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Application of Lean Manufacturing and TOC to Increase Productivity in a Company in the Hermetic Windows Sector

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Abstract

This research aims to apply Lean Manufacturing and TOC to increase productivity in a company in the hermetic windows sector. According to the diagnosis made by VSM, the company has a low productivity of 64.47%, identified in the cleaning and assembly processes. To solve the problem of low productivity, the 5 phases of TOC (Theory of constraints) are applied, implementing Lean Manufacturing tools within these phases, which increase productivity and reduce waste and time. We implement these tools to order and organize the operations area, minimizing processing times; on the other hand, the implementation of Standard Work is simulated to reduce process times by eliminating times that do not add value. For the simulation and validation of the proposed solution, the software Arena Version 22 was used, increasing and obtaining productivity of 85%.

Keywords
Manufacturing, Lean Manufacturing, TOC, Productivity.

1. Introduction
Currently, having high levels of productivity is essential to be competitive. Companies with high levels of productivity obtain more profit due to optimizing their processes and resource management. Within the Lean philosophy, we consider waste to be downtime, unfulfilled orders, and raw material waste; because they generate costs (Mor et al., 2019) (PAREDES-RODRIGUEZ, A. M., 2017). For the company, an increase in its productivity would increase its revenue and allow it to fulfill its orders, satisfying its customers. On the other hand, having a productivity deficit generates severe risks and consequences for the company. From economic losses, delays and errors in production, failure to meet objectives, or the flight of their talent to other companies.
The search for added value in the window market is becoming increasingly common. This added value would be acoustic insulation, thermal insulation, and energy saving. That is why, by 2025, we project the market for airtight windows to grow by 4.8%, increasing from USD 12.8 billion to USD 16.2 billion (NASDAQ OMX's News Release Distribution Channel, 2018).

Using Lean tools in an aluminum window company, productivity increased by 23.12% (Villasana Martinez, M. M. et al., 2017). In addition, in a glass products packaging company, implementing lean tools eliminated overtime in the processes. As a result, in the following months, the expense was reduced to USD 161,088, USD 572,196, and USD 0.00 (PAREDES-RODRIGUEZ, A. M., 2017).

The research aims to apply the lean manufacturing methodology to increase productivity in the manufacturing process of airtight windows. According to the successful results of the authors mentioned above, we will implement the 5S Standard Work tools following the TOC phases. Furthermore, we used quality tools to determine the causes of the problem. The motivation is to generate a contribution in knowledge based on the results obtained.
We will divide the investigation into five parts. The first chapter will be the introduction which will include the importance of research, analysis of the problem, and background. The second chapter will be the study's contribution explaining this investigation's proposal. In the third chapter, we will show the research results, followed by the fourth chapter, which will discuss the results. Finally, the fifth chapter of the research will be the investigation's conclusions.

1.1 Objectives
The main objectives of the study were to increase the productivity at the company; prove the efficiency of the engineering tools in the study and give the enterprise a process that can be used at any time.

2. Literature Review

High productivity standards in the manufacturing industry are essential to compete in the market. Low productivity can be caused by factors such as working methods or the work performance of operators (Andrade, A. M. et al., 2019) (Vargas-Acha, J.A. et al., 2022). Implementation of different engineering tools and methodologies is necessary to resolve this issue. The research will use 5S, TOC, and Standard Work tools, which together will solve problems within the manufacturing plant, to optimize production. With these tools, the plant can be well organized, have a good production flow, standardize production processes, and identify and treat production problems. (Gupta, S. et al., 2019) (Aisyah, S. et al., 2020) (Ali, A. M. M. et al., 2022). Furthermore, it will optimize production levels, which is a positive economic impact in the long term.

(Vargas-Acha, J.A. et al., 2022) indicate that, through the application of engineering tools, they increased efficiency by 6%. In addition, (Shahriar, M. M. et al., 2022) point out that, thanks to the implementation of 5S, in a plastic bag factory, the efficiency increased by 21.8%. Regarding implementing the Standard Work tool, (Antoniolli, I. et al., 2017) increased the OEE by 16% in a car manufacturing parts plant. Regarding the application of TOC, (Mahdi, Z. H. et al., 2021) showed that by applying the TOC tool, revenues increased by 2.67% in a beverage company and ROI by 1%. These results translate into a significant increase in productivity.

