizvodnji namještaja. To se posebice odnosi na provjeru primjene i procjenu prednosti korištenja odabranih metoda i postupaka pri prešanju furnira unutar niz koraka za poboljšanje DMAIC procesa. Primjena odabranih metoda i alata u sklopu metodologije Six Sigma, kao što su DPMO, učinkovitost i sigma razine, projektna povelja, histogram grešaka uzrokovanih primjenom ljepila, proces mapiranja SIPOC, reakcijski planovi, Ishikawa dijagram i kontrolni dijagrami, uvodi sustav i jasnoću mjerljivih rezultata u upravljanje projektima radi poboljšanja i promjene procesa. Prednosti njihove uporabe jesu smanjenje troškova i poboljšanje proizvodnog procesa.*

***Ključne riječi:*** *proces, kvaliteta, metodologija Six Sigma, DMAIC, statistički propis, svojstva procesa, proizvodnja namještaja*

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## 1 INTRODUCTION
1. UVOD

Business and business activities are the decisive driving force behind economic activity in the market economy. The successful operation of businesses in strong competition is determined by well-functioning management. In the process of quality assurance in companies, decision-making based on an analysis of the situation with the appropriate use of operational management and quality improvement tools and methods plays an important role. The actual management decisions on issues of quality improvement can be based on qualitative or quantitative data. It is precisely these data that play an important role in the appropriate choice of tools. To ensure and improve process quality, Six Sigma Methodology is used to achieve, maintain and maximize profits, increase business performance, and focus on customers. The implementation of Six Sigma, mainly in the engineering, automotive, electrical and electronics industries, as well as in providing services, has achieved enormous cost savings.

Six Sigma originated in the 1980s as a corporate strategy containing a set of techniques for the improvement of manufacturing processes and elimination of defects in the Motorola company. The main goal of the strategy was to minimize the dispersion of the characteristics critical for the quality of manufactured products and performed processes, and set the average values approaching the target values defined by the customers. The application of Six Sigma Methodology – SSM brought about changes within a short time, leading to the reduction of defects in the products using the same labor, technology, and design, at less cost. Thanks to the strategy, Motorola gained the leading position in the area of quality and was awarded the Malcom National Quality Award. Many worldwide companies like Toyota, Ford, BMW, Hilti, Allied Signal, Xerox, Kodak, Shell, General Electric, Honeywell International, Caterpillar, Raytheon, and Merril Lynch have successfully applied this methodology, as presented by Khumar, 2006; Chapman, 2005 and Al-Agha *et al*., 2015.

According to Gibbons, 2010, by applying Six Sigma in a well-known manufacturing company in the United Kingdom, overall equipment effectiveness improved significantly from 40 % to 85 %. General Electric was one of the first companies adopting the SSM from Motorola and in the three years since introduction they calculated that the method had saved them $750 million, net, after subtracting all costs, including the cost of the method.

Six Sigma processes show a proven approach for businesses and organizations to improve their performance, and that sustainability programs are in need of this operational approach and discipline. Six Sigma helps a business leader design a sustainable program for value creation as stated by Kadri, 2013.

Based on a case study done by Sujová *et al*. (2016) „Experience of Slovak and Czech companies has proven that, for example, processes in manufacturing companies in the automobile industry with an already established quality assurance system are at an average level of around 3.5 to 4 sigma. In this case, an improvement in the company's processes by 0.2 sigma represents economic benefits in the amount of 1 % of company income". Six Sigma concept on the corporate performance are used for example in Volkswagen, Slovak Telecom, U.S. Steel, T-Mobile, Allianz, Kooperatíva, Jungheinrich and Kaufland.

Six Sigma is defined as "a well-established approach that seeks to identify and eliminate defects, mistakes or failures in business processes or systems by focusing on those process performance characteristics that are of critical importance to customers" (Antony, 2008).

The designation of the Six Sigma Methodology is based on statistics. Sigma in mathematical statistics represents the standard deviation, denoted by the Greek alphabet σ, which represents the value of the amount of difference of a particular process. If the sigma is larger than the mean value, it is more variable in the resulting product (Khumar, 2006).

Six Sigma is a statistical methodology that aims to reduce variation in any process (Chakravorty and Shah, 2012; Näslund, 2008), reduce costs in manufacturing and services, make savings to the bottom line, increase customer satisfaction (Stamatis, 2004; Drohomeretski *et al*., 2013; Kollár, 2013; Manville *et al*., 2012; Näslund, 2008; Schroeder, 2006) measure defects, improve product quality, and reduce defects to 3.4 parts per million opportunities in an organization (Lee and Wei, 2009; Chen and Lyu, 2009).

The characteristics of the Six Sigma Methodology are described in the works of several authors (Pande *et al*., 2002; Janetka, 2006; Töpfer *et al*., 2008; Linderman, 2003; Joglekar, 2003; Tošenovský, 2003; Gejdoš, 2006, 2014). Based on the study of individual authors' views on the Six Sigma Methodology, it can be concluded that Six Sigma Methodology is an approach or system that combines the use of statistical methods, understanding customer requirements and reducing process variability to improve processes and increase the level of perfection expressed by the maximum number of errors per millionth opportunity, and this value should be around the number of 3.4 errors. The Six Sigma strategy credo reads: "Work smarter, not harder".

