

ANALYSIS OF EFFICIENCY OF LEAN MANUFACTURING AND SIX SIGMA IN A PRODUCTION ENTERPRISE

Mariusz Bożek, Adam Hamrol

Poznan University of Technology, Department of Management and Production Engineering, Poland

Corresponding author:

Adam Hamrol

Poznan University of Technology

Department of Management and Production Engineering

ul. Piotrowo 3, 60-965 Poznan, Poland

phone: +48 61 665-27-74

e-mail: adam.hamrol@put.poznan.pl

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ABSTRACT

The aim of the paper is to identify, on the basis of selected examples, the effectiveness of Lean Manufacturing (LM) and Six Sigma (SS) techniques in a large-production enterprise characterized by low-volume production, a wide product range, stabilized manufacturing technology and a so-called “brownfield” site. Many scholars have attempted to answer which approach, LM or SS, is more effective in a production enterprise. The authors of the paper aim to answer this question on the basis of a detailed analysis of efficiency of implementation of both techniques. The amount of savings generated from undertaken projects and increase of profitability of the analysed production system have served as performance measurements.

KEYWORDS

Lean Manufacturing (LM), Six Sigma, economic efficiency.

Introduction

Lean Manufacturing or Six Sigma: Which technique to use? Maybe both of them simultaneously? If so, which sequence of actions would be most appropriate to achieve the best results? No one has yet been able to provide a comprehensive answer to these questions. In addition, since there are no two identical organizations that could serve as samples for analysis, no one knows if such an answer exists. Every organization is different and must determine its own methods of reaching operational excellence.

The aim of this article is to share experiences in implementation of Lean Manufacturing and Six Sigma in an enterprise that manufactures medical equipment. On the basis of these experiences, supported with certain assumptions, it is possible to assess which approach is more effective. Not only should the article help a reader understand both techniques better, but it should also present areas of concern and differences between them. This can prove helpful in establishing a way to pursue operational excellence and to modify perception of both methodologies.

While reading this paper, it is important to realize who the main beneficiary of LM and SS is. Do we apply these techniques only to be able to say that our organization has implemented lean principles or that it has been using the DMAIC problem-solving cycle? Or perhaps the overriding goal of the implementation is to boost stakeholders' satisfaction? From such a perspective, it is not important which technique is applied to streamline the manufacturing system. If the stakeholders do not notice positive effects of LM and SS implementation and do not benefit measurably, utilisation of the techniques is a complete waste.

Lean Manufacturing versus Six Sigma

Lean Manufacturing

Reference books provide a variety of definitions of LM. According to the most accurate definition, Lean Manufacturing is a philosophy of production enterprise management that concentrates on identification and elimination of waste from a value stream in order

to decrease lead time between a customer's order of a specific product and delivery of the finished product to a recipient [1].

Therefore, waste is a key concept of LM. Taiichi Ohno, the creator of Toyota Production System [2], has identified seven major types of waste:

Overproduction: Producing something when it is not required or manufacturing amounts that exceed demand.

Excessive inventory: Stockpiling inventory that exceeds the level required to guarantee continuity of sales or production.

Defects: Eliminating the so called "hidden factories".

Overprocessing: Actions that are useless and do not add value and inefficient processing caused by tools in bad condition.

Unnecessary transportation: Excessive transportation of materials between particular production stages.

Unnecessary motion: Excessive motion of an operator during a production process, for example, searching for elements or tools, or reaching for or relocating them.

Waiting: Materials waiting for further processing and waste of machines' and workers' time.

According to Taiichi Ohno [3], the worst types of waste in mass production systems are overproduction and excessive inventory. A pull system he has proposed combines consecutive processes in such a way that the previous process can start production only when a signal (e.g., kanban) has been sent by the process which follows.

LM [4] methodology assumes that only 5–15% of all activities add value to a product (value-added activities). It means that the remaining 85–95% is pure waste. It must be stressed that the above values refer to a total time a product "remains" in the manufacturing system. That period includes storage of raw materials, semi-finished and finished goods, as well as time spent waiting for processing in particular manufacturing cells.

Following this course of reasoning, LM focuses on eliminating the types of waste specified above, with particular emphasis on overproduction and excessive inventory, since they constitute the largest part of non-value-added activities [5].

In 1926, Henry Ford made the following statement:

"One of the most noteworthy accomplishments in keeping the price of Ford products low is the gradual shortening of the production cycle. The longer an article is in the process of manufacture and the more it is moved about, the greater is its ultimate cost" [6].

This means that the longer a product remains in production, the higher the costs of its manufacturing are. Figure 1 presents the substance of this approach.

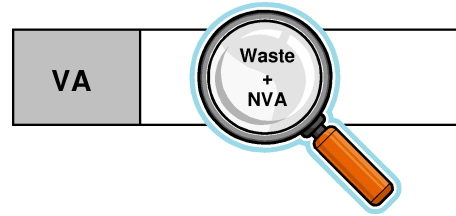


Fig. 1. The idea behind Lean Manufacturing; VA – value added activities, NVA – non-value-added activities [6].

Six Sigma

Similar to LM, Six Sigma is a strategy of enterprise management aimed at boosting financial results by systematic improvement of processes and reduction of their variability. Six Sigma utilises strictly determined data collection methods and statistical analysis tools in order to find reasons for defects and methods to eliminate them (based on [7] and [8]).

