TiAM kwartalnik naukowo-techniczny
TECHNOLOGIA I AUTOMATYZACJA MONTAŻU
ZESPOŁÓW • MASZYN • URZĄDZEŃ

Afonso Mkaka[1], Anna Burduk[2]

DOI: 10.7862/tiam.2022.1.6

IMPLEMENTATION OF THE INTEGRATED LEAN SIX SIGMA PHILOSOPHY IN AN ANGOLAN MANUFACTURING COMPANY – A CASE STUDY

WDROŻENIE ZINTEGROWANEJ FILOZOFII LEAN SIX SIGMA W ANGOLSKIEJ FIRMIE PRODUKCYJNEJ – STUDIUM PRZYPADKU

Abstract

Today, manufacturing companies strive to find the stability between satisfying their customers by producing in accordance with their expectations (quantity and quality) and keeping leading positions when it comes to competitiveness on their markets. This paper aims to compare two very well-known philosophies in the manufacturing industry: Lean Manufacturing (LM) and Six Sigma (6S). The integration of these two philosophies solves the insufficiency that the absence of one of them causes, considering that Six Sigma is based on statistical tools that focus on measuring and reducing variations in processes and achieving goals set by the customers' requirements. Lean Manufacturing focuses mainly on the value added for a client, for example,by eliminating all kinds of waste from processes what leads to the reduction of time and cost of the process. Lean Six Sigma combines the features of both methods, which means that it meets the client's requirements based on statistical knowledge and the process flow control, but simultaneously in addition to that, it reduces the time and cost of the processes. As a result, it gives manufacturing companies the possibility of having loyal and satisfied customers and who provide companies with new customers. This paper has a greater goal of persuading the Angolan manufacturing industries to implement the Integrated Lean Six Sigma (IL6S) into their production and management processes.

Keywords: quality control, Lean Six Sigma, Lean Manufacturing, production system efficiency

Streszczenie

Dziś firmy produkcyjne dążą do znalezienia stabilności pomiędzy satysfakcją swoich klientów poprzez produkcję zgodną z ich oczekiwaniami (ilość i jakość) a utrzymaniem czołowej pozycji, jeśli chodzi o konkurencyjność na swoich rynkach. Niniejszy artykuł ma na celu porównanie dwóch bardzo dobrze znanych filozofii w przemyśle wytwórczym: Lean Manufacturing (LM) i Six Sigma (6S). Integracja tych dwóch filozofii rozwiązuje problem braku jednej z nich, biorąc pod uwagę, że Six Sigma opiera się na narzędziach statystycznych, które koncentrują się na pomiarze i redukcji zmienności procesów oraz osiąganiu celów wyznaczonych przez wymagania klientów. Lean Manufacturing skupia się głównie na wartości dodanej dla klienta, na przykład poprzez eliminację wszelkiego rodzaju marnotrawstwa z procesów, co prowadzi do skrócenia czasu i kosztów procesu. Lean Six Sigma łączy w sobie cechy obu metod, co oznacza, że spełnia wymagania klienta w oparciu o wiedzę statystyczną i kontrolę przebiegu procesów, ale jednocześnie dodatkowo skraca czas i koszt procesów. W efekcie daje to firmom produkcyjnym możliwość posiadania lojalnych i zadowolonych klientów oraz zapewnia firmom nowych klientów. Większym celem tego artykułu jest przekonanie angolskiego przemysłu wytwórczego do wdrożenia zintegrowanej metody Lean Six Sigma (IL6S) w procesach produkcji i zarządzania.

Słowa kluczowe: kontrola jakości, Lean Six Sigma, Lean Manufacturing, wydajność systemu produkcyjnego

1. Introduction

Both Lean Management and Six Sigma concepts are designed to ensure customer satisfaction. Over the last two decades, it has been possible to achieve significant improvements through both methodologies in cost, quality and time by focusing on the process performance. Six Sigma focuses on reducing variations and improving the process through problem-solving approaches using statistical tools. In comparison, Lean Manufacturing is primarily concerned with eliminating waste and improving the flow [1]. The purpose of the Lean concept is the optimal use of available resources, reducing inventory and shortening a production cycle. A flexible approach to the organization of production in the case of the Lean concept favors a quick response to fluctuations in customer orders [2]. In order to understand the importance of combining both methods better, Table 1

[1] Afonso Mkaka MSc, Ministry of Industry and Commerce of Angola, e-mail: afonso.mkaka@mindcom.gov.ao
[2] Anna Burduk Prof. (coressponding author), Wrocław University of Science and Technology, Faculty of Mechanical Engineering, ul. Łukasiewicza 5, 50-370 Wrocław, e-mail: anna.burduk@pwr.edu.pl, ORCID: 0000-0003-2181-4380.

lists the limitations of each and the strategic importance of integrating them into one philosophy.