Töpfer *et al*. (2008), Mateides *et al*. (2006), Simanová (2015), George (2002) and many other authors agree on the most common application of the standard DMAIC approach to project solving, which is characterized by the following five steps:

D – Defining opportunities for improvement,
M – Identifying measurement of the level of success,
A – Identifying and analyzing causes of problems,
I – Proposal for potential improvements by Six Sigma methods,
C – Determining a control plan.

The application of statistical methods that are part of the statistical process management was dided by Mateides *et al*., 2006 into three areas: Statistical

Process Control, Statistical Survey and Process Capability.

The statistical regulation of the process can be based on the views of the authors Nenadal and Plura (2008), Nolan and Provost (1990), Montgomery (1997) and Terek and Hrnčiarová (2004), who characterize it as an instrument of process variability analysis that reveals the process, its shortcomings and their causes, their repeatability and their impact on the process.

Horálek (2004), Terek and Hrnčiarová (2004), Plura (2001), Nenadál and Plura (2008), Mateides *et al*. (2006) and Škorp (2001) recommend using the following regulatory diagrams for statistical process control by measuring:

- $\bar{x}$, *R* – chart of arithmetic mean and variation range
- $\bar{x}$, *s* – chart of arithmetic mean and standard deviation
- *Me, R* – chart of median and variation range
- $\bar{x}$, $\overline{MR}$ – chart for individual values and a slide chart.

The value $\bar{x}$ represents the selection mean of the values obtained from small subgroups and it is the process location. The *R* value is the range of values in each subgroup and it is the degree of process scattering. In all control diagram applications by measurement, it is assumed that within the selection, the quality trace is normal (Gaussian) distribution. Derogations from this assumption affect the efficiency of diagrams (Hrubec *et al*., 2009).

Control charts are the most frequently used tool in the statistical regulation of processes. They allow more accurate distinguishing of random from systematic causes of fluctuations in the value of a mark of quality, i.e. they facilitate regulation and improvement in the quality of the process. Control charts are used in monitoring processes and when ascertaining the need for corrections or changes in the process, in order to achieve a better mean value of the process or in order to reduce variability in the process. In control charts, the horizontal axis contains the times when statistical sampling of regulated values took place, and the vertical axis contains calculated values of the appropriate sample characteristics (Závadský, 2006). Interpretation of control diagrams is simple. We assume that while processes remain within the regulatory boundaries, variability arises from common causes. However, if observation proves the opposite, it is necessary to pay more attention to the observation to discover the causes of the deviations.

Based on recommendations of different authors (Plura, 2001; Töpfer, 2008; Terek and Hrnčiarová, 2004; Linczényi and Nováková, 2001), process capability analysis involves the selection of process characters, collection of measurable data, statistical assessment of the process by means of control chart, verification of the normality values for the process capability analysis and calculation of capability indexes. In order to evaluate the process capability, histograms were used as a visual synthesis of frequency distribution. Expression of process capability by a number (pointer) has led to the development of process capability indexes. In quality assurance with Six Sigma, great emphasis is put on various variants of competence coefficients and statistical models and procedures. Securing and improving process quality can be determined by other qualitative indicators such as the $C_p$ and $C_{pk}$ indexes.

## 2 MATERIALS AND METHODS
## 2. MATERIJALI I METODE

### 2.1 Methodology of the research
### 2.1. Metodologija istraživanja

Application and implementation of Six Sigma using some DMAIC tools is briefly illustrated in a case study of a furniture company that has an integrated and certified quality management system - QMS according to ISO 9001:2000 standard.

#### 2.1.1 D – Defining opportunities for improvement
#### 2.1.1. D – Definiranje mogućnosti poboljšanja

The following tools and methods were used in the phase of defining: DPMO calculation, sigma efficiency and sigma, project charter, error histogram for glue application and SIPOC mapping process. Based on the analysis of non-conforming products, a problem was identified that had to be addressed in the project. In the project charter, the project goal was formulated in precise numbers, and the deadlines for implementation of the solution and the expected duration of the phases were determined. A specific breakdown of the performance of the team members, deadlines for their implementation, checks and revisions, as well as a breakdown of the implementation of corrective actions were proposed in the preliminary draft plan. According to Nenadál and Plura (2008), Defects per Million Opportunities (DPMO) represents the number of defects that occur per million opportunities in product manufacturing. As one of the main criteria of Six Sigma, it was calculated according to the following equation (1):

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

The effectivity calculation was carried out by defining the equation:

$$(1 - \text{DPMO}/1000000) \times 100 \quad (2)$$

The level of sigma calculation was carried out by defining the equation:

$$\text{V Normal } (1\text{-DPMO}/1000000;\ 1;\ 5;\ 1) \quad (3)$$

Calculations were carried out using Excel and STATISTICA Cz (***Stat Soft. Inc., 2013).