Variability is a key notion of Six Sigma. Since manufacturing costs represent a function of variability of a manufacturing process, the main goal of Six Sigma projects is reduction of variability. The lower the variability of a manufacturing process is, the greater the stability and predictability of the process. Moreover, if variability of the process decreases, manufacturing costs and improvement of financial results are more likely to increase.

Statistical measure of variation is represented by a standard deviation σ . An organisation which has adopted Six Sigma management strategy should attempt to reach Six Sigma quality level. It means that the variance nonconformity fraction equals 3.4 per one million likely to emerge.

Figure 2 presents the relativity of a quality level measured by the Six Sigma strategy. This level depends on two factors: requirements of a process (e.g., requirements of a customer, a process, stakeholders) and individual variability of a process. With the predetermined "a" level of a customer's requirements, the blue process with a variance of $6\sigma_n$ has Six Sigma quality level ($6\sigma_a$). Using the same "a" level requirements, the red process with its own variance of $6\sigma_c$ has 3 sigma quality level ($3\sigma_a$). The same red process has Six Sigma quality level ($6\sigma_c$) when a customer's requirements are at the "c" level, whereas the same blue process reaches 3 sigma quality level ($3\sigma_b$) when a customer's requirements are at the "b" level.

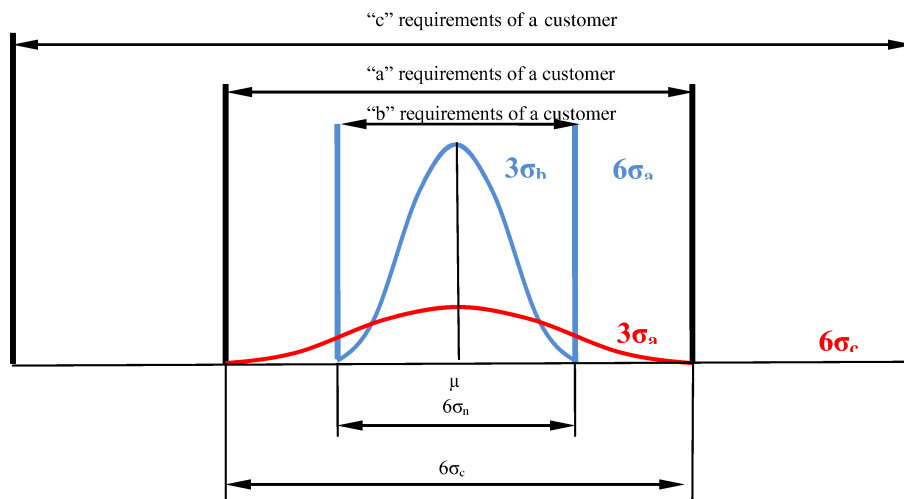


Fig. 2. Measuring quality level of processes with the use of Six Sigma [7].

Apparently, in economic reality, expectations of customers are becoming higher and higher and companies, in principle, cannot influence this. However, what companies have impact on is variability of their manufacturing processes. Six Sigma provides tools which enable control and reduction of process variability. In addition, with specific customers' requirements, application of these tools can support companies in their attempts to reach Six Sigma quality level. It can be graphically represented as a change of the red process into the blue process where the level of customer's requirements is "a".

Lean Manufacturing versus Six Sigma and Lean Six Sigma

A conclusion that can be drawn while analysing Lean Manufacturing and Six Sigma is that despite many differences, the two methodologies have one important common feature: they both belong to a group of variance management strategies focused on achieving the satisfaction of stakeholders. Moreover, both methodologies name added value, process improvement and engagement of top managers as prerequisites of success. However, the methodologies differ in terms of approach to reaching the assigned goal. In principle, LM concentrates on eliminating waste, whereas Six Sigma on reducing variability. This concept is presented in Fig. 3.

Major objectives of both approaches correlate; therefore, they can complement each other. Understanding the main differences between these methodologies is indispensable to their effective application in business practice. Some authors [9] prove that LM works better in the case of simple problems. Owing to

this method, tangible results can be observed in a relatively short term, while in the long term the method is less effective and should be used as a kind of introduction to Six Sigma. On the other hand, Six Sigma, due to its relatively formalized procedure, brings results later, but these results have larger "gravity" in economic sense. Is this true? No one knows. The fact is, however, that LM is perceived as a "softer" method than Six Sigma, because the tools it uses are not based on a properly established scientific foundation.

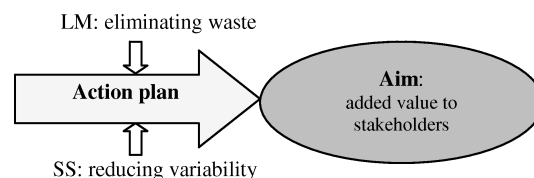


Fig. 3. Reaching strategic goals with the use of LM and SS [source: own work].

LM focuses on eliminating waste such as non-value-added activities (NVA). In economic terms they weigh less than value-added activities (VA) and reduction of variability of non-value-added activities is the major area of concern of Six Sigma. It is also more difficult to demonstrate savings accrued from LM because some enterprises prefer to calculate savings received from value-added processes and settle their accounts in relation to them.