Both approaches to the business improvement evolved independently until it was recognized that they could coexist and make each other stronger. This is because Lean alone cannot obtain stable processes, and Six Sigma alone will not eliminate all losses. This fundamental statement has given rise to a new, integrated approach – Lean Six Sigma (IL6S).

Table 1. Comparison between Lean manufacturing and Six Sigma [2]

Variable	Lean	Six Sigma
Strengths	Remove waste	No defects
	Reduce lead time	Save money
	Cycle time reduction	Uniform process output
	Work-in-progress reduction	Defect reduction
	Shorten delivery time	Culture change
	Space saving	Customer satisfaction
	Less equipment needed	Detailed statistical analysis for improvements
	Driven for efficiency	Driven for excellence
	Improve flow in processes	Reduce variation and improve processes
	Visual workplace and clean environment	Structured problem-solving methodology
Weaknesses	Statistical or system analysis not valued	System interaction is not considered because processes are improved independently
	Process incapability and instability	Lack of specific speed tools
	Lean does not link quality and advanced mathematical tools to diagnose process improvement	Six Sigma does not question existing methods of operation and if it adds value, as long as it does, it does not produce variation
	No focus on reducing variation and maintaining uniform process output	No focus on process improvement throughout an entire value stream
	Does not concentrate on dramatic improvements through innovation	Lack of the importance of visual workplace and clean work environment

The impressive results achieved by the companies such as Toyota, General Electric, Motorola, and many others and accomplished by using either one of them have inspired many other companies to follow their example. As a result, most companies have either a Lean or Six Sigma system as an approach for the effectiveness of services and/or products [1]. However, using just one of them alone instead of integrating them into one has limitations [4], [7], [8]:

- Six Sigma will eliminate defects. However, it will not address the issue how to optimize the process flow;
- Lean principles exclude the advanced statistical tools often required to achieve the process capabilities needed to accomplish the company's goals.

Therefore, this paper aims to describe the advantages of implementing the IL6S for better efficiency in achieving the world-class GE in manufacturing companies by focusing on zero defects, zero loss, zero accidents mindset and the total engagement of all employees in a company.

2. Lean 6 Sigma applications

As it was mentioned, IL6S is a philosophy created by Lean Manufacturing and Six Sigma, and it is definitely the only philosophy that joins Lean Manufacturing and Six Sigma tools and principles in order to optimize and continuously improve the quality of equipment, the process flow and the people who run the machines using differerent methds and tools. The implemented IL6S helps manufacturing companies to improve their services to the world-class levels. The general algorithm of solving problems with the use of IL6S tools is presented in fig. 1.

The IL6S is a transversal revolution of the industry and all the processes that come along with it. Its usage in assembly processes has its fundamental bases considering safety, waste elimination, optimization of processes and quality control [8], [10].

The IL6S tools go through reducing variations in processes and by setting standards. In general, these are the bases for the assembly processes, ensuring that the applied processes are safe for those working in them as well as for the end-users. Therefore, it is

crucial to ensure that the quality control system and its processes meet the customers' requirements.

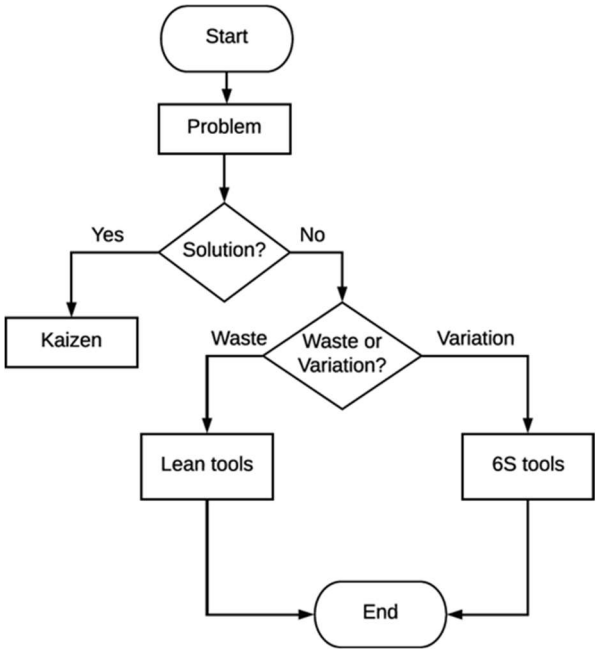

Fig. 1. IL6S approach to solving problems

Comparing the traditional and Lean management is accuracy when comes to achieving goals. Even when pursuing the same strategy, a manager who uses IL6S approaches will always outperform a competitor with a traditional managerial approach. Companies using IL6S philosophy relentlessly focus on delivering more value to their customers than competitors. Develop their people and taking the waste out of every daily process is done for the customer's benefit. Table 2 presents a comparison of the traditional management and the management based on IL6Sigma.

