

PRODUCTIVITY UPSWING THROUGH TWO-PHASE CONTINUOUS PROCESS IMPROVEMENT MODEL: THE CASE OF APPAREL MANUFACTURER

İKİ FAZLI KONTİNÜ PROSES GELİŞTİRME MODELİ İLE VERİMLİLİK ARTIŞI: KONFEKSİYON ÜRETİMİ ÖRNEĞİ

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ABSTRACT

Changes in the market in the apparel industry require changing modes of production and lead to the need to enhance production. One way to respond to such changes is the implementation of continuous process improvement. Two-phase Plan-Do-Check-Act (PDCA) procedure for continuous process improvement in the apparel industry was designed, and experimentally verified in the company in Serbia. Effects of the implementation were measured through productivity. The workplace layout, material handling system, and workplace organization were improved and the results show a significant increase in productivity. This study presents original suggestions to practitioners about how to implement continuous process improvement and make significant productivity improvements in the apparel industry.

Keywords: Productivity, Continuous improvement, PDCA cycle, Apparel industry, Sewing.

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1. INTRODUCTION

Textiles and apparel is a major sector for the industrialized and lesser developed economies, and represents a key part of employment in Europe (1). The textile and clothing industry is facing great challenges due to its highly competitive nature, which forces firms to operate more efficiently in order to survive (2). In modern business conditions, companies have to provide a competitive advantage on several grounds: cost, quality, speed of delivery, reliability of delivery, monitoring changes in demand, and speed of introducing new products (3). "One of the most important factors which increase competitive capacity of companies is to use their production bases in the most effective way" (4). The fundamental concept considering the efficient and effective use of resources is productivity – usually defined as a ratio between output and input (5). Companies are constantly looking to improve productivity, through many different methods, such as innovations, waste reduction, labour cutbacks or simply speeding up production (6). Waste reduction and speeding up production can be achieved through continuous improvement

and lean. Continuous improvement (CI) includes programs and initiatives which emphasize incremental improvement in work processes and outputs (7), and can be described as "a capability of exploiting existing resources and/or of dynamically reacting to changing conditions and requirements in manufacturing that evolves over time" (8).

Lean manufacturing appears to hold considerable promise to address the demand for competitiveness (9). Lean manufacturing is one of the most influential paradigms in manufacturing, and its shop floor techniques and production philosophies are widely recognized in the industry (10). The term "lean" was promoted in the book „*The machine that changed the world*" (11), where the authors used the term "lean" to describe Toyota's way of production. Toyota's production system (TPS) was created out of necessity, because there was not enough money to fund mass production. TPS is successfully applied in a number of companies that were in a desperate situation, and have been able through its application to re-establish positive performance. Lean manufacturing consists of a variety of

principles and techniques with the same ultimate goal: to eliminate waste and non-value-added activities in every production or service process in order to give the most satisfaction to the customer (12). Womack and Jones (13) defined five lean principles to eliminate waste in organizations: specifying value, identifying the value stream, flow, pull, and perfection.

CI efforts are closely linked to the lean principles, especially the elimination of waste (8). While the principles of lean are relatively constant, there are many different practices of lean implementation (14), and every organization's lean journey is unique (15), because each organization should develop its own lean and continuous improvement practice, based on its technical and organizational context (16).

Based on interviews and case studies of the application of lean in the textile industry, Hodge et al. (12) concluded that the implementation of lean has been introduced into textile companies just recently. The authors were mainly oriented to the implementation of lean principles or specific techniques in the apparel industry (17,18), while others worked on developing models for lean implementation in the textile industry or the apparel sector based on structured surveys, observations, and on-site interviews (12,19).

This research addresses the implementation of the lean and continuous improvement practice through a model specifically developed for the apparel industry, and also discusses the effects of the developed model on productivity. Model is based on Plan-Do-Check-Act (PDCA) cycle, a well known model for continuous improvement (20). For this study, action research was chosen as a type of case study research, because the "action research is the scientific approach to study the resolution of important social and organizational issues together with those who experienced this issues directly" (21). The phases of action research are: plan, act, observe and reflect, similar to phases of PDCA cycle.