Among the major types of waste specified above, which remain the major area of concern of LM, one can easily notice correction of defects, which Six Sigma also pays much attention to. Interestingly, according to LM, it is overproduction and excessive inventory, not defects, which are the most harmful to manufacturing systems.

Table 1
 Differences between LM and SS [source: own work on basis [1, 3, 7, 9]].

	Attribute description	Lean Manufacturing	Six Sigma
1	Aim of the method	Elimination of waste. In principle, a focus on non-value-added process steps.	Reduction of variability. In principle, focus on reduction of variability of processes, which by definition should add value.
2	Necessity to understand the need for changes for all employees	Required	Not required
3	Economic effect	Not always specified and often difficult to calculate.	Necessary for commencement of a project
4	Process improvement according to the cycle	PDCA	DMAIC
5	Organizational structure	Usually not very formalized	Usually very formalized
6	Employee engagement	Everyone involved	Involvement of everyone is not required.
7	Constant improvement	A constant improvement of processes.	Improvement of the processes is continuous only when it is economically profitable.
8	Necessity to train employees	Required for everyone. However, trainings are limited to presentation of general rules.	Not required for everyone. Only people selected to undertake projects undergo training. Unlike in LM, the training is highly specialized.

It has been justified by the assumption that over-production and excessive inventory cause other types of waste; therefore, eliminating them can indirectly diminish the level of emerging defects.

Since there is no single universal method capable of solving all the problems, there is no point in trying to prove which approach is generally better. Both LM and Six Sigma have their advantages and disadvantages and significantly differ (Table 1). The most important thing, however, is that owing to these differences, the methods can be applied simultaneously. Utilised together they can bring more profits than if used in separation.

Effectiveness of Lean Six Sigma on the basis of a selected enterprise

Description of the analysed production system

The analysed company is situated in Poland and forms a part of an international corporation that specializes in manufacturing medical items. The company produces over 3,500 models of medical tools, over 1,500 different cardiac and haemodynamic packages, and stents and right heart catheters with nationwide quality parameters. The company's manufacturing sector in Poland employs over 1,300 people in two locations.

Over 1,050 people work in the device manufacturing segment, whereas 250 work in the angiography supplies segment.

The main features of the analysed manufacturing system are as follows:

- Wide product range: The company produces around 5,000 different finished goods using approximately 25,000 various semi-finished products and components.
- Low-volume production: Single orders comprise from 10 to 500 pieces.
- Large part of manual work in the entire technological process: Payroll costs represent approximately 40% of direct manufacturing costs.
- Stabilized manufacturing technology.
- Level of stockpiled raw materials, materials, semi-finished goods, work in progress and finished goods is relatively high and constitutes 25% of the value of annual manufacturing costs.

Outcome of Lean Manufacturing implementation

The first LM implementation projects in the analysed enterprise date back to 2006.

Considering the organizational structure of the enterprise, LM has been implemented in modules. A separate implementation team has been assigned to every project and each team has dealt with tasks of a particular department.

Prior to LM implementation, an LM training cycle for managers of the analysed enterprise was conducted. The trainings took place regularly, and in accordance with LM principles, involved all front-line employees.

Several different projects connected with LM have been implemented so far. One of them, and the most typical, is presented below.

LM project in the scissors department

The project in the scissors milling department was preceded by Value Stream Mapping (VSM) workshops dedicated to a selected group of semifinished milling parts of scissors (more than 100 different models of semifinished scissors parts). A daily demand for semifinished scissors parts was 2000 pieces with no substantial deviations.

The result of VSM was replacing Batch and Queue approach for the production of semifinished milled scissor parts with One-Piece Flow approach. Work content of the technological process has been analysed and the process has been balanced once again (Operator Balance Chart and Machine Balance Chart). The production batch has been reduced from 200 to 50 pieces. Within the newly created pro-

duction line one piece flow occurred as a sequence of technological operations.

Figure 4 shows the effect of conducted Value Stream Mapping, so-called Current State Map. It presents, that the time of adding value, which is less than a minute, is only 0.02% of the total lead time in the studied area of almost 11 working days. It was due to keeping a large inventory of work in progress (WIP) before each production cell.

The result of the conducted LM project was preparation of Future State Map, namely the desired new organization of production line where One Piece Flow approach is possible. Figure 5 presents the Future State Map. A marked reduction in lead time by combining separate production cells in a line can be noticed. The new organization allowed for a significant reduction in WIP.