A. Productivity issues

One of the leading key performance indicators is productivity. To implement a TPM in a plant, the availability standards, performance efficiency, and quality rate must be 90%, 95%, and 99%, respectively (Rahman S., 2018). According to the research collected, several factors could generate low productivity in a company. One of the leading causes that give rise to low productivity and efficiency in the company is the method of work with which the tasks are performed when this needs to be improved (Andrade, A. M. et al., 2019). Low productivity also arises because most companies seek the cheapest labor, and not all these people have a good level of education since, in manufacturing, it is almost always possible to observe "the law of minimum effort in operators" (Vargas-Acha, J.A. et al., 2022).

(Vargas-Acha, J.A. et al., 2022) point out that, through the application of Lean tools, efficiency went from 75.3% to 81.3% due to the increase of sealed bags over the estimate for the same period (12,220 versus 13,198). In addition, Andrade also tells us that applying techniques to streamline and simplify work increased efficiency by 0.77% (Andrade, A. M. et al., 2019).

A.5S

Many companies in the manufacturing sector solve their problems using 5s, a tool of the Lean Manufacturing methodology. (Monnanyana, O., & Gupta, K., 2021) apply 5S to solve problems in a valve manufacturing plant, reducing material and tool search time, tidying up the plant for better equipment visibility, and reducing chaos. (Shahriar, M. M. et al,. 2022) They seek to solve problems in a plastic bag plant, implementing 5S, optimizing set-up times, reducing operations times, and increasing productivity. (Gupta, S., & Chandna, P., 2019) solved problems in assembling a scientific equipment manufacturing plant, using 5S to reduce tool search time and increase occupational security. Based on the results described, we affirm that the implementation of 5s is a broad and general tool and that, in manufacturing companies will bring many benefits that provide improvements in productivity and efficiency.

B. Standard Work

Applying the Standard Work (SW) method of Lean manufacturing generates multiple benefits for companies in the manufacturing sector. This tool standardizes production by analyzing times within workstations and reorganizing them to achieve more uniform times. (Aisyah, S. et al., 2020) Implementing SW in a metal parts manufacturing company decreased the number of defective products. (Mor et al., 2019) obtained similar results when implementing SW in a manufacturing company with problems with variability and excessive time in the production process. As a result of using the tool, there was an increase in production, productivity, and a reduction in cycle times. As a result of the cases described above, SW helped solve the problems affecting companies and provided improvements in productivity and efficiency.

C. TOC

The theory of constraints suggests focusing attention and improving efforts only on restrinctions. This is very attractive because it promises high efficiency, obtaining great results with the least possible outlay (Urban, W., & Rogowska, P., 2020). This theory focuses on identifying the main limitations or problems that arise in solving it. Ali indicates that TOC is a crucial method to identify bottlenecks and restrictions and treat them by eliminating their impact on the production process, achieving maximum performance, since, in the company of their case study, applying TOC, they increased revenues by USD 258,570.00 (Ali, A. M. M. et al., 2022). Likewise, Mahdi indicates that applying TOC resulted in a considerable increase in revenue, increasing by 2.67% and an increase in ROI of 1% compared to previous years (Mahdi, Z. H. et al., 2021). The application of TOC allows for the identification of problems in production processes, to apply them in the process and thus, reduce times, be more effective, and have greater efficiency and productivity. In the long run, this generates a positive economic impact, reducing production costs.

As for the model used for this research, we will rely on using the tools described in the state of art to solve the problems in a factory of hermetic windows. (Vargas-Acha, J.A. et al., 2022) indicate that most Peruvian industries are affected by low productivity and efficiency caused by various factors. We can use multiple engineering tools. One of them is 5s, from Lean manufacturing. (Shahriar, M. M. et al,. 2022) used 5s to achieve an increase in productivity. On the other hand, it is also essential to implement Standard Work, a Lean manufacturing tool that (Antoniolli, I. et al., 2017) used to increase OEE and productivity in a manufacturing plant. Another tool that assists in solving problems is TOC, which (Mahdi, Z. H. et al., 2021) used to increase the ROI and revenue of a beverage factory. Finally, SLP, a tool to redesign plant layout, was used by (Zulkifli, N. et al., 2017) to improve the productivity and efficiency of an automotive plant.

