

Improvement of the production processes based on the lean methodology

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Abstract: The project for improvement of the production process based on the Lean methodology in SMELT-ING DOO was implemented in four phases (mini projects). The detailed analysis of the work orders in the period of 9 months provided clear picture of the current situation. With the defined methodology and through mutual meetings with the upper management and the employees of the company, the project team managed to introduce and implement the following mini projects: improved visualisation, digital work order, implementation of 5S and portable tools trolley. All these mini projects have improved the organization of the production process and helped the process of waste elimination in the company.

Keywords: IMPROVEMENT, PRODUCTION, LEAN, PROJECT, WORK ORDER, VISUAL MANAGEMENT, 5S, MANUFACTURING.

1. Introduction

Lean is an approach to manufacturing that focuses on eliminating waste and improving workflow. It is particularly associated with the production system established at Toyota, with its twin pillars of just-in-time inventory management and automated quality control. In recent decades the principles of 'lean thinking' have been increasingly applied within the various industries to banish waste and create value [1].

The authors were part of an international project Increasing the Competitiveness of the Domestic SMEs in Order to Improve Their Cooperation with Foreign Investors' Companies [InComSMEs] where 6 SMEs from North Macedonia were selected and industrial projects were carried out, www.mf.edu.mk/incomsmes. This case presents one of the projects, implemented in SMELT-ING DOO.

SMELT-ING DOO was founded in 1996 as a company for trade of electrical materials. Since then, the company is constantly growing and investing in various other businesses in North Macedonia and the region. SMELT-ING DOO is famous for its flexibility and the individual approach to each of its clients. They produce electrical cabinets, complex metal assemblies and production of welding machines. SMELT-ING DOO team has provided significant support during the entire InComSMEs project. They were included in all training sessions organized by the Faculty of Mechanical Engineering – Skopje and the Technical University of Vienna. After they were selected as one of the companies for implementing this industrial project, the employees strongly engaged in the process and proposed many improvement ideas for their organization. The project plan for implementation of the project is shown in Figure 1.

Project name		Improvement of the production processes based on the lean methodology										
Phases		MONTH										
		Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	
1	Preparatory activities	■										
2	Collecting data and analysis		■									
3	Identifying and prioritizing problems			■								
4	Development of solutions				■							
5	Implementation of the solutions					■						
5	Monitoring of the solutions						■					
7	Standardization of the processes							■				
8	Preparation of documentation								■			
9	Preparation of the final report									■		
Project leader		Assoc. prof. Bojan Jovanoski (Faculty of Mechanical Engineering – Skopje, UKIM)										

Fig. 1 Project plan

2. Prerequisites and means for solving the problem

One of the first tasks that were completed in the phase of the project was an analysis of the layout i.e., the material flow on the

shop floor of SMELT-ING DOO. Figure 2 is presenting the material flow analysis for three specific products. The flow in the production area is chaotic and this is understandable because they have a heterogeneous product line. But there are no overlapping lines, as seen in Figure 2, which means that the current machine layout is acceptable. This means that the efforts of the project team shouldn't be directed towards the improvement of the transportation paths and reorganization of the production shop floor (redesign of the layout).

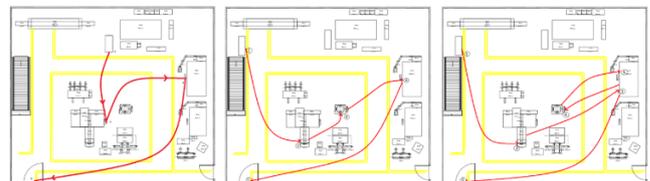


Fig. 2 Analyzed layouts and flow paths for the products (red lines)

After this, as shown in the project plan, in a six-month time span, a detailed analysis of one of their main client's programs was performed, according to the real manufacturing demand and work orders. The goal of this analysis was to determine the distribution of time for each product (and batch) and based on these findings, the team to propose future improvements (Figure 3).