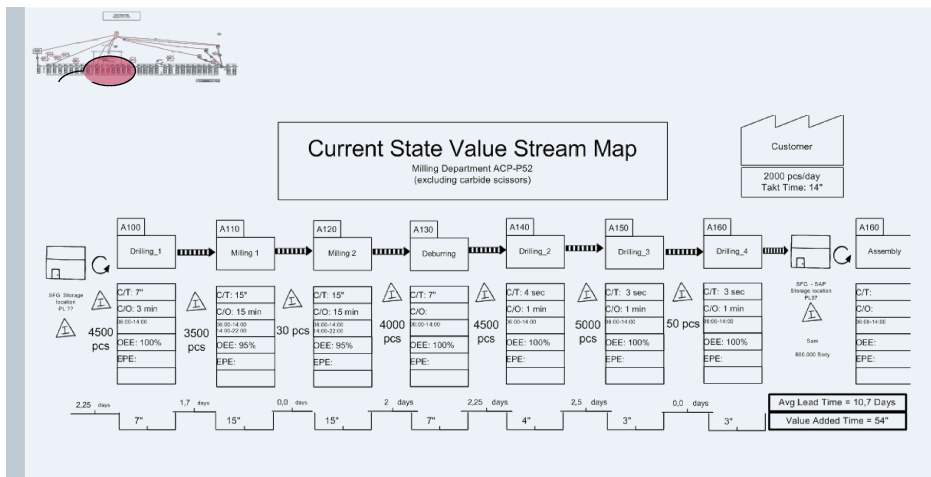
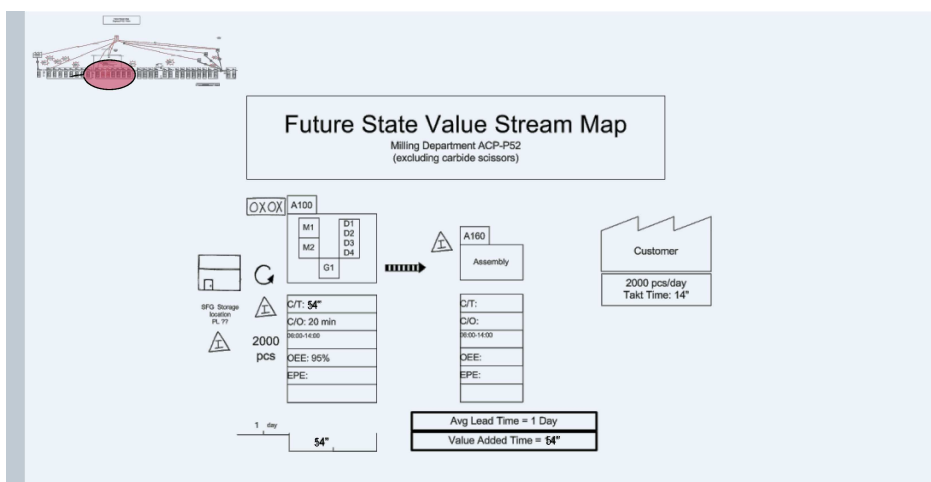


Fig. 4. Value Stream Mapping (VSM) Milling Scissors – Current-State Map [source: own work on basis [10]].



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Fig. 5. Value Stream Mapping Milling Scissors Line – Future-State Map [source: own work on basis [10]].

Table 2
 Expected Savings after OPF Implementation [source: own work].

Type	Lead Time	WIP (Pieces)	Inventory SFG Storage PL07	Production Space	Workers
Current conditions	In average 10 days	20 000 pieces (10 days × 2000 pieces per day)	40 000 pieces approx. 400 000 PLN	11.5 m × 4 m = 46 m ²	2.5 Workers
One – Piece – Flow condition	1 day	Max of one shift (approx. 2 000 pieces) Annual frozen capital savings approx. 15 000 PLN	0 PLN annual frozen capital savings approx. 30 000 PLN	Estimated 30 m ²	Less than 2.5 workers

To get to the future state no significant investment has to be done!

Results of implementation of all activities based on a map of future circumstances have been presented in Table 2. Most of all, considerably long process duration and high inventory level, which characterised the semifinished parts of scissors production prior to introduction of the changes, could be reduced. In summary:

- the average order lead time has been reduced from 10 to 1 working day and is the effect of 10 times WIP reduction,
- the stockpiling period of semifinished parts has dropped from 40 to 0 days,
- due to the above, annual amount of PLN 45,000 was gained as a result of the reduction in frozen capital.

Based on the mentioned project and its outcome, it is possible to point out the major benefit of LM implementation. The benefit consists in shortening and stabilizing lead time. As a result, inventory can also be reduced and, in economic terms, requires less financing.

However, the undertaken projects have not provided measurable proof that LM contributes to a substantial (as it is presented in reference books) 20–30% boost of labour productivity. The results presented below in the pie charts prove, that there is no significant difference between the efficiency of labour force operating in the areas where LM projects were conducted (OPF in scissors milling department) compared to areas where these kinds of projects have not yet been performed (Clamps Milling Department). There are several reasons why tangible LM-related proof for productivity increase in the analysed area cannot be delivered. The most important causes are wide production assortment, fluctuating demand for particular groups of products and a programme of acquiring new production items from other locations of the corporation. This does not mean that productivity growth is unattainable.

It only implies that it has not been given enough attention. During these projects, the entire emphasis has been placed on reduction of work in progress and warehouse inventories. The effects have been reached when previously independent production cells were connected by supermarkets taking on the role of FIFO queues. By this means, excessive inventory between production cells has been reduced, and thus movement of materials between workplaces has been improved.

In order to check the reasons for the status quo, a video analysis of work in two areas (chip machining on conventional machines in the surgical clamps and in scissors department) has been conducted. These two areas differ mainly in production organization. Semifinished parts of clamps are milled in the separate cells (Batch and Queue). Yet, semifinished parts of scissors are produced in the production line (One Piece Flow), which is the result of the presented above LM project.