Based on the research and previous review of scientific articles, we propose a new production management model, implementing tools such as 5s, SLP, Standard Work, and TOC to optimize the production process in a manufacturing plant of hermetic windows. The model is made by 5 phases, following the TOC methodology, which is the following: 1) Diagnosis of problems and identification of system restrictions; 2) Exploit system restrictions through the implementation of SLP and Standard Work; 3) Organize and order the process applying 5S; 4) Verification of the improvements applied through revision; 5) Return to step 1, identifying new restrictions following with continuous improvement.

The proposed model uses several engineering tools together to maximize the effect achieved by each one and increase productivity (figure 1). In this model, we apply the 5 phases of TOC, implementing tools such as 5S, Standard Work, and SLP throughout the process. Next, we will go into detail about each of them.

• PHASE 1
The proposed model starts with phase 1. This phase consists of diagnosing the problems and identifying the constraints in the process. For this phase, we made a diagram of process operations, route diagram, relational analysis, and material balance to diagnose the restrictions and their root causes correctly.

• PHASE 2
This phase will implement two engineering tools: SLP and Standard Work. First, it will start with the performance of the SLP tool with the information obtained from the analysis carried out in phase 1 and the manufacturing plant space required and available; we will develop two different plant design alternatives, choosing the optimal design with better results. Second, it starts with the implementation of Standard Work (SW). It begins by describing the process and the time taken by each machine and manual operation (operator activities). Then define what type of activity each is (VA or NVA), where "VA" means "activity that adds value" and "NVA" means "activity that does not add value." Next, we measure the cycle time and calculate the average cycle. A production table is then created for machinery and manual operations. Then, we perform a sequence of combined production operations, and within the frame, it is determined whether they are VA or NVA. Then we make proposals to eliminate the NVAs identified above. Finally, we perform the Standard Work Combination Table (SWCT), where production activities are shown in a timeline, using the data collected in the previous steps. Each operation describes tips for removing NVA. Finally, each workstation's standard amount of work in process is defined. After implementing the proposals, we analyzed them to see if there were improvements.

• PHASE 3
In the third phase, we implement the 5s tool. It starts with the first S (Seiri), then the second S (Seiton), the third S (Seiso), the fourth S (Seiketsu), and the fifth S (Shitsuke). In this phase materials will be labeled, tools, and waste that is no longer necessary in the process, removing or repositioning, work, and circulation areas will be delimited, signaling them. Furthermore, we elaborate maintenance and cleaning plans, standardizing the plant's operations by implementing work guides, daily tasks, and checklists, to finally maintain a standard on operating to achieve the 5s correctly through applying incentives and training.

• PHASE 4

The fourth phase of the proposed model consists of mapping and evaluating the proposed improvements considering the new indicators obtained. This compares the new indicators with the indicators before the improvement.

• PHASE 5
The fifth phase consists of returning to the first step to find new restrictions to reapply the five stages of TOC and thus achieve constant improvement and growth.