#### 2.1.2 M – Measurement parameters and critical process selection
#### 2.1.2. M – Mjerni parametri i odabir kritičnog procesa

Important answers to the questions about the essence of measurement are *What will we measure* and *What we want to measure.* The evaluation of the obtained values results in the selection of the critical process. The aim of the measurement was to reduce the variability of the pressing process - the operation of gluing with the output of quality parts and low occurrence of misalignments. The second step was to define a specific quality mark, namely the weight of the adhesive coating on one side of the piece in g, which was subsequently calculated as g/m$^2$. The nominal value of the quality mark according to the technical conditions and the processing scheme for the oak veneer was 52 g/m$^2$ with a tolerance of ± 4 g/m$^2$. Upper control value USL = 56 g/m$^2$ and lower LSL = 48 g/m$^2$. The pressing process was performed on a synchronized line. The production equipment, whose competence was examined, was the adhesive application. Most misfits were found on the machine. In the application design and implementation of the Six Sigma Methodology, the values of the glue weights were used to determine the variability of the pressing process - the application of the adhesive through the coefficients of capability. In the calculation of the indexes, the process is generally assumed to be stable, the observations are statistically independent and have a normal distribution. In our experiment, we have used indexes of competence, which are considered as first generation indexes.

**Capability index $C_p$** is an indicator of the potential capability of the process and characterizes the dispersion of the process. Generally, it is the ability of the process to achieve values with lower variability relative to the tolerance interval. To calculate $C_p$ index, we used the equation (4):

$$C_p = \frac{USL - LSL}{6\sigma} \tag{4}$$

Where
USL – upper tolerance limit
LSL – lower tolerance limit
$\sigma$ – standard deviation
$6\sigma$ – $3\sigma$ on the left and $3\sigma$ on the right on the target value T

In practice, $C_p$ = 1.33 can be considered as the minimum admissible value, because there is always a certain fluctuation, and the measurement process is never in a perfectly matched state. Boundary 1.33 should be considered earlier for the measurement process. This criterion corresponds to approximately three discrepancies on one tolerance limit for the production of 100,000 pieces. For the newly introduced process, the required index values are higher (e.g., $C_p$ = 1.50). At $C_p$ = 1.67), and virtually zero percentage of nonconforming products is expected. The $C_p$ limit value for comparison was set at $C_p$ = 1.33.

**Critical capability index $C_{pk}$** is an indicator of the actual, real capability of the process. This index is characterized not only by the variability of the quality trace, but also by its position in relation to the defined tolerance area (tolerance field), i.e. the distance of the upper or lower limit from the mean value.

$$C_{pkUSL} = \frac{USL - \bar{\bar{X}}}{3\sigma} \qquad C_{pkLSL} = \frac{\bar{\bar{X}} - LSL}{3\sigma} \tag{5}$$

Where
USL –upper tolerance limit
LSL –lower tolerance limit
$\bar{\bar{X}}$ – average mean value in subgroups, overall selective mean
$\sigma$ – standard deviation

Capability index always considers the lower value:

$$C_{pk} = \min(C_{pkUSL}, C_{pkLSL}) \tag{6}$$

#### 2.1.3 A – Analysis of measured data
2.1.3. A – Analiza izmjerenih podataka

On the basis of conclusions from the Measure phase, the Analysis phase emphasized the identification of the main problem, identification of possible causes and identification of the mistakes that caused the variability of the pressing process - the application of the adhesive. The brainstorming method was used to interpret the analyzed measurement data, to identify a particular problem, to arrange the possible causes of the problem, and to form the Ishikawa chart.

#### 2.1.4 I – Improve phase
2.1.4. I – Poboljšanje

The main objective of the Improve phase is the elaboration and implementation of the design of the reaction plan for the pressing process - application of the adhesive. The response plan includes a graphical representation of the location of the glue weight values in the individual bands of the flowchart, and the procedure to be followed by the operator in setting, measuring, checking and transmitting information. On the basis of the instructions given in the reaction plan, measurements were carried out with the time gap in the verification of the measures to reduce the misalignment due to the poor application of the adhesive in the critical pressing - gluing process. In the Improve phase, the following tools and methods were used: brainstorming, Ishikawa diagram, $C_p$ and $C_{pk}$ process capability indexes, sigma process, histogram, industrial statistics & Sigma. In the furniture manufacturing process, it was essential to achieve a glue coating according to the 52 g/m$^2$ technology with a deviation of ± 4 g/m$^2$, which in our case was a regulated quantity.

#### 2.1.5 C – Control phase
2.1.5. C – Kontrola

Since the controlled variables were measured on a continuous scale, we used control in the Control phase to illustrate a pair of control charts. One graph characterizes the position of the controlled variable - the mean value (diameter) and the second is used to regulate the variability of the controlled variable by means of the regulation of the span and standard deviation. The control count determined the number of subgroups, the number of selections $k$ = 20. The control interval (constant time interval between two consecutive selections) was determined based on technological limitations every 20 minutes. The range of sub-groups was determined, the selection size $n$ = 5, which represented the number of controlled products in one subgroup $k$. Overall, 100 measurements were taken. In the process, the necessary conditions for regulation were provided, namely the immediacy of all known effects, as well as the equipment of the workplace and the training of employees. Descriptive Statistics module and Industrial Statistics and Sigma module - Quality Management Plans were used for the calculations.