NEEDED PROCESS CAPACITY										
Name of the process		Part number		Requirement				Monitored by		
Metal processing		GEH-0656		30				Aleksandar		
				Net Operating time in sec. (I)				Date		
				25.200				20-Mar-19		
				Basic time in sec.				Total changeover time in sec.		
#	Operation	Machine	Manual work A	Automatic work B	Machine work C = A+B	Changeover time D	Quantity during changeover	Time/part F=D/E	Summary in sec. Total time for one part G=C+F	Process capacity H=I/G
1	Trail		30	110	140	765	30	25.5	165.5	152
2	Cut through		165	920	1085	5	30	0.166667	1085.1	23
3	Grinding		605	0	630	5	30	0.166667	605.1	42
Total			800	1030						Max. output 23

Standard Work Combination Sheet										
Name of the process		Part number		Net Operating Time in sec.					Legend	
Monitored by				Date					→ Motion → Manual work → Automatic work → Waiting	
				Operational time in sec.						
#	Operation	Operator	Automatic work	Motion						
1	Taking material		5		10	20	30	40	50	
2	Set on the machine		65							
3	Positioning		8							
4	Positioning		20							
5	Cutting		900							
6	Taking out and control		87							
7	Grinding		605							

Fig. 3 Detailed analysis for specific products

From all these observations, a table containing all the products that SMELT-ING DOO is manufacturing for KEMET was generated, with the time needed for manufacturing (T_i) and setup time (T_{p_i}) for each machine separately. In the period when this observation was performed, there was no demand for all products. Therefore, for those products (that were not observed), the project team adopted the times for the most similar product that was observed during the project (if needed, some of the times were modified based on past experiences), Figure 4.

After processing the collected data, the project team analysed the work orders from the past year, to provide reliable analysis for

the utilization of the capacities. After this detailed analysis, a presentation in SMELT-ING DOO summarized the conclusions from the observations of the manufacturing process in the past months.

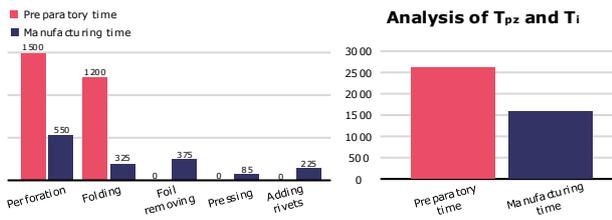


Fig. 4 T_{pz} and T_i analysis

Besides the fact that this analysis provided many various results such as the utilization of every machine for the selected production program, the team was especially interested in the setup time data – which are times that are not adding any value to the process. The results are shown in Figure 5.

Order ID	Order Name	Order Date	Order Status	Order Type	Order Category	Order Sub-category	Order Item	Order Qty	Order Unit	Order Price	Order Total	Order Tax	Order Net Total	Order Net Total (incl. tax)	Order Net Total (excl. tax)	Order Net Total (incl. tax)	Order Net Total (excl. tax)	Order Net Total (incl. tax)	Order Net Total (excl. tax)
1	1000000000	2020	Open	Standard	Standard	Standard	1000000000	1	1	1000000000	1000000000	0	1000000000	1000000000	1000000000	1000000000	1000000000	1000000000	1000000000
2	1000000000	2020	Open	Standard	Standard	Standard	1000000000	1	1	1000000000	1000000000	0	1000000000	1000000000	1000000000	1000000000	1000000000	1000000000	1000000000

Fig. 5 Detailed analysis of T_{pz} per product

3. Challenges

Right after the analysis of the production system, the upper management of the company organized several workshops including all employees from the manufacturing department. The project team was leading the process according to a previously set methodology. Before the application of each new tool or method, the team explained the tool/method and ensured that all employees are aware of its meaning and application. During the process, many ideas were proposed and through filling of CIP cards [2, 5] (Continuous Improvement Process) shown in Figure 6 the team prepared KAIZEN board, specially designed for SMELT-ING DOO, as shown in Figure 7.