The research was conducted in an apparel company which operates in Serbia. The poor position of textile companies in Serbia in the global market arena is characterized by negative aspects that are reflected in reduced competitiveness, and a lack of technology, trained staff and standards (22). Export oriented apparel manufacturers in Serbia are required to produce a wide range of high quality modern products in small quantities, with short delivery times. In order to achieve and maintain competitive advantage, apparel manufacturers must operate according to principles of zero defect, on-time delivery, and price and relevant customization, which is quite opposite to the prevailing model of mass production (23), which is wide spread among Serbian apparel manufacturers. In addition, it is necessary for apparel manufacturers to increase productivity and efficiency in order to operate in international markets (2,24).

The research was conducted during the period of two years, which supports the rationale for using a single case study approach (25).

2. MATERIALS AND METHOD

For this research, "Javor" was chosen as a representative apparel company in Serbia. This firm is export oriented, with more than 80% of its products intended for foreign markets.

Its major products are: men's shirts, blouses, boxer-shorts, pyjamas, protective clothing, and bedclothes, with 174000 pieces of monthly production. The production in "Javor" was predominantly organized according to principles of mass production: small numbers of different products are manufactured in large batches; equipment layout is fixed; material is "pushed" through production in lots; internal transport is carried out by hand or by fixed transportation line; employees are narrowly specialized and self-taught; the working method is not defined and time standards was not precise. Apparel production is divided into five phases: cutting, sewing, cleaning from excess thread, quality control, and ironing and packing. The cutting is carried out by stacking a number of layers of material of the same colour, and cutting out a greater number of pieces of the same size. The cut pieces are pushed into the sewing department, on the first operation. The workplaces are arranged around the central table for material disposition. After the first sewing operation is done on all pieces, the batch is pushed to the next operation, and this procedure is repeated until the last sewing operation. After that, one piece is cleaned from excess thread, inspected, ironed and packed. The same colour and size pieces are packed in one box. In today's conditions, this production model cannot provide competitive advantage, since it carries with it efficiency problems.

2.1 Material

The company started apparel production in 1960's, and became a leader in the production of men's shirts as its basic product constituting more than 70% of the production program. The study was focused on men's shirts sewing process.

2.2 Method

The goal of the process improvement project was to increase the volume of production and sales of high quality products according to customer requirements, through the joint efforts of all employees, and better use of available resources. The second goal was to train brigadiers and workers to work on process improvement independently. This project involved researchers, management of the company, and brigadiers and employees. The research was conducted during the period of 24 months.

In order to accomplish the goals, the two-phased PDCA model for continuous process improvement was designed through action research and presented on Figure 1.

The model takes into account workplace layout, material handling and workplace arrangement (ergonomic). The approach is based on the "learning by doing" principle.

The first phase of the model includes four steps: analysis and design of a new setup, improvement through line optimization, new setup check, and production line management.

The *analysis and design* include: analysis of production program, machinery, space, current work method, and design of new layout and transport routs, electrical installations, air steam, and lighting and setting-up types and a number of transport vehicles based on the previous knowledge about lean manufacturing and the results of analysis. The researchers proposed solutions and management was responsible for purchasing the proposed