**Control chart -** $\overline{X}, R$ is the most commonly used control chart. It allows you to track the entire distribution, making it easier to find a source of significant impact. This is a combination of two charts. One is the arithmetic average $\overline{X}$, with drawings control limits $UCL_{\overline{X}}$ and $LCL_{\overline{X}}$. In the second chart, the selection range $R$ draws the regulatory limit $UCL_R$ and $LCL_R$. The values of the relevant indicators $\overline{X}$ and $R$ are determined for each selection. The average values obtained $\bar{x}_1, \bar{x}_2, \bar{x}_3, \dots \bar{x}_n$, are used to calculate the diameter (7). The values $R_1, R_2, R_3, \dots R_n$ obtained by (9) are used to calculate the average of the range (9):

$$\bar{x} = \frac{1}{k}(\bar{x}_1 + \bar{x}_2 + \dots\dots \bar{x}_n) = \frac{1}{k}\sum_{i=1}^{n} x_i \tag{7}$$

$$R = xmin_{\max} \tag{8}$$

$$\overline{R} = \frac{1}{k}(R_1 + R_2 + \dots\dots R_n) = \frac{1}{k}\sum_{i=1}^{n} R_i \tag{9}$$

For the calculation of control limits UCL and LCL for control charts, values $\bar{x}$, R and conversion coefficients $A_2$, $D_3$ and $D_4$ are used for the average and range within a subgroup n = 25, in accordance with the norm Shewhart regulatory charts STN ISO 8258.

The control limits are calculated to determine the width of the field in which the diameters ($\overline{X}$) oscillated in a range ($R_i$). The control chart parameters for the average and range are calculated by Hrubec *et al.* (2009) and Terek and Hrnčiarová (2004) as follows:

The upper control limit for the average

$$UCL_{\overline{X}} = \overline{X} + A_2 \cdot \overline{R} \tag{10}$$

The lower control limit for average

$$LCL_{\overline{X}} = \overline{X} - A_2 \cdot \overline{R} \tag{11}$$

The central line for average

$$CL = \overline{\overline{X}} \tag{12}$$

The upper control limit for range

$$UCL_R = D_4 \cdot \overline{R} \tag{13}$$

The lower control limit for range

$$LCL_R = D_3 \cdot \overline{R} \tag{14}$$

The central line for range

$$CL = \overline{R} \tag{15}$$

**Control chart -** $\overline{X}, s$

The control chart parameters $\overline{X}$ are calculated according to Eq 13-15. Parameters for the control chart according to Terek and Hrnčiarová (2004) are calculated as follows:

The upper control limit for standard deviation

$$UCL_S = B_4 \cdot \bar{s} \tag{16}$$

The lower control limit for standard deviation

$$LCL_S = B_3 \cdot \bar{s} \tag{17}$$

The central line for standard deviation

$$CL = \bar{s} \tag{18}$$

Conversion coefficients $B_3$ and $B_4$ are for the different ranges of subgroups n listed in the Shewhart regulatory charts STN ISO 8258.

**Control chart -** $\overline{MR}$**, s**

In the case of the individual variability control chart, the variability of the process varies as the control procedure uses the selective sliding range of the two subsequent measurements and is defined as follows:

$$MR_i = | X_i - X_{i-1} | \tag{19}$$

which is understood as the selection range $R$ in the absolute value for the selection range $n = 2$. The average sliding range is calculated according to the equation:

$$\overline{MR} = \frac{MR_1 + MR_2 + \dots MR_m}{m} \tag{20}$$

The control chart parameters ($\overline{MR}$, s) are calculated according to Eq. 21-23. According to Terek and Hrnčiarová (2004), the parameters for the control charts are calculated as follows:

The upper control limit for the sliding range

$$UCL_{MR} = D_4 \cdot \overline{MR} \tag{21}$$

The lower control limit for the sliding range

$$LCL_{MR} = 0 \tag{22}$$

The central line for standard deviation

$$CL = \overline{MR} \tag{23}$$

According to Shewhart regulatory charts STN ISO 8258, conversion coefficients $D_4$ are used for different ranges of subgroups n (***STN ISO 8258).

## 3 RESULTS AND DISCUSSION
## 3. REZULTATI I RASPRAVA

The analysis of source data in the production of 437,781 pieces revealed the resulting average DPMO values, efficiency and sigma level of selected company processes such as pressing, gluing of side surfaces of furniture parts, surface treatment, joining and manipulation. Worst values were reached in the pressing process, according to DPMO, which accounted for 107,536.58 defects per million opportunities; the output yield of the pressing process was expressed by an average efficiency of 89.27 % and an average sigma level of 2.7. The pressing process was based on the analysis identified as critical. Other processes showed efficiency over 99 % and sigma levels from 4.1 to 4.7. The company gives priority to saving the cost of disagreements by 10 % and increasing the level of sigma critical process from 2.75 to 2.85. Reducing the number of disagreements and thus increasing the customer satisfaction was considered a priority benefit.