The ideas were classified as mini projects and were assigned to a responsible team member:

- Improved visualisation (Bojan Nestorovski),
- Digital work order (Bojan Jovanoski),
- Implementation of 5S (Aleksandar Neveselov),
- Portable tool trolley (Zarko Angeleski).

Name		Date	
<input type="checkbox"/> Safety	<input type="checkbox"/> Quality	<input type="checkbox"/> Productivity	<input type="checkbox"/> Costs
Description of the problem			
5 Why analysis		Suggested countermeasures	

Fig. 6 CIP card template

KAIZEN is an approach that continuously improve operations and involve all employees [2, 4]. It is a business philosophy or system that is based on making positive changes on a regular basis, as to improve productivity [6]. For this project, a KAIZEN board was implemented where the team and the company employees can generate and monitor all the ideas for a particular topic. From total of 12 ideas, in accordance with the timeframe for this project, the

project team decided to prioritize 4 ideas for further development and implementation.

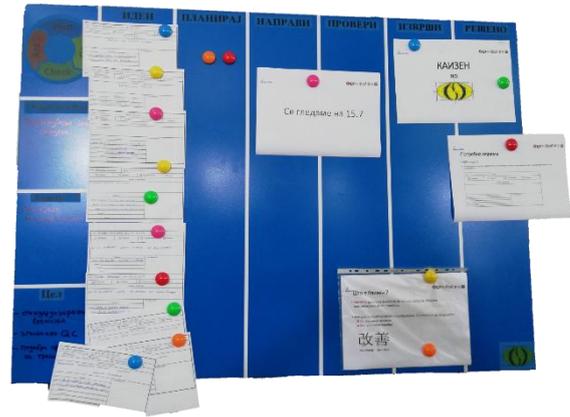


Fig. 7 KAIZEN board

4. Results and effects

It is very important to mention that from the start of the entire project and during the initial visits of SMELT-ING DOO, the project team could recognize a well-organized company and successfully set systems. All mini projects that are subject to this study, are simply improvements of the currently well-organized shop floor. All these projects were directed towards the elimination of the waste time (the non-value adding time).

4.1. Improved visualisation

The goal of this mini project was to enhance the visualisation of the manufacturing shop floor. During the project, many crucial positions were labelled such as the movement paths, the machines and most importantly, labels were placed on the tools needed in the manufacturing process (Figure 8).

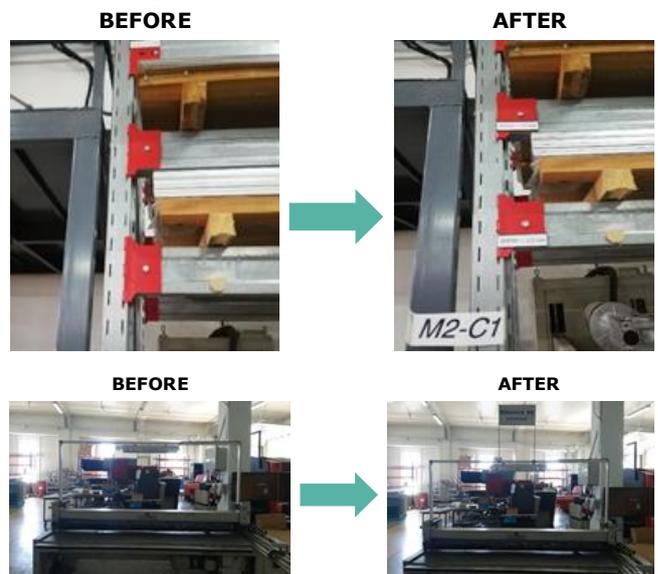


Fig. 8 Part of the improvements of the visualization on the shop floor

4.2. Digital work-order

SMELT-ING DOO had ideas for the introduction of ERP system. But considering that this company is connected to many other organizations that still don't use this ERP system, in this timeframe, implementation of such a system was ruled out. Instead, the project team prepared a solution that will still fulfil the requirements of the company for digital work order until the ERP system is implemented. Based on the observed times in the previous phase, a digital work order template was prepared in Microsoft Excel (Figure 9). This enabled flexibility for the employees, but also it was a system for better planning and control of the production.