Table 2. Traditional management vs IL6Sigma [1], [9], [11]

Traditional	IL6S
Lack of Zero Loss Mentality	Zero Loss Mentality in Place
Only Managers and Engineers know the plant and business performance	100% of the Plant employess know the plant and business performance
Only Managers and Engineers are capable to solve problems	Core team is capable to tackle losses
Mainly Seniority is awarded	Contribution, Participation and Performance of any employee is rewarded
Average results are pursued	World Class results are pursued
Results are obtained through a lot of muscle power.	Everything is achieved based on methods, processes and systems
There are a lot of crises	Everything is under control
Competitors reach/surpass them	Always above competitors

Companies using the IL6S approach know what they have to deliver in precise details in a manufacturing branch. They set targets and strive to become the best internally and externally by looking for better ways to provide their services and products to customers. That is why, these companies become more efficient on timing, zero loss, zero defect and 100% engagement of its employees, just as shown in fig. 2.

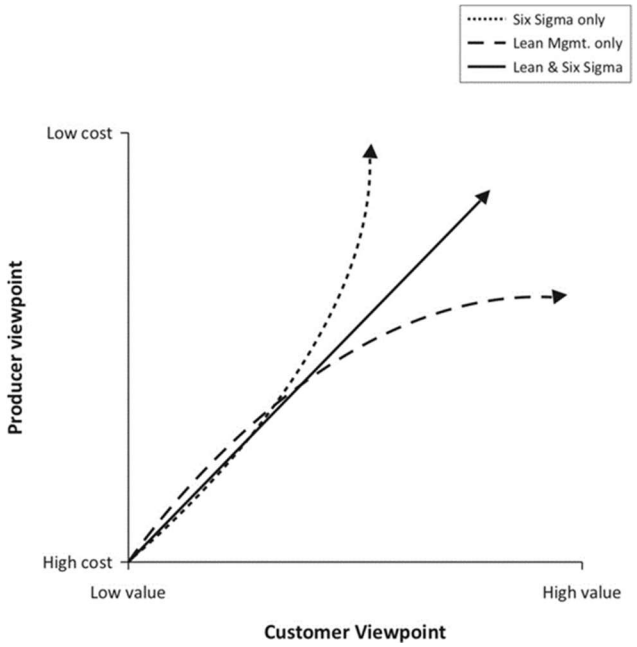

Fig. 2. Advantages for enterpises using Six Sigma, Lean and IL6S tools [1]

The application of IL6S in practice allows to achieve shorter production time, better quality and significantly lower the costs compared to the traditional approach because [1], [2], [12], [13], [14]:

- It is the only method that is strictly focused on people, machines and methods; it builds a career path and ownership;
- Its production and planning is focused on the customer's needs only;
- It focuses on high quality products and on cutting off over-production;
- Safety comes first, zero accident and zero loss mindset;
- Full ownership and engagement of people regardless of their primary positions;
- It is driven by long-term and short-term goals;
- It is focused on competence skills, an internal development and continuous learning process of its employees; it builds capabilities;
- Working in order with IL6S, employees do not spend time in the office they do gemba, what means that they work at the site, at the working place with the operators; it a builds career path;

- It liminates defects, downtimes, stops through the ownership of equipment and the process flow becomes sustainable:
- The results are reviewed or present activities are discussed with managers and all the employees/operators.

As described, both Lean Manufacturing and Six Sigma are critical methods for manufacturing companies. Combining these methods into one, including Total Productive Maintenance (TPM), High Performance Work System (HPWS), for the continuous improvement of people's technical knowledge and soft skills leads to better effectiveness of companies' outcomes and, most importantly, the satisfaction of the customers is guaranteed. A Diagram of IL6Sigma construction is shown in fig. 3.

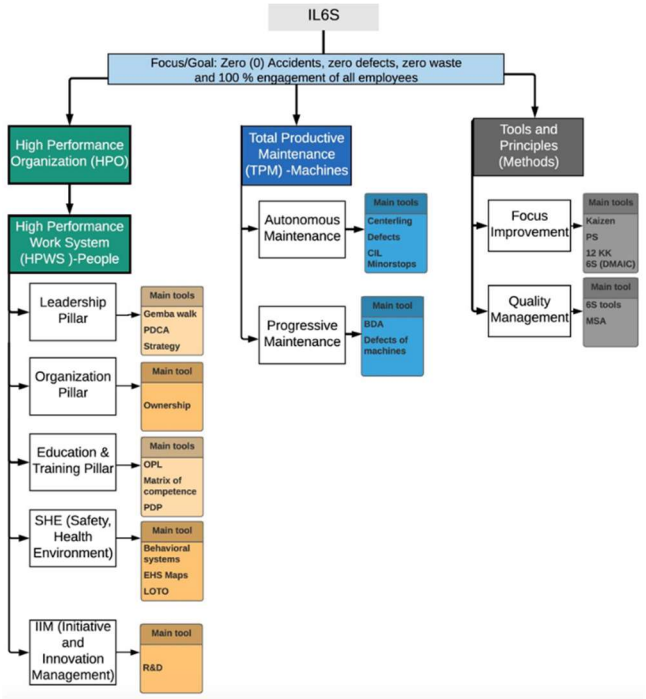

Fig. 3. Diagram of IL6Sigma construction

An integrated Lean Six Sigma pillar is a center of excellence that progressively develops a set of activities, systems, tools, and methodologies in order to build the required capability and to achieve the company's core values and goals. It is a structural element that needs to work in combination with other pillars to support the achievement of the planned goals by engaging 100% of all the employees.