3. Methods

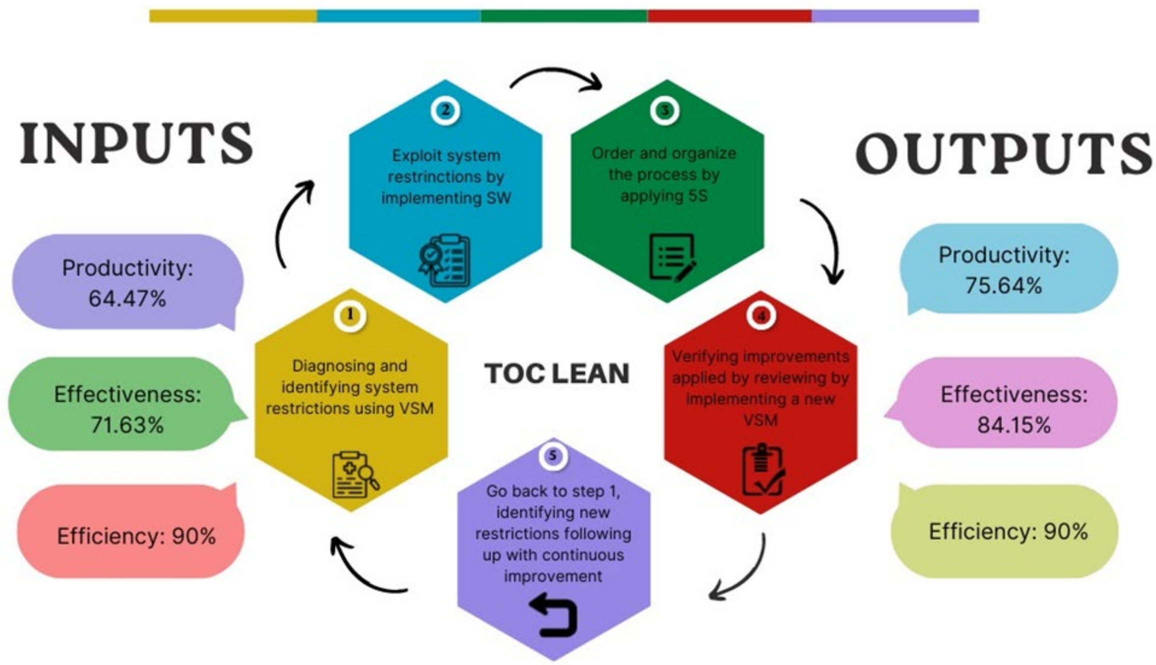

Figure 1. Proposed model

4. Data Collection

We collect the data on the production process to validate the present investigation. Among the most relevant data obtained are the cycle times per station, the total process time, the linear PVC meters entering the process, the final linear meters that leave, the waste generated in linear meters of PVC, and the planned production orders vs. the orders produced.
The time taken was calculated by timing each station 58 times. Also, we figured out the manufacturing times of each frame in each station, along with the LTP (Lead Time Process), which were the effective operating times for each transfer, and the LTP (Lead Time Process). The present data collection was carried out on different days to have a large and valid sample for the study of times. In the current data collection, we perform the stratified random sampling technique to identify the sample size, as there was no known population variance. We used the following formula:

$$n = \frac{N * Z^2 * p * q}{e^2 * (N-1) + Z^2 * p * q}$$

N: Population
Z: Confidence Level
e: Margin of error
p: Probability in favor
q: Probability against

The population is 66 windows per week, the margin of error is 5%, and the confidence level is 95% (Z=1.96), with a p-value of 50% and q of 50%. As a result, it gives us a sample of 57 windows.
Thus, we determined the time taken in twenty-nine days; therefore, we took two-cycle times per day; this yields a sample size of 58 effective operating times and 58 processing times in 29 days (table 1). Furthermore, the data of the

production orders of the company were collected annually and monthly, thus obtaining the data of the planned production orders and those that were carried out (table 2). During the present data collection, it was evident that, on several occasions, the operators did not have the necessary tools to perform their tasks, so they made unnecessary movements to obtain their tools, unnecessarily increasing the cycle times per operation per frame and the LTP.

Table 1. average effective operating times

Operation	Average Effective Operating Time
Cut	1.13
Screwed	4.83
Weld	2.73
Cleaning	4.87
Assembly	9.58
Total	21.88

Table 2. Annual planned production vs real annual production

Year	Planned	Completed on time
2021	4449	3187

Considering the data collected, we evidence a plant productivity of 64.47%. Therefore, by applying 5S and Standard Work tools, it is proposed to improve productivity to 85% (table 3).

Table 3. Main indicators, current and targets

Indicator	Productivity	Efficiency	Effectiveness
Actual	64.47%	90%	71.63%
Objective	85%	90%	90%

5. Results and Discussion

5.1 Numerical Results

Applying the proposed improvements begins with implementing Standard Work to correct NVA times. Next, table 4 details the activities performed on each workstation, which we classified into VA and NVA. Then, we provide suggestions to delete the selected NVAs, and the next column estimates the time saved.