**In the measurement phase,** values are measured by weight of the adhesive coating. The average adhesive weights in 12 sets of measurements and 576 samples ranged from 51.44 g/m$^2$ to 53.23 g/m$^2$. As a measure, the minimum adhesion value of the adhesive was

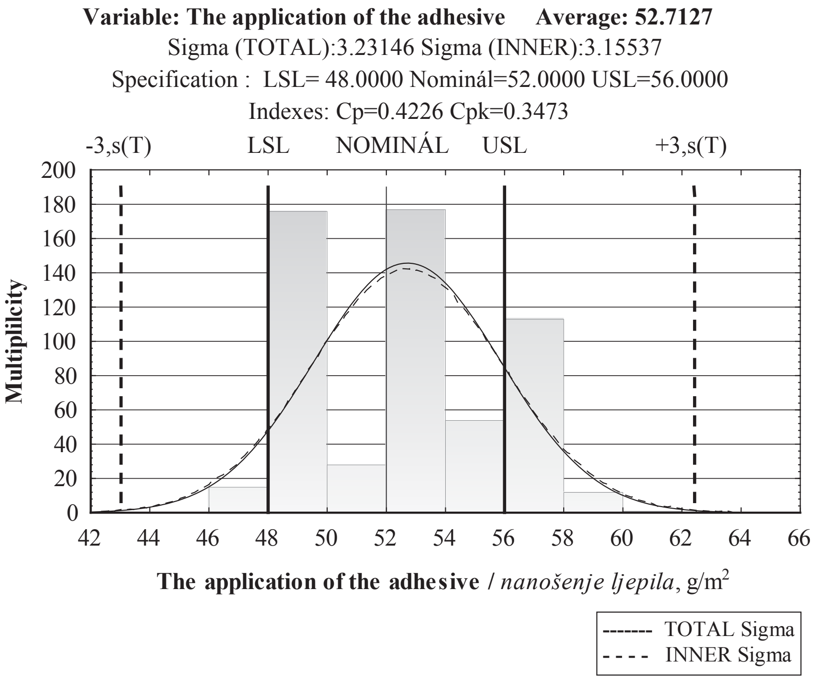


**Figure 1** Histogram of weight distribution in adhesive application
**Slika 1.** Histogram raspodjele mase pri nanošenju ljepila

46.26 g/m$^2$ and the maximum value was 60.50 g/m$^2$. The lower tolerance limit of 48 g/m$^2$ was exceeded in 16 cases, ranging from 46-48 g/m$^2$. For example, the weights exceeded the range of 56 to 58 g/m$^2$ above the tolerance limit in 138 cases. The upper tolerance limit was exceeded in a range of 58 – 60 g/m$^2$ in 15 cases and in one case in the range of 60 - 62 g/m$^2$. For illustration, the output modules of statistics to measure the weight of adhesive application are presented (Figure 1).

The ridge shape of the histogram indicates that the variability of the process was high and was not due to the natural variation/variability in the process. Index capability values were also low, the total $C_p$ index was 0.4226 and the critical index $C_{pk}$ = 0.3473. Both coefficients were less than 1.33, so it was possible to conclude on the basis of aggregate results **that the production process is inappropriate**. Furthermore, it was important to point out that the coefficient $C_p > C_{pk}$, which means that the process was not positioned at the center of the tolerance interval and responded to the deflection of the actual mean value of the process μ from the center of the tolerance interval. On the basis of the above, it was possible to conclude that there were definite, systematic causes in the process.

**In the analysis phase**, attention has to be paid to checking the technical parameters of the adhesive -

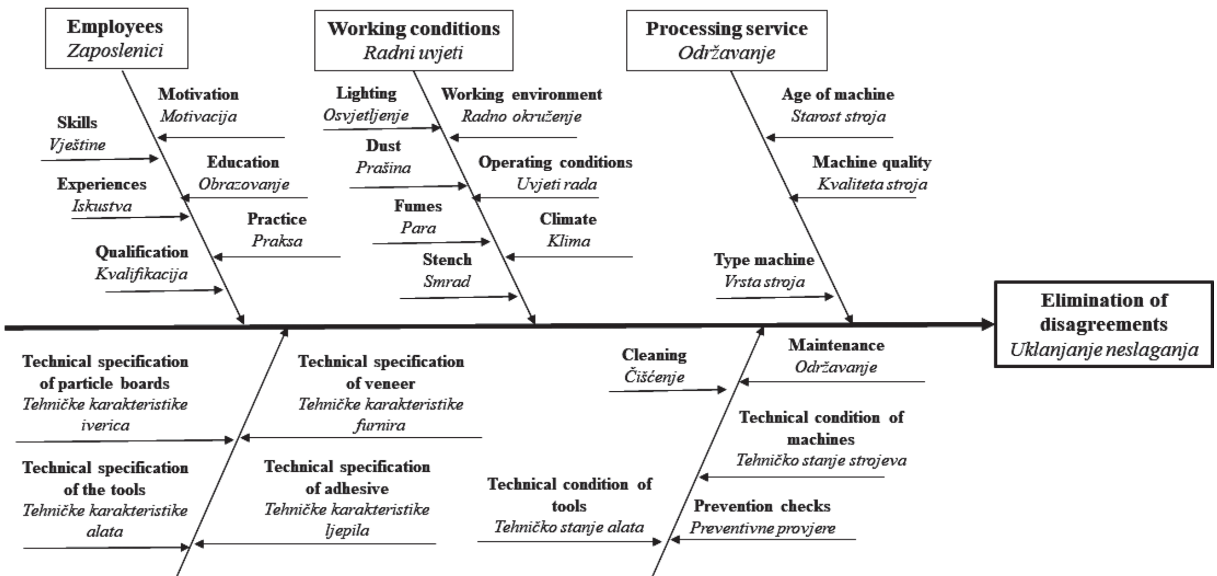


**Figure 2** Ishikawa diagram of decomposition of elimination of disagreements
**Slika 2.** *Ishikawa* dijagram dekompozicije uklanjanja neslaganja