Work order number _____							
Contract number	Order number	Client	Materials				
Product	Quantity	Starting date					
Delivery date	Completion date						
Notes							
#	Activity	Machine/tool	Time (sec.)	Batch time (min.)	Control	Responsible	Notes
0	Taking material						
1	Cut length						
2	Grind						
3	Grind						
4	Removing foil						
5	Press						
				Total (min)	or (h)	work	
							Finishing date
Control of the finished product							
Date							
Responsible							
Corrective measures							

Fig. 9 Digital work order with previously defined technology and times

4.3. Implementation of 5S

5S is an approach to organize, order, clean, standardize and continuously improve a work area. 5S is not just about housekeeping, it is one of the most efficiently working tools of Lean manufacturing [3]. This approach was introduced to SMELT-ING DOO's workplace to enhance the effectiveness of the production and eliminate unnecessary objects (devices, machines, documents, etc.). The steps to implement 5S are **sort, set, shine, standardize and sustain**.

The 5S activities usually seem very simple and easy, but the project team spent most of the time and energy on this mini project as they are time consuming. Sometimes, full implementation of 5S can take up to 3 years, but the project team had only 2 to 3 months. Considering the time constrains, the team focused only on the most frequently used machine, but also the machine where the T_{pz} values were the highest (as identified in the observations at the beginning of the project). The goal was to empower the employees to be involved in this process on a daily basis and therefore sustain the solutions set up with this project. Considering one of the most important goals of the project – to connect the output control of SMELT-ING DOO and the input control of their client, it was suggested to use the client's 5S checklist and adapt it accordingly (Figure 7).