Table 4. Standard work operations

No Activity	Average Time (minutes)	Suggestions for removing NVA	Time saved (minutes)
Cut	1.13		
Screwed	4.8307	We carried out the implementation of a manual with the necessary specifications for the activity	0.75
Welding	2.73	Indicate which profiles are from the same order using tags, minimizing the verification time	0.2184
Transfer 1	1		
Cleaning	4.87	Implementation of a manual with necessary specifications on the activity to be carried out	0.4

Transfer 2	15.45	Reduction of time if elevator movement	5
Assembly	9.58	Implementation of workbench shootings, assembly instruction manuals	0.65
TOTAL	39.5907		7.0184

As it was appreciated, by implementing the SW tool, we came out with several suggestions to reduce time. First, we used labels at the welding station, indicating to which order each profile belongs. Second, to minimize the time, we checked the shapes to be welded. Third, in the cleaning station, we implemented an instruction manual with the necessary specifications to carry out the activity; In this way, the operator no longer wastes time consulting the supervisor. Fourth, we reduced the frequency with which the elevator moves the material to the assembly floor for elevator transfer. Then, at the assembly station, shoots are implemented on the work table. In this way, the operator no longer has to move around the table when rotating the frame since it slides over the bearings. Finally, in this same station, an instruction manual is implemented, as in cleaning, so when the activity happens, the operator does not need to consult the supervisor about it. After implementing the improvements mentioned above, we reduced the total processing time by 7.0184 minutes per frame, equivalent to 17.73%; So, the new real processing time is 39.59 minutes per frame.

For applying the 5s, first, an analysis is carried out in which we evaluate the situation of the company, assigning a score for each "S" to the process (figure 2). We evidence a deficiency in almost all 5s. That is why we decided to carry out the following improvements.

Due to this, after the implementation of 5S, the new search times proposed by the station are established, evidenced in table 5, and collected using the data collection technique. Finally, we show the results of the post-implementation evaluation in figure 3.

Table 5. New search times

Activity	**VA / NVA**	**Average time (minutes)**	**New time (minutes)**
Finding tools in the screwing station	NVA	0.749	0.311
Search for tools to perform manual cleaning	NVA	0.292	0.274
Search for tools and assembly materials	NVA	0.574	0.476

After implementing 5s, we established the new search times, and a reduction of 34.24% in the search times of tools and materials is evident.
Thus, the new times are established after the application of both improvements, thus obtaining a total reduction of 19.66% in working times, as shown in table 6.

Table 6. Average times after the application of the improvements

No Activity	**New Average Time (minutes)**
Cut	1.13
Screwed	3.43
Welding	2.512
Transfer 1	1