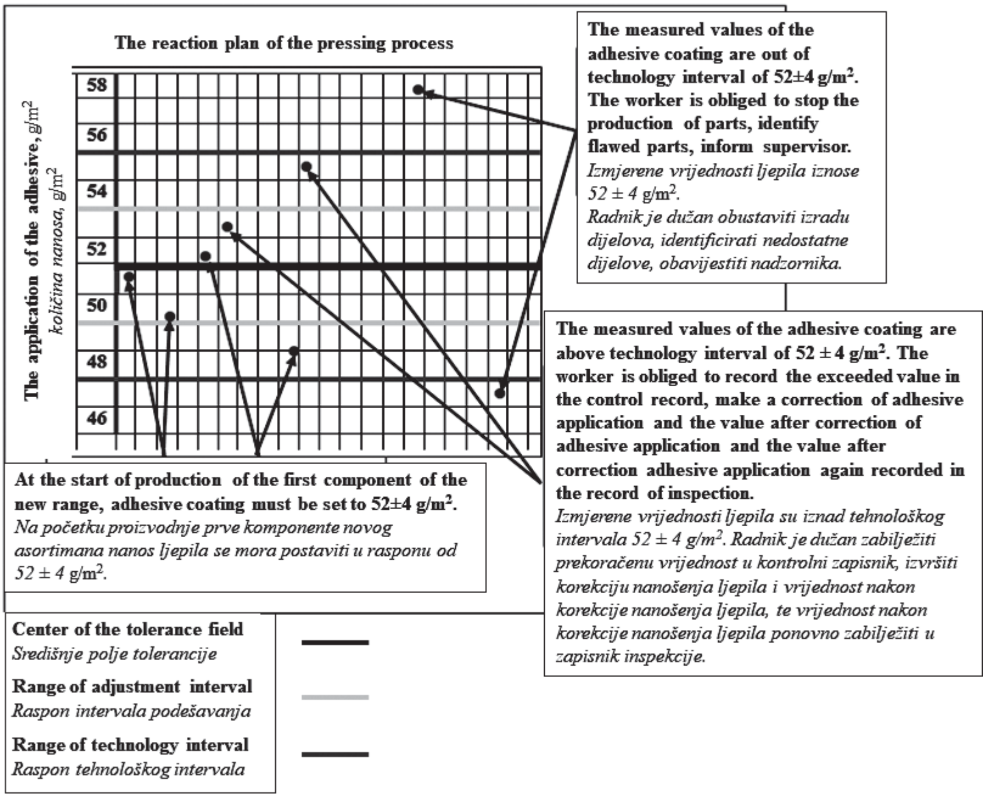


**Figure 3** Draft of the reaction plan for pressing
**Slika 3.** Nacrt reakcijskog plana prešanja

such as temperature and viscosity. These parameters had a primary effect on the weight of the adhesive coating applied on the chipboard parts to which the oak veneers were glued. The impact of non-compliance with the chipboard and veneer technical parameters did not materialize significantly during the measurement. The form of disagreement was found defective with respect to technological discipline by the operator of