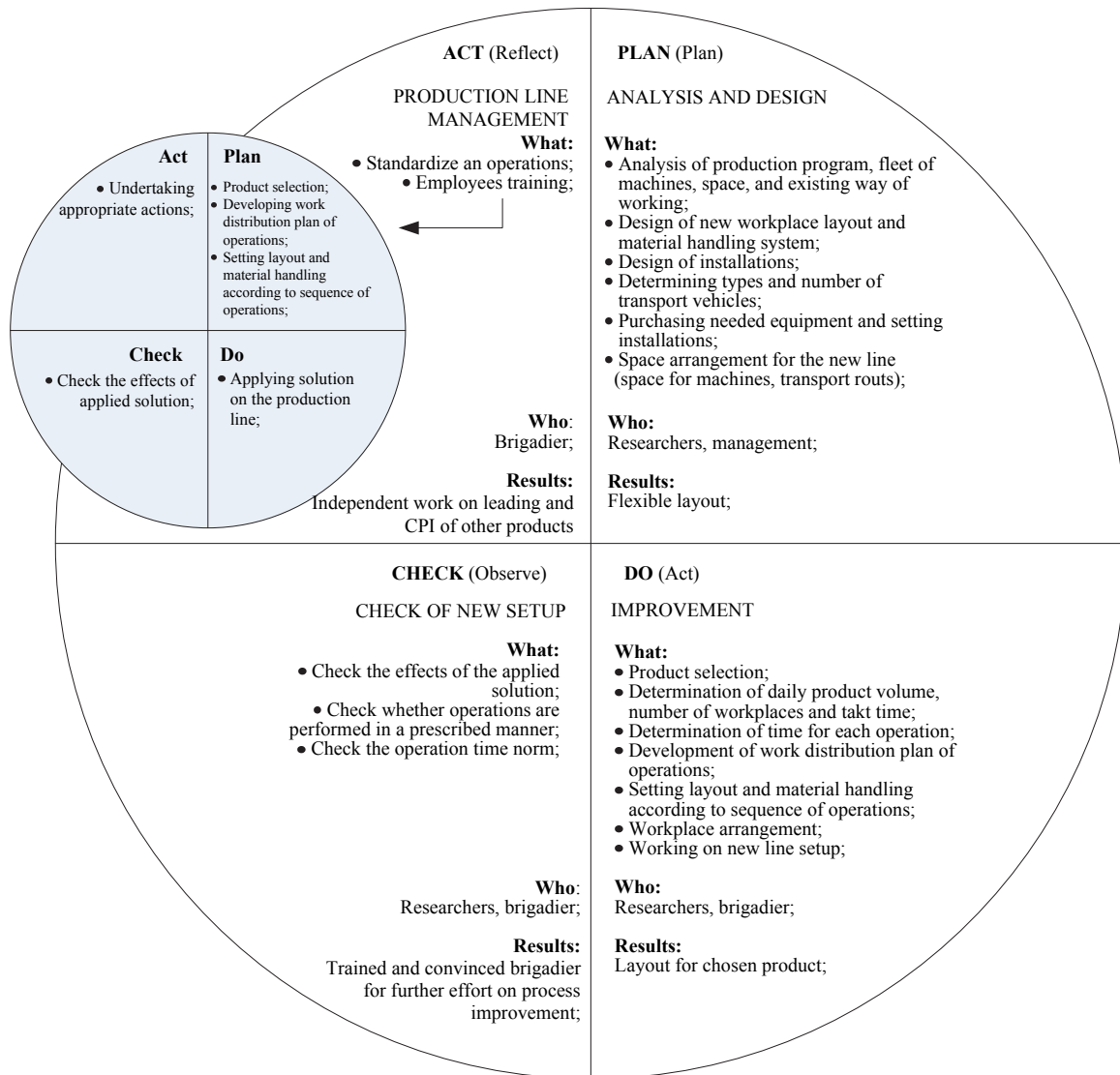


Figure 1. Two-phase PDCA continuous process improvement model

equipment. At the start of the process improvement project pilot, the sewing line was selected as the pilot line for improvement. Problems in sewing arose from the insufficient training of the workers and poor organization of workplaces. The workers were not trained for special stitching techniques, and they were able to perform only a small number of operations in a way they thought was appropriate. In the department Garment 1, eight brigades were formed. One of them was organized in a new way, and labelled Euro 1. The current state of material flow in presented on the Figure 2.