Cleaning	4.453
Transfer 2	10.45
Assembly	8.831
TOTAL	31.806

5.2 Graphical Results

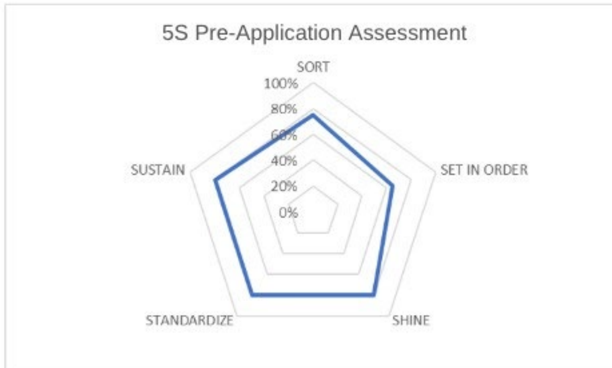

Figure 2. 5S Pre-Application Assessment

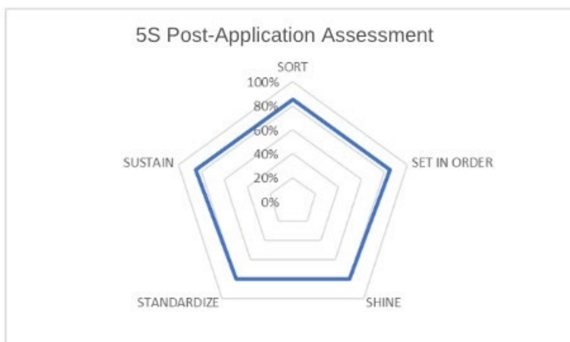

Figure 3. 5S Post-Application Assessment

5.3 Proposed Improvements

Among the results obtained, after the simulation with the improvements, there is a new production of 13 frames per day, and the recent cycle times for the entire operation are 31,806 minutes. In this way, the indicators in table 7 are evident. In addition, figure 4 shows the VSM after the enhancements are applied.

Table 7. New indicators

Indicator	Productivity	Efficiency	Effectiveness
Current	64.47%	90%	71.63%
New	75.64%	90%	84.15%

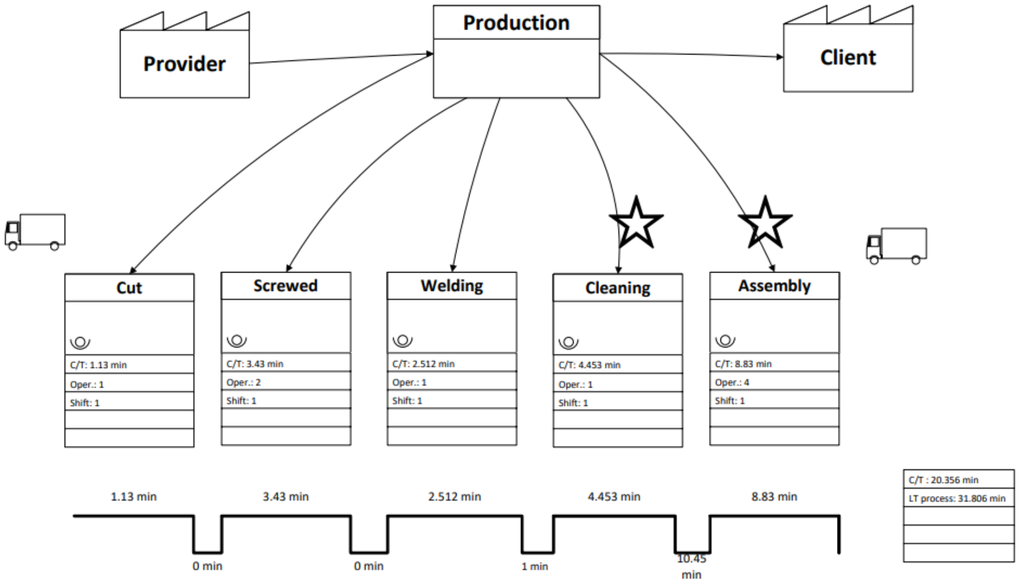

Figure 4. VSM of the process after improvements

5.4 Validation

For the validation of the tools used, we used the Arena software. This software allows you to simulate the conditions of the process of the plant, both with the times before the improvements and with the new estimated times. For example, the process is simulated 500 times since it is higher than estimated in calculating the number of replicas needed. We make this procedure to obtain more accurate results. Figure 5 shows the diagram of the process proposed in Arena.

Among the results obtained, after the simulation with the improvements, there is a new production of 13 frames per day, and the recent cycle times for the entire operation are 31,806 minutes.

As stated in the hypothesis, using SW and 5S under the TOC procedure increased productivity. We achieve this by reducing the non-valuable time of the process and, in this way, reducing the total time to gain more outstanding production.