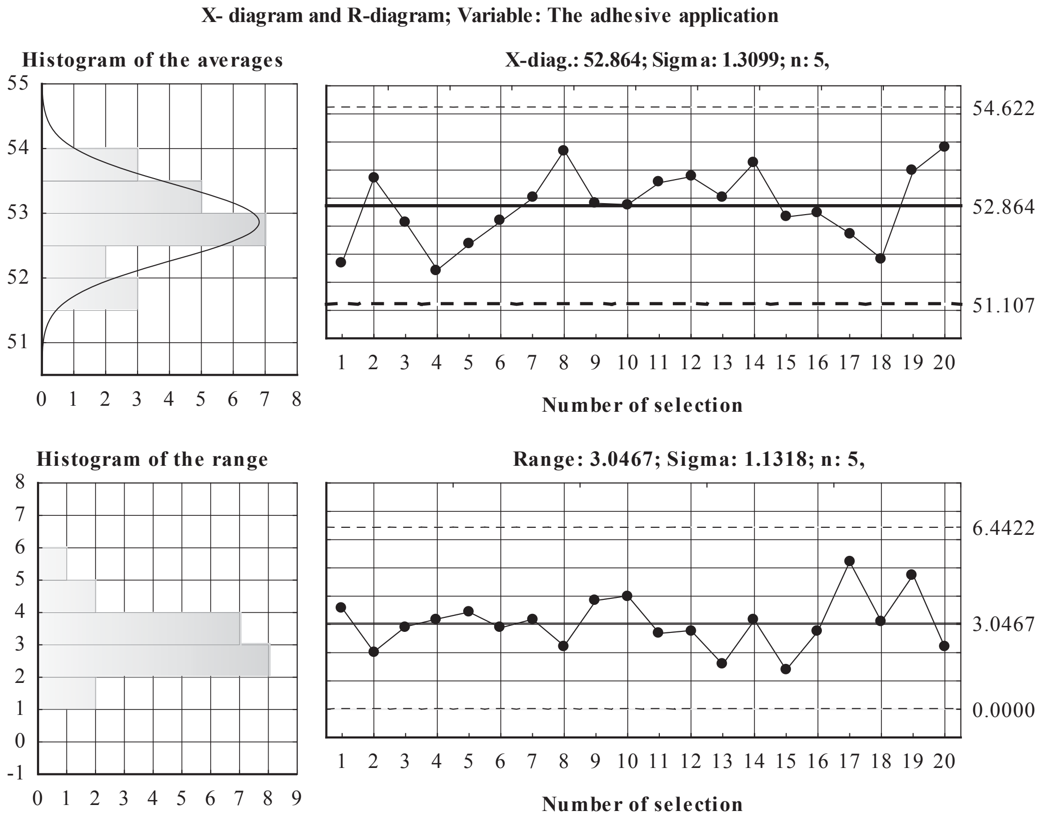


**Figure 4** Control charts and histograms of averages and range for the adhesive application
**Slika 4.** Kontrolni dijagrami i histogrami prosjeka i raspona nanosa ljepila

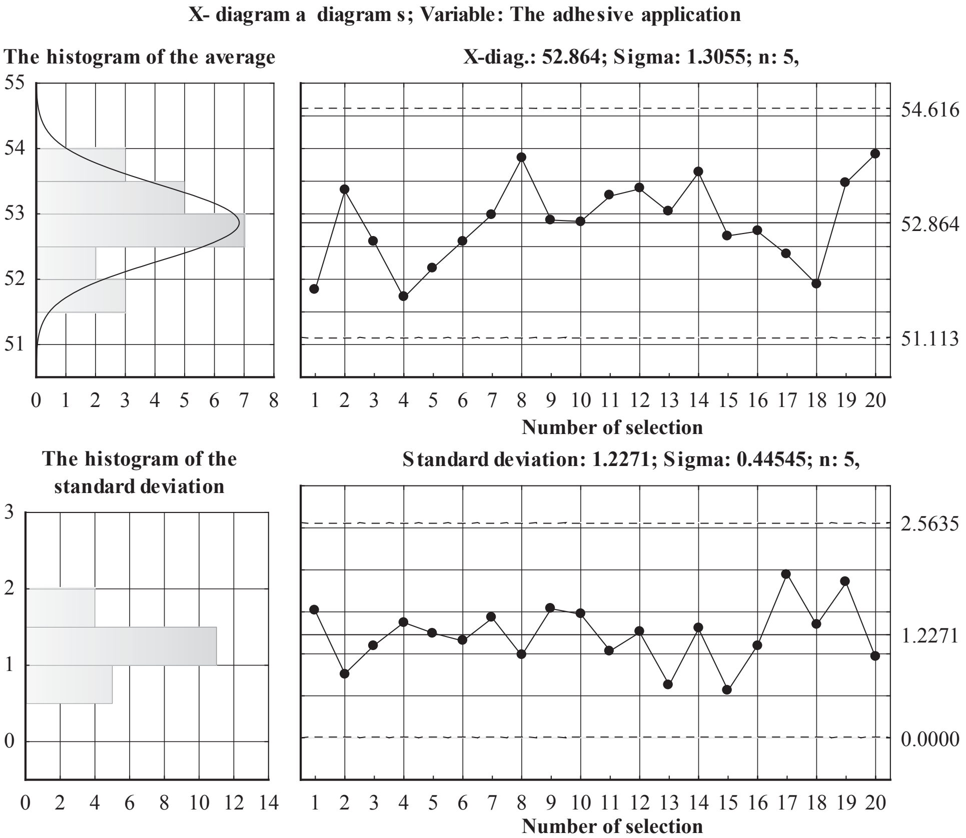


**Figure 5** Control charts of average and standard deviation for the adhesive application
**Slika 5.** Kontrolni dijagrami i histogrami prosjeka i standardne devijacije nanosa ljepila

the adhesive application, particularly when setting the adhesive coating. Low adhesion of the adhesive resulted in dry places. In order to avoid this error when applying the adhesive, the operator adjusted the adhesion of the adhesive that exceeded the upper limit. Problems also arose due to the change in the type of adhesive. The foaming was used to reduce the weight of 82 g/m$^2$ to 52 g/m$^2$. The Ishikawa diagram design, which depicts the decomposition of the causes of the first stage to the causes of the second and third stage, is shown in Figure 2.

In the Improve phase, the reaction plan was developed as measures to eliminate the disagreements in the process. The draft of the reaction plan for the pressing is shown in Figure 3.

Control was performed in the Control phase. From the control diagrams of the averages and the range for the controlled variable - the adhesion of the adhesive showed that the measured values were not outside the control limits of the respective control diagram. In this case, it was possible to assume that the process was stable and that the calculated control limits could be used in the statistical regulation of the given variable as shown in Figure 4.

The control charts of the standard deviation presented in Figure 5 show that the average value of the standard deviation is 1.2271 and the other values range from 0.5-2 and do not exceed the control limits. This confirms the assumption that common causes are present in this process.

For a more detailed assessment of the situation, a selection range of n = 1 was chosen as well as the possibility of using a control chart for individual measurements as shown in Figure 6. In this case, the flowchart of individual values with a control chart of moving ranges was used. From the control chart of the moving range as the difference between the results of two successive measurements, it can be seen that the average value is 1.7827 and the largest group ranges between 0-1. This diagram would be better used if automated control and measurement were applied in the process, and if the measured quantity were measured for each product. This would be economical and time-saving.