The workplace groups in the brigade were arranged in two columns around the central table, and electricity and air installation are positioned above the central table. There were smaller tables for material storage next to the workplaces. The current layout is shown in Figure 3.

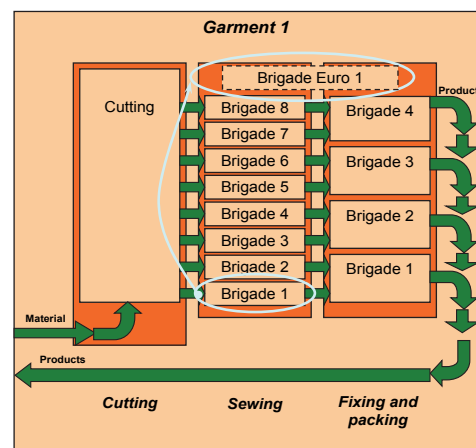


Figure 2. The current state of material flow in Garment 1



Figure 3. The current layout in production

This layout is typical for mass production, with an idea of “push” system in material handling. The working conditions were exacerbated by bad lighting, which was not at the appropriate height. The workspace was narrow and the central table was fixed to the floor. At the beginning of the line was a table for opening orders and job scheduling, and at the end were tables for cleaning thread and control. The sewing brigades were followed by the brigades for rework. The material flow through the brigade was not adequate; the workplaces were not lined up according to the sequence of operations, which affected transport path lengths. The separated group of presses and irons also interrupted the material flow. The large central table and the narrow space hindered machine movement, so it was hard to change the layout according to the specific product. The brigadier and the server were responsible for the material transport between the cutting department and the sewing brigade. The material was handled manually, or with trolleys. The cut pieces for one order were gathered in bundles, which is then transported to the brigade. At the beginning of the brigade, the bundle was opened and the pieces were scheduled to the workplaces by the brigadier or the server, so a large quantity of the material was in queues waiting to be processed. The disposal space was not defined, and this caused the mixing of the materials from different bundles and material losses. Improvement started with the creation of a flexible layout. In this phase the central table was eliminated, the electric and steam installations were rearranged, and appropriate lighting was set. The workplaces in the sewing department were arranged in two columns, with 2.4m between them for a transport path. Each workplace was 1.8m in width, consisting of a sewing machine, chair, and other necessary tools. These changes resulted in an empty space, which facilitated fast and easy layout changes, according to the needs of a specific product production process (Figure 4).

The researchers proposed the use of different types of trolleys as means of transport, depending on the phase in production. The trolleys were labelled by colour (depending of the sector they are transported to) and by different numbers (depending of the sequence of material processing). The result was a flexible inner-transport system, designed to meet the needs of the flexible layout.



Figure 4. New layout and workplace organization

The improvement phase includes a specially designed improvement procedure based on improving the working method. The main goal of this step is line optimization for producing a specific product, and training brigadiers to understand the system and to implement the improvement procedure depending on the chosen products which are to be produced. Brigadiers and employees are required to actively participate in asking questions about the new way of working, and providing ideas on how the current situation can be improved. In this phase, a new flexible system is to be utilized, by arranging workplaces and establishing transport paths according to the sequence of operations for a specific product. The selected product in the sewing line was a men’s shirt. The daily production volume and average production time were calculated according to customer demand. Each operation was analyzed on the motion level, in order to eliminate unnecessary movements and increase sewing quality. The unnecessary motions of reaching and transferring were eliminated, and the necessary motions were shortened and extenuated by placing parts on in the appropriate position. The quality problem in stitching occurred during the stopping and restarting the machine, so the workers and the brigadier were additionally trained in the sewing technique, in order to complete a stitch in one go. After analysis of men’s shirt sewing operations, time for each operation was determined and a work distribution plan was developed. The workplaces were grouped into four areas: collar and cuffs, front of the shirt, back of the shirt and sleeves and shirt assembly. Layout is adapted to follow sequence of operation for men’s shirt. Material handling is conducted with a specially constructed trolley, with enough space to store 10 to 25 pieces. The first workplace in the line is for the job that opens the process, and trolley preparation. Trolleys were “pulled” between workplaces according to a defined schedule, and pieces are sewn together according to the First-In, First-Out (FIFO) principle, meaning that pieces are sewn together in order of their arrival. This way of material transportation enables visual production flow control, where bottlenecks and idle work centres can easily be seen. The brigadier’s assignment was to monitor production and take actions which will enable uniform trolley movement. The workplaces were organized in a way where material is taken and placed on the left-hand side, with additional devices being used to decrease the number and length of movements. During this phase, the line started to operate according to the new setup.