The analysis consisted in filming the entire area from a bird's-eye view, allowing the following measures to be established for each production cell:

- total duration of value-added-activities (VA); marked in green; the aim of the assessment was to verify if work performed in a given cell was in line with technological objectives,
- total duration of non-value-added activities (NVA); marked in yellow; refers mainly to activities connected with resupplying a workstation,
- total duration of activities perceived as waste; marked in red; refers to circumstances where a cell is not operating because an employee left a workstation or remains at the workstation but performs activities unrelated to the nature of their work.

Owing to the analysis, it has been possible to estimate the potential improvement of effectiveness resulting from utilisation of LM. The outcome of the analysis is presented in Fig. 6–11.

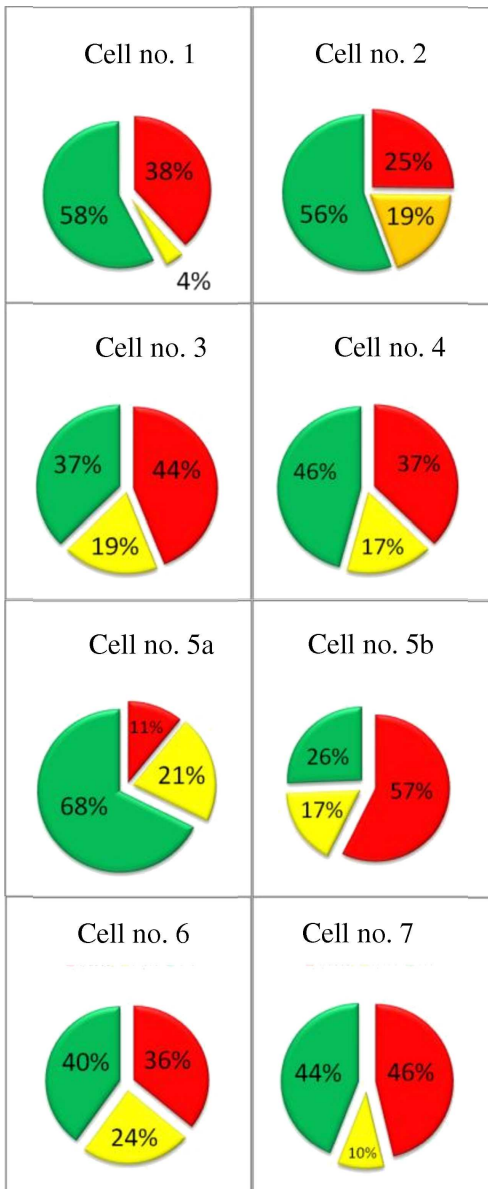


Fig. 6. Analysis of the time worked by 8 employees in the surgical clamps department; the first day [source: own work].

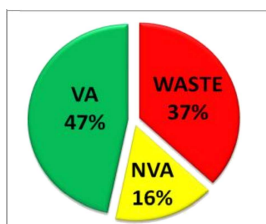


Fig. 7. Total work time of 8 employees in the surgical clamps department; the first day [source: own work].

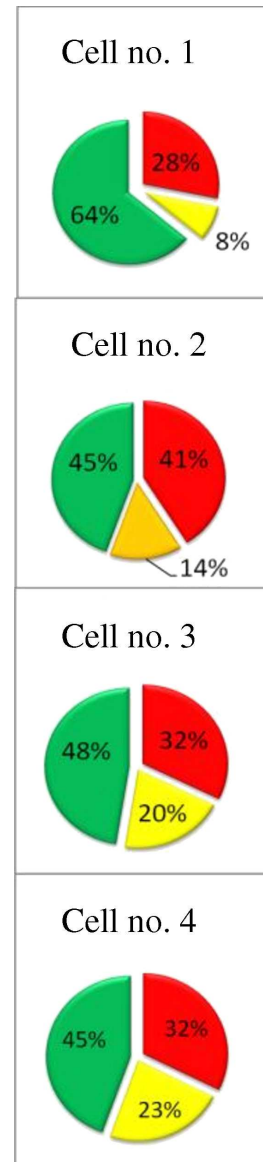


Fig. 8. Analysis of the time worked by 4 employees in the surgical clamps department; the second day; red – waste, green – VA, yellow – NVA [source: own work].

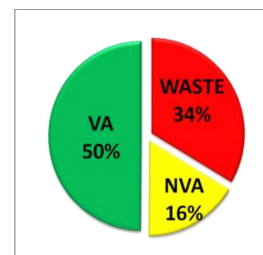


Fig. 9. Total time worked of 4 employees in the surgical clamps department; the second day [source: own work].

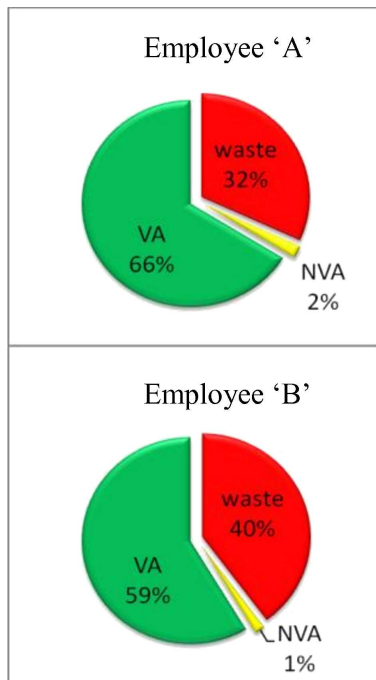


Fig. 10. Analysis of the time worked by 2 employees in the surgical scissors department [source: own work].