Fig. 10 5S checklist

Чек - листа		Област					Внеси име на оддел		Забелешка	Вредност	Процент
1	2	3	4	5	6	7	8				
Безбедност											
1	Дали подеште патети, патети до ППА и патети за кола се одржуваат?					X		Да, патетите патети и патети за кола се одржуваат.			
2	Дали "СТОП" знамето и во функција и исто не е достапно место за работен?					X		Во функција и исто не е достапно место каде работниците може лесно да го пратат, доколку има потреба.			
3	Дали инфо-листа за електрика (средите) се чуваат затворени?					X		Да, списокот се чуваат затворени.			
4	Скоблата за лична безбедност се достапни и се во употреба?					X		Да.			
5	Многу е важно, се користат транспортни средства за превозувачи тежи товар					X		Да.			
Вредност: 0 0 0 0 0 0 0 0 0 25 25 100%											
Сортирање											
6	Дали има лажни предмети на работното место					X		Има помалку од (пет) телефон. За да одлучиме да ги оставиме и оти имаме времето да се отстранат од работното место и да стојат само каде работите што се потребни.			
7	Постат инструментите или машини кои не се користат или се оштетени / расклатени, кои не се користат на проект					X		Постат, има машини со кола во работно на не се користат. Вредностите би биле крај од работите ризици на кола работниците кои што не се користат би биле обичај.			
8	Материјали / остатоци / Антуспатици доколку се чуваат соодветно на соодветен начин и се приклучат во соодветна област					X		Недостаток документирање на соодветно.			
9	Материјали / запалки кои се во лоша состојба правилно се идентифицирани / се користат?					X		Не се користат и исто се идентифицираат.			
10	Дали мену инструменти или приклучоци не е поправен / оштетен на проектот за замена?					X		Не. Се замалкуваат само оние мену или што се потребни за работите на еден проект.			
Вредност: 0 0 0 0 0 0 0 0 0 18 25 72%											
Поредок											
11	Промена / додирани делови се достапни и нивната позиција е правилно идентифицирана и јасна за сите					X		За сите 5 потребни и делови да бидат достапни за сите, да се знае нивната позиција со што да дефинира повторно временски интервал за нивно промена.			
12	Апати кои се користат за поддршка / инструменти се достапни и добро користени					X		Да, но да се дојде до сите 5 потребни и нивната позиција да се достапна треба да се наоѓаат на видно место за истража, за сите 5 потребни и нивните работници.			
13	Материјали што се користат во производството да работат идентифицирани и соодветни на соодветен начин и се блиску до машините каде што исто се користат					X		Да, тие се наоѓаат блиску до машините што по јавноста на сите материјали / инструменти на употреба. За сите 5 потребни и нивните работници да има свое место.			
14	Работното подрачје / машини е оставена на правен начин за нареден ден					X		Доколку не се постави колектор, би требало да бидат достапни до сите 5.			
Вредност: 0 0 0 0 0 0 0 0 0 15 20 75%											
Поредок / чисти											
15	На проект на сепарат (за машини) и на проект на сепарат (голем) сите работни станици се правено чистички					X		Да, на проект на работното место станиците се чистички, но не во целост, што значи за сите 5 потребни и нивната позиција да бидат соодветни на работното.			
16	Превентивното одржување и вклучувањето се прават на правен начин (поредок / чистички)	X						Се извршува превентивно одржување, но исто не се стандардира по план. Исто работниците имаат (работно време). За да одлучиме до сите 5 работници превентивното одржување на машините и инструментите да се стандардираат.			
17	Места за контрола се чисти на соодветен начин					X		Има малку за контрола.			
18	Место за вклучување се одржува често и на организирани начин					X		Се одржува, но не во целост. За сите 5 потребни и нивната позиција да бидат организирани за сите 5 работници во целост, доколку не се постават материјали да бидат организирани за сите 5 работници во целост, доколку не се постават материјали да бидат организирани за сите 5 работници во целост.			
19	Инструментите и документите се одржуваат на соодветен начин (чисти, без оштетени, документи)					X		Да, нивната и инструментите се одржуваат.			
Вредност: 0 0 0 0 0 0 12 0 1 12 20 60%											
Стандартизација и одржување											
20	Многу е важно, извршена е проверка на пример парче и документирање соодветно					X		Да, се прават.			
21	Евиденцијата за превентивното одржување е достапна и добро изработена (четка и јасна)	X						Има евиденција.			
22	Симболи работни станици / машини се стандардизирани за контрола, документирање, евиденција					X		Да, доколку дозволуваат на работниците.			
23	Место за материјали по следни евидент метод за идентифицирање и овој е стандардизирани					X		На едно место е ставено се. За сите 5 потребни и да се наоѓаат (со материјали), за сите материјали посебно место или тоа да се обележи (со материјали) доколку се ставени сите на исто место.			
24	Враќајта што не се одржува затворена и навистина затворена? Дали има валана врата / мид / мид.					X		Да, нивната и инструментите се одржуваат.			
25	Средни / оштетени работи (запалки, врата, прозорци, мост, шафери) се идентифицираат и се приклучат за нив да бидат поправени или отстранети делови кои не можат да се поправат					X		Да, се идентифицираат и се приклучат или поставени или се поправат или се отстранети, доколку нив не можат да се поправат. Сите 5 работници треба да бидат потребни и постојат од нареден ден.			
Вредност: 0 0 0 4 3 4 0 0 1 11 25 44%											
Вредност: 0 0 0 0 0 0 0 0 0 11 25 44%											

Figure 11 is showing some of the before and after photos of this project.

1S

The **sort** step was implemented using specially designed red tags.



2S

The **set** step was implemented using different boxes and labels in different colors. The tools were selected according to the frequency of using.

All tools that are commonly used was **set** in specially designed cabinet. This enables the operators to find the tools easier and identify if any tools are missing.

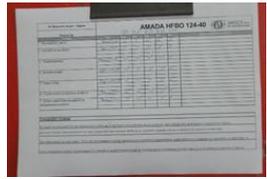


3S

The company already has **cleaning** system in place.

4S

To ensure that all implemented changes are respected by the employees, simple daily checklist were created to ensure **standardized** work of the operators over the workday.



5S

To **sustain** the solutions, the upper management will perform yearly 5S audit according to created checklist.