The next step was a *new setup check*. The aim is to verify if operations are performed in a prescribed manner, check time norms, and record effects in the production volume. By applying two steps of the first phase, average productivity for men's shirt increased from 9,0 pieces by the present worker in the previous year before implementation to 12,0 pieces in pilot line, and conditions for further process improvement were created. The most important result of this phase was convincing the brigadiers that the new way of working is giving results, and providing them with the skills needed for further efforts on process improvement.

The last step of the first PDCA phase is *production line management*, which includes standardization of operations, further employees training and continuation of management and improvement of the line for the chosen product.

The second phase of the model implies that brigadiers independently conduct the necessary adjustments for each product and continuously improve the current state. Brigadiers prepare a work distribution plan, change the layout of workplaces in the group and transportation paths according to the sequence of operation for a specific product, help workers to organize the job, train them, and control whether operations are performed in a prescribed manner. In addition, brigadiers are responsible for improvements and undertaking appropriate actions within the workgroups. During this phase, brigadiers gain necessary experience in implementing new group organization and new process improvement procedure. Moreover, in this phase the brigadier takes over the researcher's role and trains employees to work further on the process improvement. The second phase of the model was implemented in two additional sewing lines. This two-phase approach of the continuous process improvement enables creating the "avalanche effect" in the firm through spreading the process improvement to other lines and providing brigadiers and workers with necessary skills for process improvement. During the observed period, the proposed model was also used in cutting and reworking departments, in order to improve their performance as well. The sewing process improvement is achieved by changing the workplace layout, material handling system, workplace arrangement and standardization of operations. These changes enabled waste elimination (delays, unnecessary motions, transportation) and the adoption of lean principles: creating the flow, pull system and path to perfection.

3. FINDINGS

In order to demonstrate the relation between the implementation of the proposed model and increased productivity, eight brigades were monitored over a 24 months period. Brigade productivity was measured as a ratio of earned and actual hours in this period. Earned hours is the time during which products are being manufactured, and actual hours is time spent at work. Earned hours is calculated by multiplying a number of pieces by the determined time norm for one piece. Actual hours is calculated on the basis of daily attendance records. Average productivity can be over 100% if workers make pieces of garment in a shorter period of time than the one initially determined. In order to determine whether changes in productivity can be attributed to the implemented procedure, the Kolmogorov-Smirnov test for one sample and ANOVA for a single factor were conducted with post-hoc Bonferroni and Tamhane procedure, using the SPSS Statistics

software package. Three brigades (sewing lines) were improved according to the model described earlier. The first phase of the model was initially implemented in brigade 1, starting in the eighth month of the referenced period. The second phase of the model was initiated in the tenth month in brigade 2, and in the fifteenth month in brigade 3. The dynamics of the model implementation is given in Table 1. One field in the table represent one month.

During the referenced period, the average productivity of the eight brigades was measured for each month. The data are divided in into three groups:

- Group I – brigades that were to be improved (brigades 1, 2, and 3) – experimental group –pre-implementation productivity measures;
- Group II – brigades that were not improved (brigades 4, 5, 6, 7 and 8) – control group –productivity measures from the whole period;
- Group III – improved brigades– Euro brigades (euro 1, 2 and 3) – experimental group – post-implementation productivity measures.