Through the TPM approach, the methodology developed in Japan to improve the equipment efficiency and other results by re-educating the operators and getting their full involvement, workers [3]:

- Act as a plant owner due to the responsibilities every one holds, and the open management system;
- Develop generally either professionally or out of it;
- Feel helpful and proud to work for the company because they see their ideas being implemented at the plant;
- Are unique and important;
- Working better as teams rather than in solos;
- Teach and learn from the others.

Some of the main tools used in IL6Sigma result from the combination of Lean and Six Sigma techniques in order to improve business results by pinpointing the goals set and customer satisfaction are shown in fig. 4.

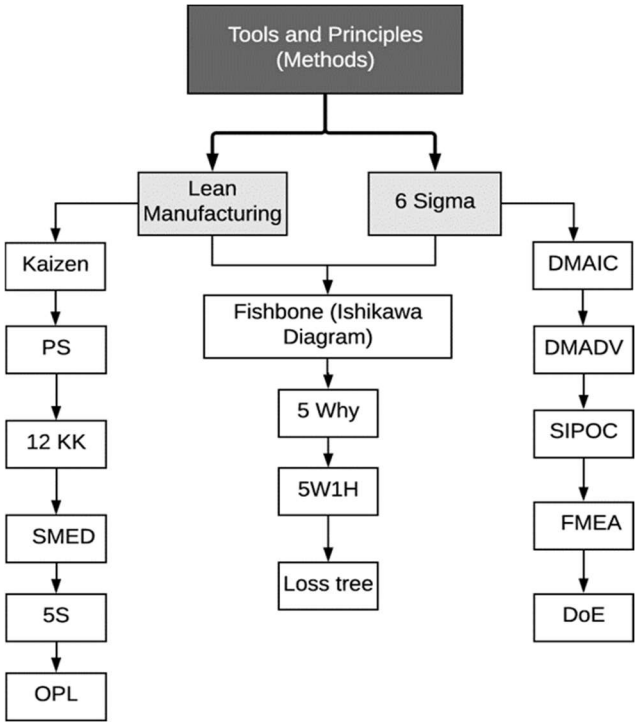

Fig. 4. IL6S tools

Three working stations where defected products were detected at the Quality control (QC) station and for which the reason is unknown are shown below. This is the exact moment where Problem Solving (PS) tools are applied.

3. Contribuition to the development of the industry in Angola

Angola is recovering from a post-war period that was followed by an economic crisis caused by the drop in the price of oil on the international market and, very recently, the collateral effects of COVID-19 which, on the one hand, left the economy totally vulnerable and weakened but, on the other hand, opened an opportunity for the process of economical reinvention and diversification as well as for the implementation

of reforms in the strategic sectors and improvements in the business environment.

At this moment, Angola is going through a very crucial moment as there is an accelerated growth of the industrial sector, considering the fact that industry is the a determining factor for the development and evolution of Angola aimed at promoting and fostering national production. However, in order for this growing number of industries in the most varied sectors to meet expectations, to match the competitiveness with the industries in neighbouring countries, SADC – Southern African Development Community, ZLCLA – Free Zone of African Continental Trade and industries in other continents, it is very important to standardize and conform national production to the world's highest standards of quality and efficiency.

With the standardization of the Industrial Activity in Angola (by the Ministry of Industry and Commerce), Angola will not only increase the level of competitiveness or improve the quality of products and services provided by the already installed and future industries, as it will also help the Ministry of Industry and Commerce coordinate it in an easy and orderly way. It is because the industry standardization will help to reduce waste, occupational accidents and increase the quality of skills of the employees in the industrial sector through the application of the IL6S philosophy.

This is an ongoing process, similar to what happened in Japan in the post-war period. Angola is designing sustainable, efficient and effective goals in order to organize the industrial sector through the IL6S philosophy.

The Ministry of Industry and Commerce (MINDCOM), which is a public sector specialized to define and implement policies and strategies in order to standardize and meet the national and international customer requirements by using ISO, IFS and national norms. Its been a challenge since 2020 when the country started a general diagnosis to get to know the processes andpolicies used in the different industries installed in Angola in 1975-2020. Therefore, it is possible to standardize it. Considering the benefits of the IL6S Philopphy, the Angolan government is looking forward to implementing it.