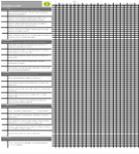


Figure 11: Improvement of the 5S – before and after implementation

This small project was thoroughly planned, and the implementation was monitored and controlled very closely by the team. Before each phase, the project team had presentations for the employees for each 5S phase and the outcomes of each phase. After this, with deadlines in place, SMELT-ING DOO employees implemented the activities for the phases. Before moving to the next 5S step, an evaluation of the 5S implementation was undertaken using the audit checklist.

Figure 12 is showing the progress of the 5S in the company.

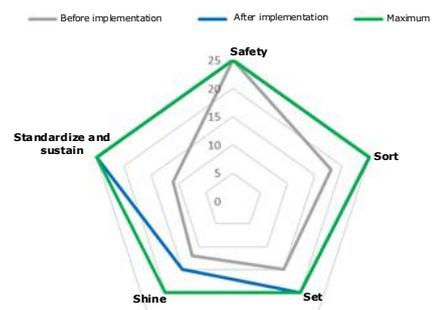


Fig. 12 Improvement of the 5S

According to Figure 12, in the beginning, the 5S score was 81 points. At the end of the implementation, the score was enhanced up to 110 points out of 115 possible. Due to time constraints, the procedure for preventive and corrective maintenance of the machines was not implemented.

4.4. Portable tools trolley

Due to the many different tools that were usually left all over the machines in the production area, without any order, the need for a solution for better organization was needed. With the implementation of this trolley, every tool got its own place which was labelled accordingly. The trolley is designed to be portable, and the operators can move it on the shop floor (Figure 13).

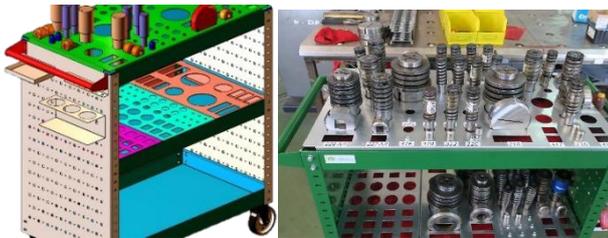


Fig. 13 Portable tools trolley

The trolley is equipped with brakes so that the operators can stop the trolley when they are working with the tools, or they are simply storing it on the shop floor. The trolley consists of three drawers, where the first drawer is dedicated for the most frequently used tools. Both vertical sides of the trolley are also utilized with the most common tools as screwdrivers, pliers, etc., as well as protective equipment for the operators (gloves, anti-noise earplugs, etc.). This trolley directly helped the previous mini project and significantly helped achieve the satisfactory 5S score in the company. The trolley is designed and produced by SMELTING DOO and is now offered to the clients as one of their products.

5. Conclusion

The project with title "Improvement of the production processes based on the lean methodology" was implemented in SMELTING DOO. The project lasted for nine months, was carefully planned and consisted of four mini projects with specific results from each:

- Improved visualisation
- Digital work order
- Implementation of 5S
- Portable tool trolley

The demand for those mini projects was established at working meetings and mutual agreement, aided by the KAIZEN board. Before that, a 4-months detailed analysis was conducted where the following elements were created: spaghetti diagrams, process capacity tables for the products, standard work combination sheet, process chart, diagram of the document flow – from order to delivery, and capacity analysis for all machines. The conclusion from the analysis was that the company needs to work more on decreasing the time for setup and less for the operative time.

The implementation of 5S required the most time to be executed, as planned. Every stage of the methodology was organized with a presentation for the workers, plan of tasks to be undertaken, time to implement actions and evaluation of the performance at the end. The digital working order helped the company better plan and control the production processes, clearly stating the check points. The improved visualization, together with the portable cart, organized the production department even further and decreased the time the workers need to initiate the work orders.

The involvement of the company's employees was essential during this project and that is one of the main lessons learned during

the implementation. They welcomed the improvements with great enthusiasm and provided many creative ideas for improvement of their organization. The changes were easily managed and accepted as the project team ensured to present and communicate the newly implemented changes prior to the implementation.

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