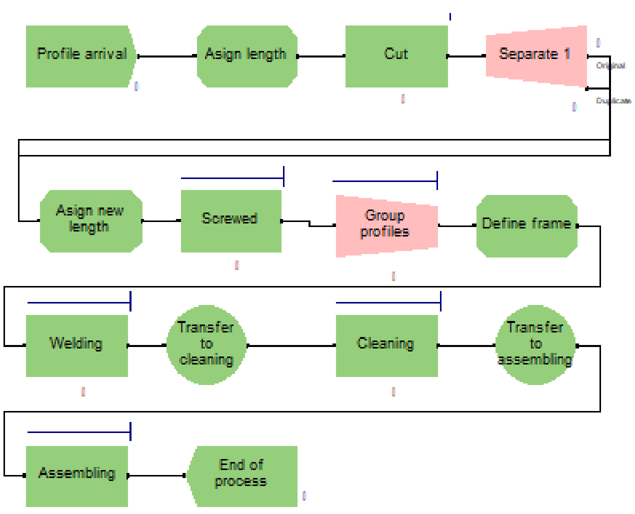

Figure 5. Improved process review

6. Conclusion

In conclusion, as we stated our main objective at the beginning of the investigation when implementing Lean manufacturing, using tools such as 5S and Standard Work, following the steps of the TOC methodology, we reduced times by 7,785 minutes per frame. Consequently, it was possible to increase the productivity of the process by 11.17%. Considering our secondary objectives, efficiency and effectiveness had to be optimized to increase productivity. Thus, by applying both tools, efficiency remained constant at 90%, and effectiveness increased by 12.52%
Furthermore, by implementing the 5S tool, it was possible to reduce the search times for materials and tools in the plant by 34.24%. By applying both tools together, it will be possible to reduce the total cycle time by 19.61%.

References

Mor, R. S., Bhardwaj, A., Singh, S., & Sachdeva, A., Productivity gains through standardization-of-work in a manufacturing company: IMS. *Journal of Manufacturing Technology Management*, 30(6), 899-919, 2019. https://doi.org/10.1108/JMTM-07-2017-0151

PAREDES-RODRIGUEZ, A. M., Aplicación de la herramienta Value Stream Mapping a una empresa embaladora de productos de vidrio. *Universidad del Valle, Cali, Colombia, 2017.* http://www.scielo.org.co/pdf/entra/v13n1/1900-3803-entra-13-01-00262.pdf

The insulating glass window market is projected to grow from USD 12.8 billion in 2020 to USD 16.2 billion by 2025, at a CAGR of 4.8% from 2020 to 2025: The key factors for the growth of the insulating glass window market such as optimal energy saving performance of insulating glass windows, the growing construction industry in regions like the Middle East and Asia Pacific, and the rising demand for value-added glass products are driving factors for the growth of insulating glass window market. (2020, Oct 08*). NASDAQ OMX's News Release Distribution Channel, 2020.* http://fresno.ulima.edu.pe/ss_bd00102.nsf/RecursoReferido?OpenForm&id=PROQUEST-41716&url=https://www.proquest.com/wire-feeds/insulating-glass-window-market-is-projected-grow/docview/2449093149/se-2?accountid=45277

Villasana Martinez, M. M. & Gonzalez Rodriguez, H. & Delgado Gallardo, A.S.,Mejoramiento del flujo del proceso en el armado de ventanas de aluminio. *Revista de la invencion tecnica* (Vol.1 No.2 8-13), 2017 . https://www.ecorfan.org/taiwan/research_journals/Invencion_Tecnica/vol1num2/Revista_de_Invencion_Tecnica_V1_N2.pdf#page=15

Rahman S.,, Implementation of Total Productive Maintenance (TPM) to Enhance Overall Equipment Efficiency in the Jute Industry – a Case Study, 2018. https://www.researchgate.net/publication/326836353_Implementation_of_Total_Productive_MaintenanceTPM_to_Enhance_Overall_Equipment_Efficiency_in_Jute_Industry_-_a_Case_Study

Andrade, A. M., del Río, C. A., & Alvear, D. L., A study on time and motion to increase the efficiency of a shoe manufacturing company | Estudio de Tiempos y Movimientos para Incrementar la Eficiencia en una Empresa de Producción de Calzado. *Informacion Tecnologica, 30*(3), 83–94, 2019. https://doi.org/10.4067/S0718-07642019000300083

Vargas-Acha, J.A., Aramburu-Linares, T. & Quiroz-Flores J. C., Application of the SMED method to increase the efficiency of the sealing process in a Peruvian company that produces flexible plastic. *Proceedings of the International Conference on Industrial Engineering and Operations Management Istanbul, Turkey, March* 7-10, 2022.