Figure 5 shows average productivity of eight brigades during the referenced period.

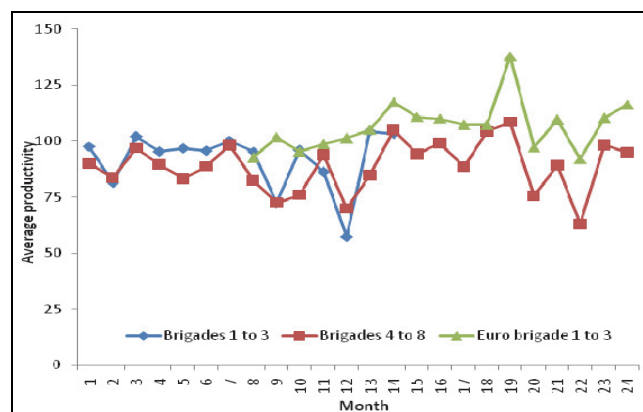


Figure 5. Average brigades productivity in 24 months period

Figure 5 shows that the average productivity of Euro brigades (Group III) is greater than the productivity of the brigades in Group II. In order to test if this difference is significant, productivities for each group were compared between them. In order to test if productivity improvement can be attributed to CI model implementation, one factor ANOVA was conducted. Groups I and II were compared in order to check if their productivity was equal before improvements. Group I and III were compared in order to determine if productivity increased after the implementation of CI model in brigades 1, 2 and 3. Group III and Group II were compared in order to determine if there is a difference in the control group and the experimental group, after the CI model was implemented. The average productivity per month of an individual brigade was used as sample unit. The total sample size was 185 out of 192 (24 months* 8 brigades – 7 months), because one brigade from Group II was inactive for 7 months due to the collective vacation and decreased demand. The sample size in Group II was 113 elements (24months*5brigades-7months). Table 2 shows average productivity for all three Groups. It can be seen that the coefficient of variation is lower in the Euro brigades compared to the brigades from Group I and II, which means

that the Euro brigade experienced a lower level of variations in productivity after CI model was applied, compared to the period before the implementation. Kolmogorov-Smirnov test for one sample confirmed that the collected data follow normal distribution ($p > 0.05$).

According to variance analysis, which is presented in Table 3, it can be concluded that process improvement does influence the productivity, because the probability that the influence of this factor is the same in all three groups is equal to 0,000 ($F(2,182) = 30,124, p = 0,000$).

Effect size of 0,25 would be considered as large effect (26), so it can be said that there is large influence of CI model implementation on average brigades productivity. Leven's test for homogeneity of variances showed that probability that variances of productivity in all groups are equal and amounts 0,048. That means that with significance level of 0,01 hypothesis that all variance are equal can be accepted, and with significance level of 0,05 the same hypothesis can be rejected. Therefore, impact factor analysis was conducted with Bonferroni and Tamhane procedure (Table 4), with null hypothesis being that variances are equal.

Table 1. Dynamics of program implementation

Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Brigade 1																								
Brigade 2																								
Brigade 3																								

Before implementation	After implementation

Table 3. Analysis of variance of brigade's productivity

	Sum of squares	Degree of freedom – df	Middle square	F	Significance
Between the groups	11306,980	2	5653,490	30,124	0,000
Inside the groups	34157,182	182	187,677		
Total	45464,161	184			

After variance analysis, effect size was calculated with Equation 1:

$$\text{Eta squared} = \frac{\text{Sum of squares between groups}}{\text{Total sum of squares}} = \frac{11306,98}{45464,161} = 0,25 \quad (1)$$

Table 2. Average productivity for all three Groups

	N	Productivity of Group I Brigades 1-3	Productivity of Group II Brigades 4-8	Productivity of Group III Euro brigades1-3	Productivity Total
Sample size		30	113	42	185
Parameters of	Arithmetic mean	93,210	88,767	107,971	93,848
Normal distribution	Standard deviation	12,0573	14,6812	11,8950	15,7190
Coefficient of variation		12,9%	16,5%	11,0%	16,7%
Significance (two-tailed)		0,159	0,775	0,466	0,341