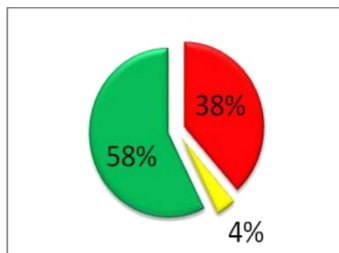


Fig. 11. Total time worked by 2 employees in the scissors department; red – waste, green – VA, yellow – NVA [source: own work].

The pie charts below present the analysis of 8 working hours of 10 different employees and 4 working hours of 4 different employees, which together constitute 96 hours of the video analysis.

96 hours of the video analysis show that:

- 37% of working time of employees in the analysed area is pure waste,
- 14% of activities are non-value-added,
- 49% of activities are value-added.

Reasons for such situations are not essential for the purpose of analysis. What remains of great importance, however, is awareness of potential improvement hidden in each production system. The majority of 37% of activities that the analysis has classified as pure waste can be eliminated by improving flow of information between a given production cell and its surrounding. Performance of the cell heavily relies on the performance of its surrounding. Assuming that 25% of these activities are transformed into value-added activities (such an assumption, based on the long-term experience of the authors' in managing production systems, is possible), one gets a 10% increase of labour productivity. For the analysed enterprise, this translates into saving 100 employees and, consequently, PLN 3.6M a year.

Summarizing potential effects of implementation of LM in the analysed enterprise, one can conclude that LM projects facilitate reduction of inventory by shortening lead time and enable labour productivity growth by enhancing flow of information and materials. Based on the outcome of the analyses and particular historical data, one can estimate economic savings for the future. Figure 12 presents savings generated with the use of LM projects between 2008 and 2011, as well as estimated value of savings up to 2017. The chart also shows an indicator of manufacturing productivity growth after implementation of LM projects.

Curves of obtained savings and productivity growth initially manifest an upward trend (Fig. 12). The values remain steady at a particular maximum level and finally the trend goes down. Assuming that a change of manufacturing technology has no strong impact, LM projects, regarding their area of concern (reduction of inventory and increase of productivity through eliminating unnecessary activities), “exhaust” in time and become less and less effective, because the inventory reduction and the elimination of unnecessary activities have natural limits. On the example of the studied company it can be seen, that Six Sigma approach boosts stability of the production processes more than LM techniques (e.g. Kaizen activities) and as a result it increases labour force productivity.

SAVINGS AND INCREASE OF PROFITABILITY CAUSED BY LEAN MANUFACTURING PROJECTS

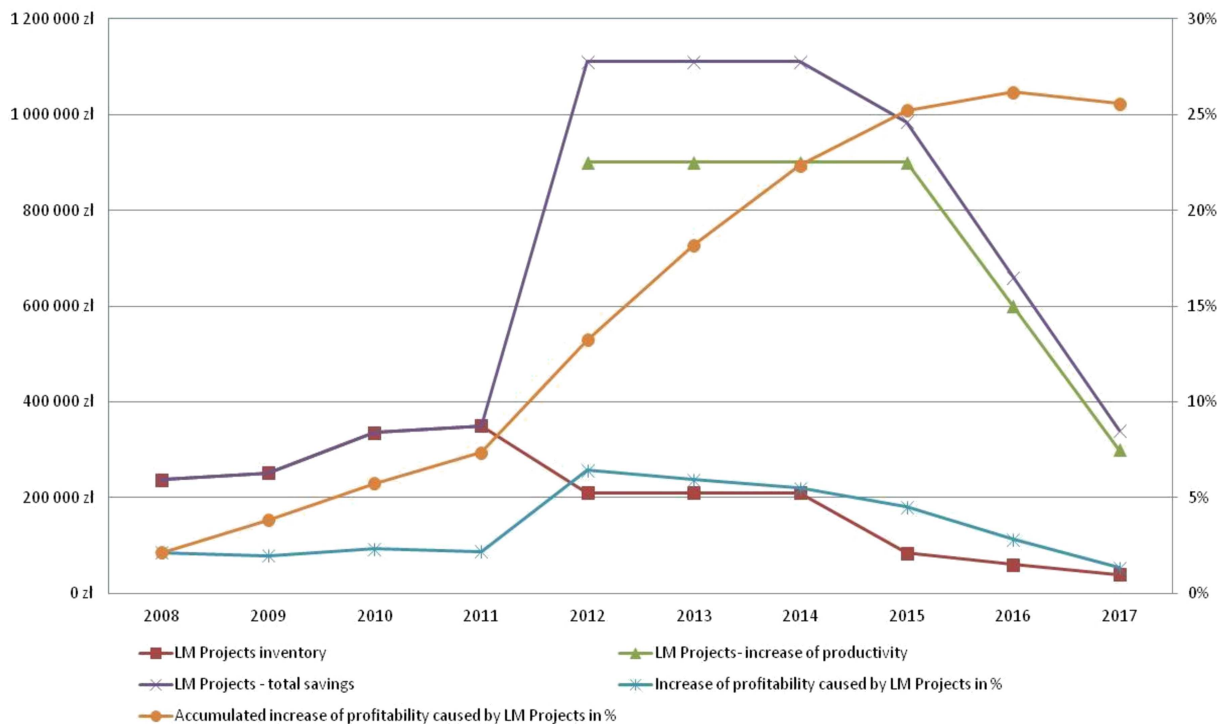


Fig. 12. Outcome of implementation of LM projects [source: own work].