Gupta, S., & Chandna, P., Implementation of 5S in scientific equipment company. *International Journal of Recent Technology and Engineering*, 8(3), 107-111, 2019. doi:10.35940/ijrte.C3894.098319

Aisyah, S., Purba, H. H., & Septian, D. S., Analysis Work Standardization Using The Standardized Work Combination Table on CNC of Mission Case Line Process at PT Astra Otoparts, Tbk - Nusametal Division. IOP Conference Series.*Materials Science and Engineering*, 1003(1), 2020. https://doi.org/10.1088/1757-899X/1003/1/012044

Ali, A. M. M., & Jabir, S. M., Using attribute-based costing and theory of constraints for product-mix decisions: an empirical study in Iraq. Journal of Management Information & Decision Sciences, 25, 1–10, 2022. https://search.ebscohost.com/login.aspx?direct=true&db=bth&AN=154576679&lang=es&site=ehost-live

Shahriar, M. M., Parvez, M. S., Islam, M. A., & Talapatra, S.,Implementation of 5S in a plastic bag manufacturing industry: A case study. *Cleaner Engineering and Technology*, 8, 2022. doi:10.1016/j.clet.2022.100488

Antoniolli, I., Guariente, P., Pereira, T., Ferreira, L. P., & Silva, F. J. G., Standardization and optimization of an automotive components production line. Procedia Manufacturing, 13, 1120-1127, 2017. doi:10.1016/j.promfg.2017.09.173

Mahdi, Z. H., Abboud, A. H., & Hussain, B. B., The use of Constraints Theory in Managing, Reducing Costs and Improving Profitability (Study in Baghdad Soft Drinks Company). *Review of International Geographical Education Online,* 11(5), 3576–3582. 2021. https://search.ebscohost.com/login.aspx?direct=true&db=eue&AN=152946204&lang=es&site=ehost-live

Monnanyana, O., & Gupta, K., A Case Study on Implementation of 5S in a Manufacturing Plant to Improve Operational Effectiveness. *EDP Sciences, 2021*. http://dx.doi.org/10.1051/matecconf/202134603109

Urban, W., & Rogowska, P., Methodology for bottleneck identification in a production system when implementing TOC. *Engineering Management in Production and Services*, 12(2), 74–82, 2020. https://doi.org/10.2478/emj-2020-0012

Zulkifli, N., bin Md Yasir, A. S. H., & Abd Aziz, F. , Systematic planning layout and line balancing for improvement in an armoured vehicle manufacturing plant. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 1702–1705, 2017.

Rizkya, I., Syahputri, K., Sari, R. M., & Siregar, I., 5S implementation in welding workshop-A lean tool in waste minimization. *Paper presented at the IOP Conference Series: Materials Science and Engineering*, , 505(1), 2019. doi:10.1088/1757-899X/505/1/012018 Retrieved from www.scopus.com

Ali Naqvi, S. A., Fahad, M., Atir, M., Zubair, M., & Shehzad, M. M., Productivity improvement of a manufacturing facility using systematic layout planning. *Cogent Engineering*, 3(1), 2016. https://doi.org/10.1080/23311916.2016.1207296

Febriandini, I. F., & Yuniaristanto, Re-design Facility Layout using Systematic Layout Planning Method: A Case Study : ro Cosmeceutical Sdn. Bhd*. IOP Conference Series: Materials Science and Engineering, 495*(1), 2019. https://doi.org/10.1088/1757-899X/495/1/012027

Goyal, G., & Verma, D. S., Optimization of plant layout in the manufacturing industry. *International Journal of Recent Technology and Engineering,* 8(2), 3115–3118, 2019. https://doi.org/10.35940/ijrte.B2679.078219

Biography

Erik Andrade Rozas graduated from Universidad de Lima, in Industrial Engineering, being 23 years old. He currently works at a company dedicated to wholesale of fuel and hydrocarbon derivatives, in the sales area; with previous experience in EY, in consulting area. Currently interested in sales and supply chain.

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