**The economic evaluation of the implementation and application of selected methods and tools within Six Sigma**

Basic data for the economic evaluation of the proposal were the number of non-conforming parts of defects broken down by type. After the implementation of the Six Sigma tools, disagreements in the pressing process decreased by 20.89 % compared to the original state. The total amount of non-conforming parts in the pressing process was reduced as shown in Table 1. We can say that following the implementation of the proposed Six Sigma Quality Improvement, the cost savings of 16.47 % were achieved. The goal stated in the project charter, namely to reduce the cost of complaints and non-conforming products by at least 10 %, was achieved.

The improvement was observed in a reduction of DPMO and increase of efficiency. The sigma level increased from 2.75 to 2.95. One of the goals set in the project charter was to increase the sigma level from

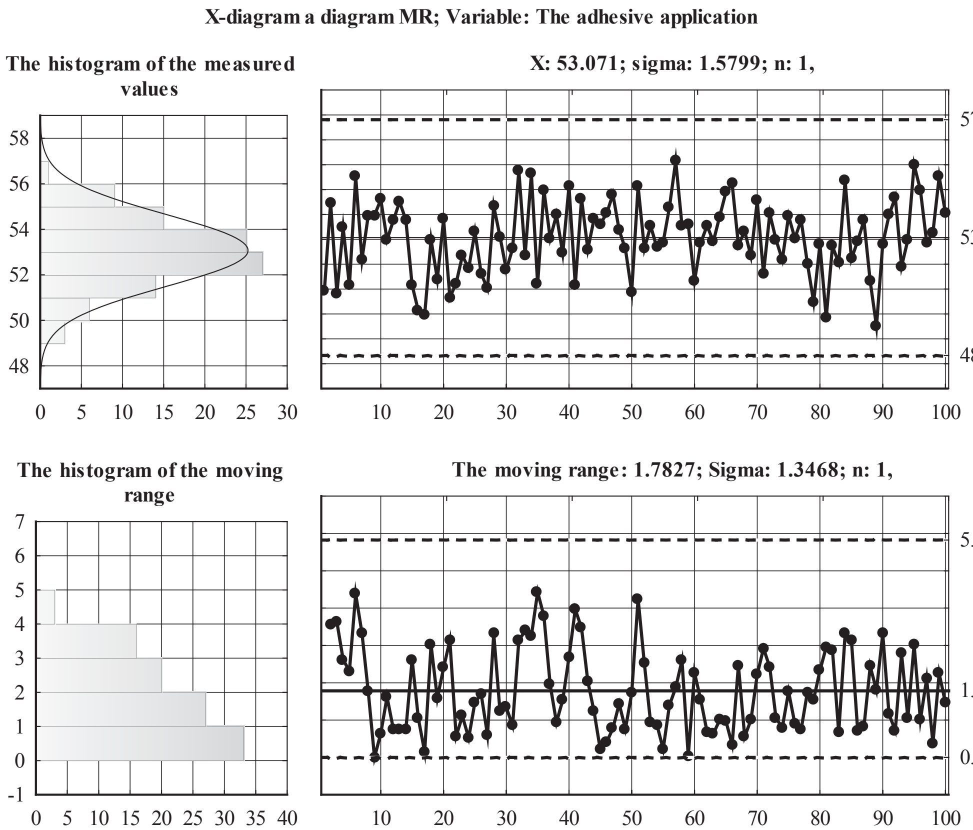


**Figure 6** Control charts of the measured values and moving range for the adhesive application
**Slika 6.** Kontrolni dijagrami izmjerenih vrijednosti i raspona nanosa ljepila

**Table 1** Economic evaluation of the draft changes in the pressing process
**Tablica 1.** Ekonomska procjena nacrta promjena u postupku prešanja

| **Situation** *Položaj* | **Number of non-conforming parts, pcs** *Broj nesukladnih dijelova, kom.* | **Price per piece, €** *Cijena komada, €* | **Total amount, €** *Ukupna cijena, €* |
|---|---|---|---|
| Before the change / *prije promjene* | 5,879.00 | 9.24 | 54,321.96 |
| After the change / *nakon promjene* | 4,911.00 | 9.24 | 45,377.24 |

2.75 to 2.85. Based on the above analysis, it can be stated that the charter goal regarding the pressing process has been fulfilled.

## 4 CONCLUSIONS
## 4. ZAKLJUČAK

Based on the above-mentioned theoretical knowledge and practical experience verified directly in furniture manufacturing processes, it can be stated that Six Sigma Methodology is appropriate for improving the quality and process performance in furniture manufacturing processes. Six Sigma application and implementation, using DMAIC steps, provides a system for defining, measuring, analyzing, improving and managing processes, by choosing methods that are not strictly prescribed, which can be chosen by the implementation team according to the needs and type of problems considered. The results of the case study presented in this paper have shown that, after the implementation of the selected tools of Six Sigma, non-conforming parts in the pressing process were reduced by 968 pieces, which represents 8,944.72 euros of cost savings. Specific outcomes of the case study provide guidance for the selection of methods and tools within the Six Sigma Methodology related to project management for process improvement and implementation of changes in processes. The woodworking industry and specific furniture industry represent a perspective industry whose advancement and growth of competitiveness stems from the use of new management methods, traditional and modern methods and procedures considered in this paper.

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