Outcome of Six Sigma implementation

The analysed enterprise first became interested in Six Sigma at the beginning of 2010. The company wanted to find an effective method to solve complicated manufacturing problems connected with instability of manufacturing processes which caused a relatively high level of defects and corrections. LM techniques the enterprise had been using since 2006 had been inappropriate to successfully eliminate instability of manufacturing processes.

Formation of Six Sigma culture in the analysed production system was initiated by gradual training of managers and engineers of Six Sigma techniques at postgraduate studies. To date, 26 people have received the green belt level and 24 more people are to achieve the level within the next year. Currently, 4 out of 26 green belts have been training for a black

belt. The number of black belts is to gradually rise to reach 8 as new green belts emerge.

The table below (Table 3) presents topics of 15 Six Sigma projects which were completed in the last 12 months in the analysed production system. Projected annual PLN savings were estimated for each project (Fig. 13). The aggregate amount of the planned savings on projects which have been conducted so far has reached PLN 1.7M.

The 15 executed projects of the Six Sigma program have proven its incredible potential for generating savings. Due to this, the programme is still supporting further development of the analyzed company. According to estimations, Six Sigma-related savings will amount to PLN 20 million in the next 5 years. With Six Sigma alone, projected productivity growth in the analyzed area will reach 15–20% a year and amount to 80% after 5 years (Fig. 14).

An example of a completed Six Sigma project sheet is presented below.

Table 3
 Summary of completed Six Sigma projects [source: own work].

No.	Project topic	Departments included in the project	Amount of projected savings/year
1	Assessment of effectiveness of annealing forgings	Smithy PLN 143 000	
2	PRZ complaints VS production	PLN 66 000	
3	Improving stability of soldering hard inserts of medical instruments	Production of instruments – P30	PLN 193 800
4	Minimizing costs of incompatibility of finished goods in the Scissors Department	Production of scissors – P52	PLN 350 000
5	Stabilizing the process of polishing scissor blades on CNC BERGER machines	Production of scissors – P52	PLN 450 000
6	Reducing incompatibility in the production of forging matrices produced with HSC technology	Tool room	PLN 33 600
7	Reducing losses in the process of forming right heart catheter tips	VS production	PLN 10 000
8	Stabilizing physical parameters of a clean D1 room and defining alarm limits for a ventilating and forced air unit which is compulsory in the room	VS production	
9	Statistical control of temperature in the semi-hot forging process	Smithy	PLN 100 000
10	Reducing defective fractions in the production of cardiac catheters in the injection moulding area	VS production	PLN 55 000
11	Polishing products with the use of sandpaper strips	Production of tools	PLN 100 000
12	Decreasing costs by establishing reliable durability of tools for the Mikron UCP 600 machining centre	Production of instruments – P20	PLN 17 000
13	Reducing defects of products with hard inductively soldered inserts	Production of instruments – P30	PLN 130 000
14	Improving stability of the process of manufacturing wound retractors	Production of instruments – P75	PLN 24 000
15	Improving quality and decreasing costs of the process of forming and welding handles made of acid resistant tinplate	Production of instruments – P30	PLN 16 500
			PLN 1 688 900

SIX SIGMA PROJECT SHEET

Topic: ASSESSMENT OF EFFECTIVENESS OF ANNEALING FORGINGS OF SURGICAL TOOLS IN ACP		
Problem description: <ul style="list-style-type: none"> the project consists in assessment of effectiveness of annealing forgings of surgical tools with regard to their expected firmness and related machinability the current annealing process is very unstable; as a result, the levels of firmness of forgings is wide with a firmness over 100 HRB cause damage to expensive machining tools diversified firmness of forgings causes losses related to instability of the machining process 		
Current status : Group of products over 100 HRB is approximately 1.25% Sigma level of the process 1-2		Target status: Group of products over 100 HRB is less than 1/10000 Sigma level of the process 4,5
Expected benefits: a) quality dimension (description and beneficiary): Reducing variability of firmness of forgings. Improvement of machining. Improving ACP's image as a manufacturer of forgings in the corporation. b) financial dimension: Eliminating repeated annealing. Reduction of costs PLN 143,000.		
Other important information:		
Team		
Role in the team	Name and surname	
Sponsor of the project		
Manager of the project		
Member of the project team		

Fig. 13. Example of a Six Sigma project sheet [source: own work].