4. Case study

The implementation of the selected tools of IL6Sigma will be presented in a company producing steel products in Angola. The project aimed at optimising a chosen production process according to the criteria:

- production time,
- resources utilisation and
- inventory levels.

The obtained results will allow quick elimination of broadly defined waste in the analysed process, which has a negative impact on the production capacity and company's financial condition. In order to reach the project's objective, LM techniques were used, namely Value Stream Mapping (VSM) and Single Minute Exchange Of Die (SMED).

The implementation of the assumed goals took place in four stages. The first stage consisted of building a production line model for individual products and checking the production capacity. The model was used to test the planned variants of solutions. The existing technology of the performance of the current machines and stations and the plan of a layout were used to build the model. The ProModel modelling and simulation software was used to build the model. The model from stage 1 was used to compare the results from the other stages of the project.

The second project stage consisted in conducting the analysis of existing problems in the two chosen processes and indentifying the sources of waste within the enterprise. The VSM method was applied, enabling to scrutinise holistically the production system in the search for losses. The general present state map is presented in fig. 5.

Organisational changes were proposed. The introduction of them should shorten the lead time by 50% and minimise work-in-process inventory. Such a result was achieved through changing the existing production scheduling system to a kanban-controlled system, and by introducing supermarkets, what consequently decreased the storage area and allowed the removal of storage – switching station.

Additionally, an altered operating principle of the assembly cell, shifting to a continuous flow cell was proposed. A detailed analysis of fitter's activities led to their modification so that a single employer will carry out as much activities as possible without having to change the instrument. That solution decreased production cycles, enabled the reduction of employees as well as the elimination of redundant movements and redundant parts transport.

Subsequently, theinformation flow within the enterprise was subjected to an analysis. Anassembly cell was proposed as a process peacemaker, and the assumption that schedulling will be done at that cell was made. Consequently, the company is capable of processing a client's order within one day, not instantly of course, but the order will await the completion in the tasks-in-process queue.