Table 4. Comparison of average brigade's productivity

Bonferroni procedure					
(I) Group of brigades	(J) Group of brigades	Mean difference (I-J)	Standard error	Significance	
I – Brigades 1-3	II – Brigades 4-8	4,4427	2,8137	0,348	
	III – Euro brigade	-14,7614(*)	3,2748	0,000	
II – Brigades 4-8	I – Brigades 1-3	-4,4427	2,8137	0,348	
	III – Euro brigade	-19,2042(*)	2,4758	0,000	
III – Euro brigades	I – Brigades 1-3	14,7614(*)	3,2748	0,000	
	II – Brigades 4-8	19,2042(*)	2,4758	0,000	

Tamhane procedure					
(I)Group of brigades	(J) Group of brigades	Mean difference (I-J)	Standard error	Significance	
I – Brigades 1-3	II – Brigades 4-8	4,4427	2,5987	0,254	
	III – Euro brigade	-14,7614(*)	2,8661	0,000	
II – Brigades 4-8	I – Brigades 1-3	-4,4427	2,5987	0,254	
	III – Euro brigade	-19,2042(*)	2,2970	0,000	
III – Euro brigades	I – Brigades 1-3	14,7614(*)	2,8661	0,000	
	II – Brigades 4-8	19,2042(*)	2,2970	0,000	

* Mean difference is significant at 0,05

Post-hoc comparison (Table 4) indicates that productivity improvement can be attributed to process improvement because:

- a) mean score for Group I (M = 93,21, SD = 12,06) does not differ significantly from Group II (M = 88,77, SD = 14,68), which means that brigades 1, 2 and 3 had the same productivity before improvement, as a brigades 4 to 8, which were not improved;
- b) there is significant difference between Group I (M = 93,21, SD = 12,06) and Group III (M = 107,97, SD = 11,89), which means that productivity in Euro brigades 1, 2 and 3 has been increased after CI model implementation, compared to the period before implementation; and
- c) there is significant difference between Groups II (M = 88,77, SD = 14,68) and Group III (M = 107,97, SD = 11,89), which means that after improvements, productivity in Euro brigades 1, 2 and 3 was increased compared to control brigades 4 to 8.

According to the results presented above, the null hypothesis that variances are equal can be rejected, so it can be concluded that there is a significant impact of process improvement on the productivity of brigades, and relative value of this impact is determined based on differences between average productivity in all brigades on the beginning and at the end of referenced period is calculated with Equation 2:

$$\text{Increase of productivity} = \frac{108,9 - 93,8}{93,8} \times 100 = \frac{15,1}{93,8} = 16,09 [\%] \quad (2)$$

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4. CONCLUSIONS

This paper describes the two - phase PDCA continuous process improvement model which was experimentally tested in "Javor" in the process of sewing men's shirts. The results show that, with the implementation of this approach, productivity is increased and in this case significant improvement was achieved. The shirt sewing process is improved with changes to the workplace layout, material handling system, workplace arrangement and standardization of operations which enabled flow production according to the pull principle. The result of the implementation is the line which can be changed quickly, according to the needs of a specific product. The implementation of this model contributes to creating the environment where workers, by working in the easiest, safest, and most efficient way, in a stable, clean and safe environment, with lowest costs, can achieve production of quality products according to customer requirements. The model also enables and facilitates the development of skills for brigadiers and employees needed for further efforts in process improvement. Although the research was conducted with sufficient rigor, and the devised model can be universally applied everywhere, the main limitation of this research is that it was done only in one company. Therefore, it would be beneficial to see if the good results could be replicated by applying the model to another apparel manufacturer, or even a company outside of the apparel sector.

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