SAVINGS AND INCREASE OF PROFITABILITY CAUSED BY LEAN SIX SIGMA PROJECTS

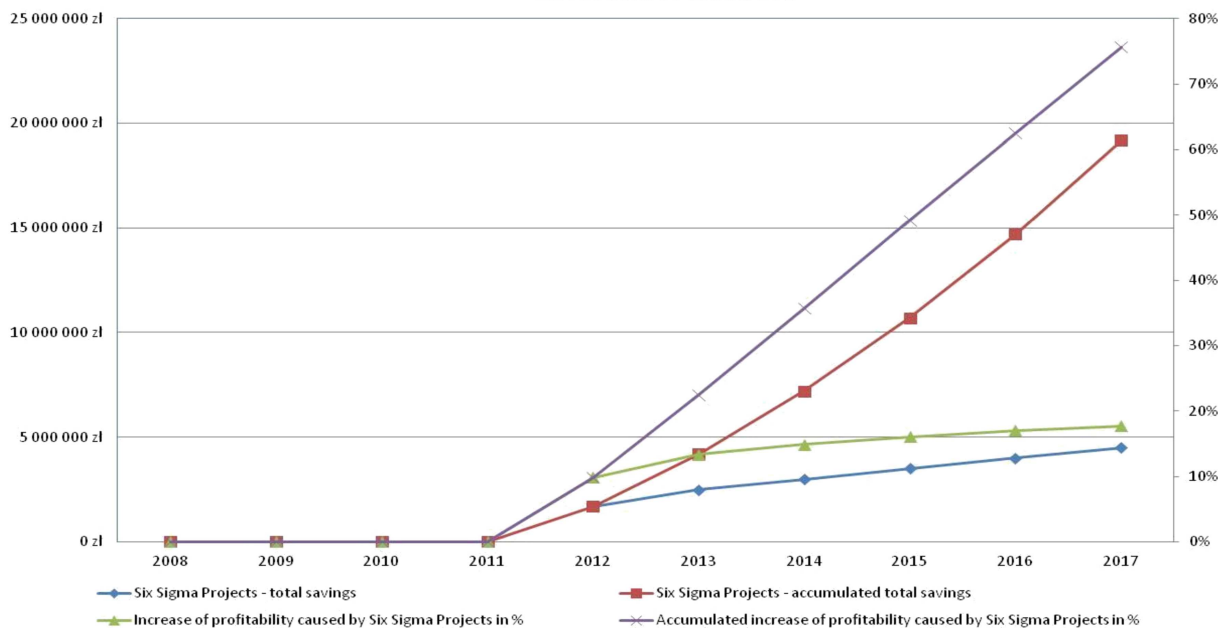


Fig. 14. Outcome of implementation of Six Sigma projects [source: own work].

Conclusions

A conclusion drawn from experiences with LM and Six Sigma implementation projects in the analyzed enterprise is that both approaches concentrate on different, rather than independent areas. LM focuses on elimination of waste, which then contributes to reduction of inventory and growth of employees' productivity. Six Sigma, on the other hand, aims at preventing any variability in manufacturing processes, which, as a result, leads to elimination of defects and flaws (e.g., hidden factories). Both approaches differ with regard to employee trainings and changes in organizational structure. LM requires that all employees of the enterprise are involved in changes. It is not obligatory in the case of Six Sigma, where only a group of highly qualified people who have previously undergone specialized trainings is selected to run the projects.

The experiences of managers of the analyzed enterprise show that it is easier to create and implement Six Sigma culture than LM, because Six Sigma directly concerns a selected group instead of all employees. This is particularly true in the so-called "brownfield" companies, where introducing massive changes of employees' awareness is much more complicated than in "greenfield" companies.

Having analyzed both approaches, one can conclude that Six Sigma is much more effective for the purposes of the analyzed enterprise. Fig. 12 and Fig. 14 present data concerning already achieved and projected future savings. Current benefits of using LM have had significant influence on reduction of capital frozen in inventory, which in turn resulted in annual savings of around PLN 0.4M. It has also been noticed that further savings connected with LM can be obtained. By cutting down on unnecessary activities performed by employees, thus increasing productivity, it is possible to save PLN 0.9M a year in the next couple of years.

The first year of application of Six Sigma has demonstrated a very high potential of this approach, which has also been reflected in savings amounting to PLN 1.7M. Six Sigma experiences can also constitute a basis for forecasts concerning effectiveness of the methodology in the future. Analysis of data presented in Fig. 12 and Fig. 14 conclude that in the long term, Six Sigma has a strong advantage (measured by its contribution to the company's productivity growth) over LM. The ratio is 4 to 1 in favor of Six Sigma.

Analyses and results presented in this article show that if companies wish to strive for perfection, the best solution is to create their own procedures based on the experiences of other companies

described in reference books or on their own. No single pattern is available – each and every company has its own corporate culture, different human capital and undergoes different stages of organizational development. Even though examples provided in the article prove that Six Sigma is four times more effective than LM, it is not certain that the same rule would hold for another company. One should also bear in mind that the analyzed enterprise became interested in Six Sigma only after a couple years of using LM. In this particular enterprise, the process of learning LM methods may have accelerated the results of using Six Sigma. Despite many differences between the two approaches and difficulty in estimating the effects of synergy, such effects definitely exist. Therefore, simultaneous application of both methodologies, notwithstanding the order, is highly recommended.

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