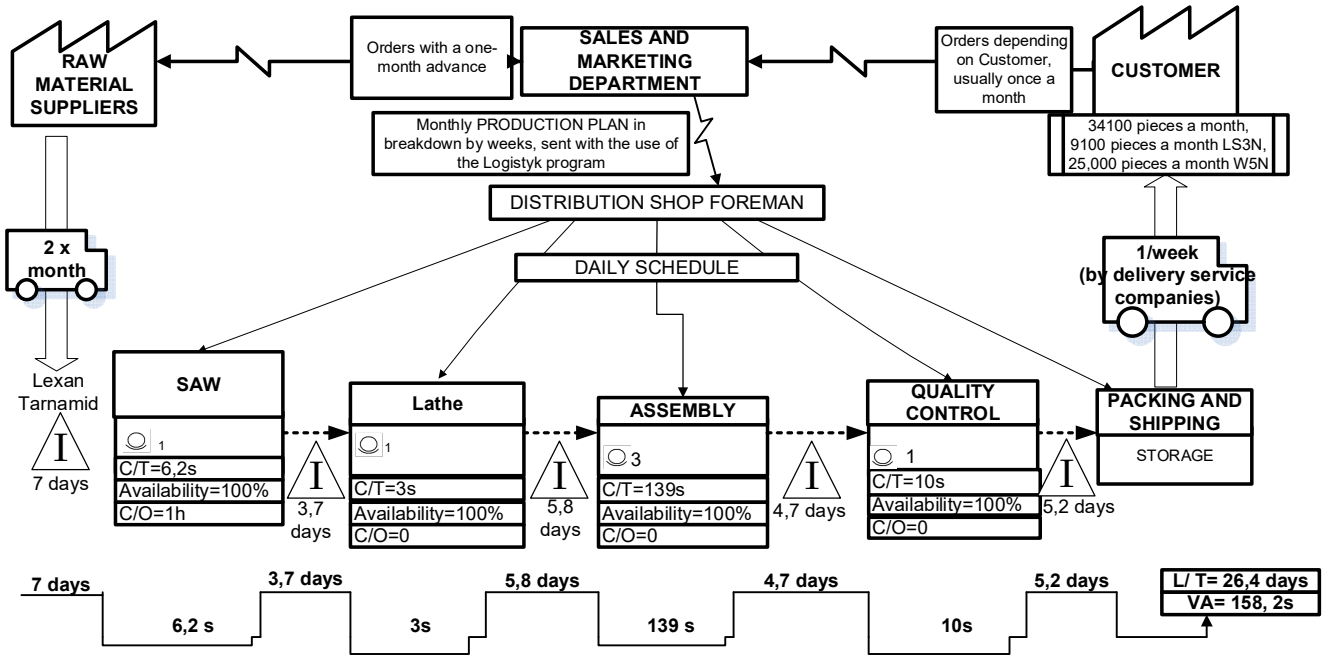

Fig. 5. Production process map – current state

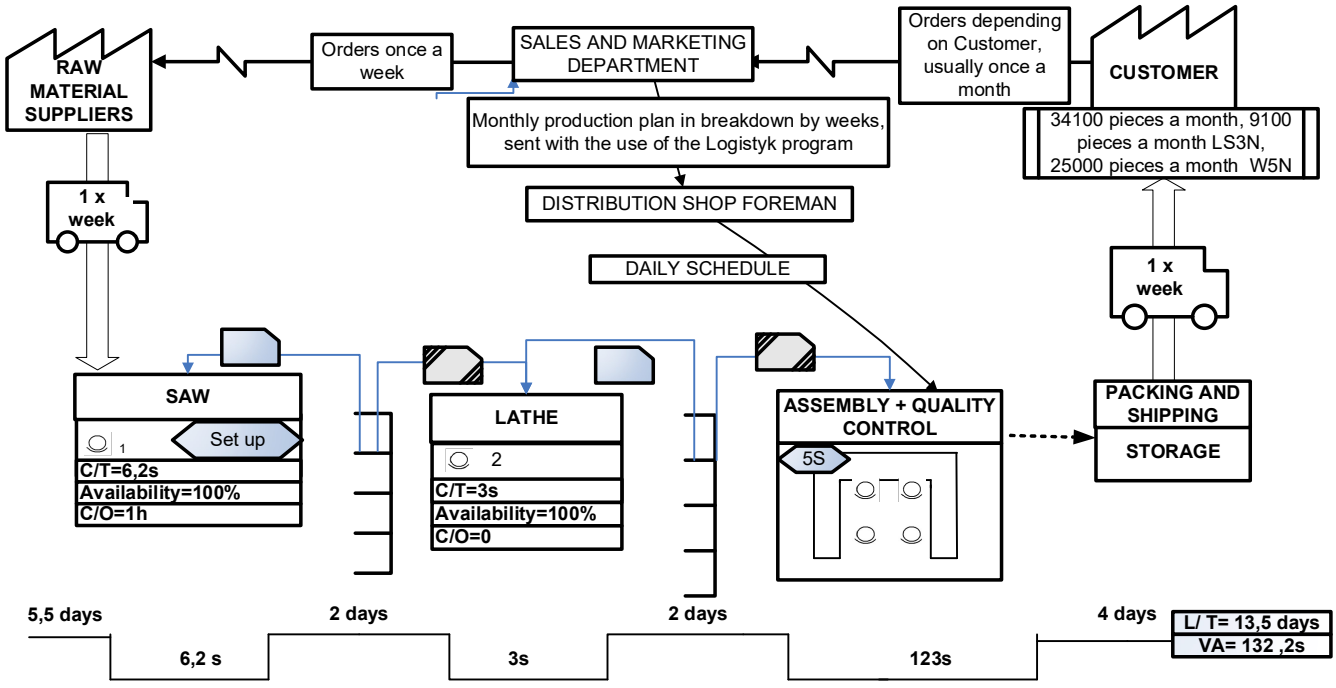

Fig. 6. Future state map for the analysed process

In the third stage of the project, in order to eliminate the bottlenecks, organizational changes were suggested including introducing the third shift for the selected workstations, employing new workers or purchasing other instruments and equipment, depending on the expected investment costs. A new distribution of operations between workstations was introduced and the quality inspection so far performed in the main production line was relocated. The optimized U shaped production line is shown in fig. 7.

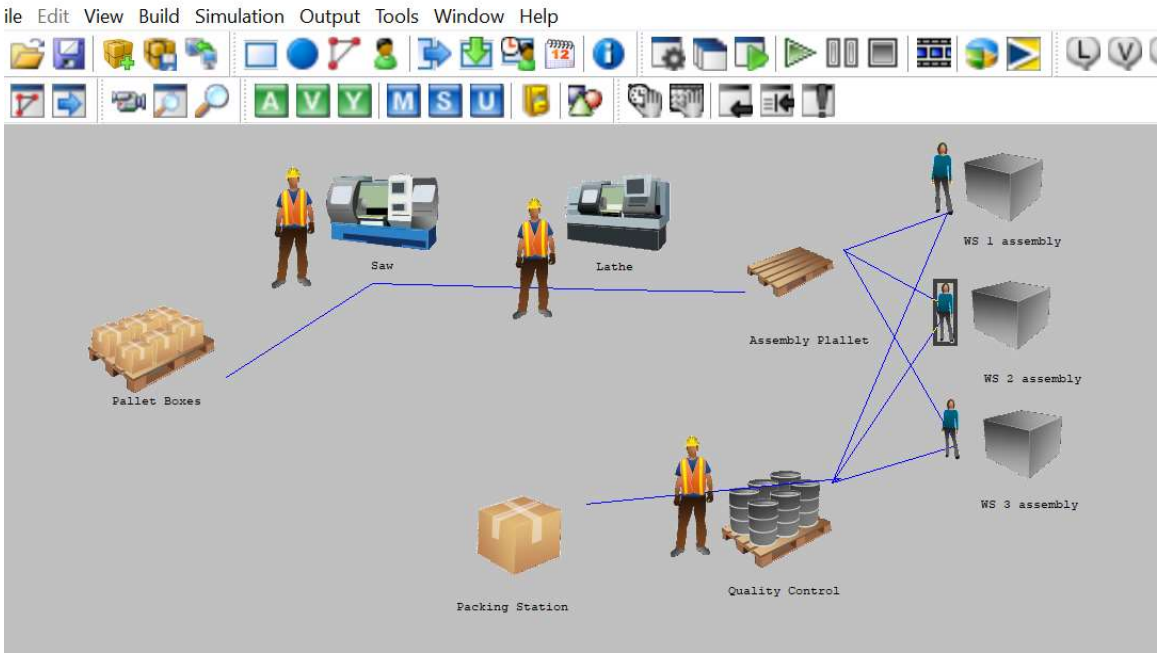

Fig. 7. Optimized U shaped production line

The project's fourth stage was to use one of the Lean manufacturing methods - SMED (Single Minute Exchange Of Die) focused on the waste reduction in manufacturing processes and to provide a rapid and efficient conversion and optimization. In this specific case study, by using SMED, it was possible to optimize the production time, the distance in-between the production stations and the time spent by each employee at every station, cutting off the wasted time and making it more productive in order to maximize the results. Individual steps of the SMED Method carried out in the project are shown in fig. 8.

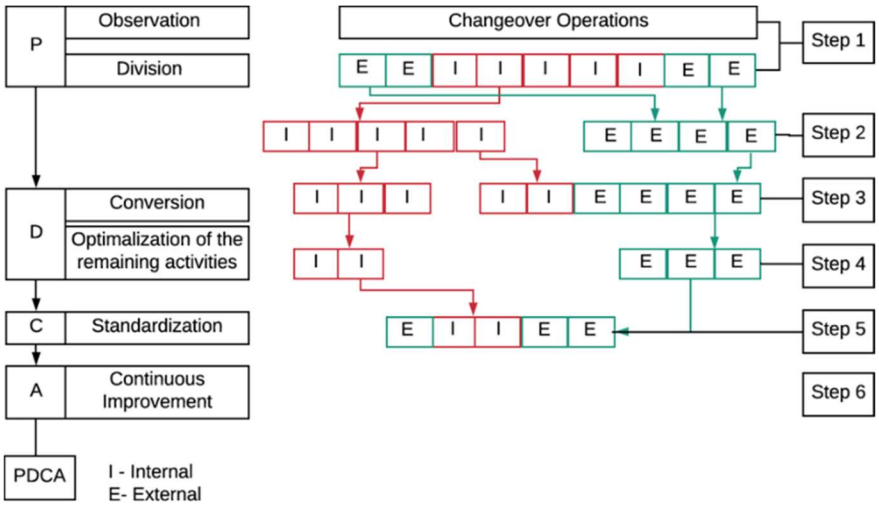

Fig. 8. Steps of the SMED method carried out in the project

The productivity of the selected workstations before and after the changes is shown in figure 9.

To summarise, applying lean methods such as VSM, SMED method and modelling and simulation tools provides enterprises with tangible benefits. In the current market situation, cost-cutting becomes ever-more difficult. The best practice is to seek economies at the source of their origin, i.e., eliminating waste. The presented process optimizing methods allow to achieve a considerable efficiency improvement because the proposed changes render the enterprise capable of producing-to-order by utilizing the production resources and labor to the maximum extent.

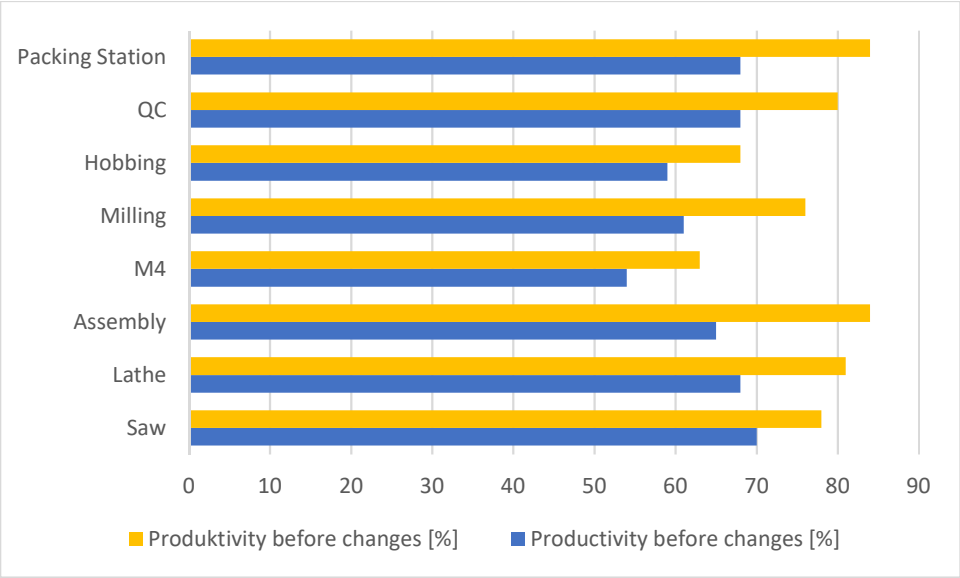

Fig. 9. The productivity of the selected workstations before and after the changes

5. Conclusion

The philosophy IL6S provides a better management and more effective result achievement for the manufacturing companies. As companies look forward to reducing costs, accidents, defects and they aim to produce on time and with high quality by reducing batch sizes, changing setup times and have a more effective flow of systems, looking forward to satisfying the requirements and/or needs of their customers, the IL6S is a perfect philosophy to usebecause it focuses exclusively on achieving zero (0) accidents, zero (0) defects, zero (0) waste and 100% involvement of every and each of the employees in order to provide products and/or services on time to the customer with higher quality and lower costs.

Through this philosophy, the problems of the companies are handled timely and efficiently, considering the fact, that, every individual in the organization is able to highlight problems, ask for help whenever is needed and he/she is focused on fixing the problems in his/her area. Thanks to IL6S, manufacturing companies have well-planned, detailed and deployed targets. Based on this philosophy manufacturing companies develop a mindset of a highly professional organization that takes losses and defects as personal challenges and works to eliminate them by fixing the root causes.

Integrated Lean Six Sigma improves the GE of manufacturing companies to the world-class levels, up to 75–85% of outcomes, and a total guarantee of satisfaction of their customers, stakeholders and all users of their products/services.

References

[1] Arnheiter, E. D., Maleyeff, J. The integration of lean management and Six Sigma. The TQM Magazine, 17(1), (2005).

[2] George M.L. Lean Six Sigma: Combining Six Sigma Quality with Lean Speed, The McGraw-Hill Companies, (2002).

[3] Rathilall, R., Singh, S. A Lean Six Sigma framework to enhance the competitiveness in selected automotive component manufacturing organisations. South African Journal of Economic and Management Ssciences, 21(1), pp. 1-13, (2018).

[4] Eckes G. (2011). Six Sigma jako trwały element kultury organizacji, MT Biznes, Warszawa.

[5] Marchwiński, John Shook, Alexis Schro-eder. Wrocław : Lean Enterprise Institute Polska, cop. 2010. pag. [86].)

[6] Alhuraish, I., Robledo, C., Kobi, A. A comparative exploration of lean manufacturing and six sigma in terms of their critical success factors. Journal of Cleaner Production, vol.164, pp.325-337, (2017).

[7] Salah S., Rahim A., Carretero J.A. The integration of Six Sigma and lean management. International Journal of Lean Six Sigma (2010).

[8] Stadnicka, D., Stępień, P. Zastosowanie wybranych metod Lean Manufacturing do doskonalenia produkcji palet transportowych. Technologia i Automatyzacja Montażu, (3), pp. 46-52, (2012)

[9] Pepper M., spedding P.J, Trevor A. The evolution of lean Six Sigma. International Journal of Quality & Reliability Management, (2010).

[10] Antosz, K., Kuźdżał, E. Doskonalenie procesu przezbrajania maszyn montażowych z wykorzystaniem metody SMED. Technologia i Automatyzacja Montażu, (1), pp. 49-53, (2015).

[11] Antony J., Snee R., Hoerl R. Lean Six Sigma: yesterday, today and tomorrow. International Journal of Quality & Reliability Management, (2017).

[12] Drohomeretski E., Gouvea da Costa S. E., Pinheiro de Lima E., Garbuio, P. A. D. R. Lean, Six Sigma and Lean Six Sigma: an analysis based on operations strategy. International Journal of Production Research, 52(3), pp. 804-824, (2014).

[13] Sarman S., Soediantono D. Literature Review of Lean Six Sigma (LSS) Implementation and Recommendations for Implementation in the Defense Industries. Journal of Industrial Engineering & Management Research, 3(2), pp. 24-34, (2022).

[14] Yadav V., Gahlot P., Kaswan M. S., Rathi R., Singh M. Sustainable Green Lean Six Sigma Methodology and Application Status: A Perspective Review. Recent Trends in Industrial and Production Engineering, pp. 251-266, (2022).