Lean-SLP production model to reduce lead time in SMEs in the plastics industry: A Empirical Research in Perú

David Cordova-Pillco, BSc[1], Mirian Mendoza-Coaricona, BSc[1], and Juan Quiroz-Flores, PhD[1]
[1]Facultad de Ingeniería, Programa de Ingeniería Industrial, Universidad Peruana de Ciencias Aplicadas, Lima, Peru,
u201621601@upc.edu.pe, u201714372@upc.edu.pe, pciijqui@upc.edu.pe

Abstract*– The current context of the plastic manufacturing sector has suffered a significant alteration in recent years due to external factors such as the pandemic caused by Covid-19. On the other hand, at the national level it has been detected that 64% of companies use only between 61% and 70% of their installed capacity. In addition, the sector's profitability has fallen by 3% in the last 8 years. In this sense, this research work took as a case study an SME in the plastic sector to determine the leading causes directly related to efficiency and productivity problems. Such causes have resulted in the delayed of delivering orders, consequently lowering profitability; the reversal of loss has been the main incentive of this work. By understanding the roots of the problem, we propose the development of a double-focus optimization model that values both the operational improvement and the working conditions, such as team spirit that motivate the actions of the collaborators. This model utilizes tools corresponding to the Lean and Systematic Layout Planning (SLP) methodology. Moreover, the novelty of this proposal is the integration of a sustainability phase with a focus on continuous improvement over time by incorporating these tools as part of the company's routine. Finally, some of the main results obtained from this research were an increase of the order fulfillment index by 13.4%, a reduction of the effort of the operators by 62%, a decrease of the set-up time by 57%, and an increase of the Overall Equipment Effectiveness (OEE) by 7%.

Keywords*-- Plastic industry, Set up time, 5S, Order delivery fulfillment, Systematic layout planning (SLP), Total productive maintenance (TPM)

I. INTRODUCTION

The importance of plastic in the manufacturing industry has continued over time since its emergence in the market, more than 70 years ago. According to the latest report made by PlasticEurope, the production of this material globally has increased from 359 million tons recorded in 2018 to 368 million tons by 2019. Likewise, the Asian continent concentrates the most considerable production with 51% of the total. As for Latin America, it remains with a low participation level of 4% [1]. The global plastic injection market was valued at 265.1 billion dollars in 2020, and a compound annual growth rate of 4.6% is projected for the period 2021-2028. However, the coronavirus pandemic has considerably slowed down production activities in this market, therefore shortcomings have become evident both at the administrative and operative production levels [2]. In this sense, the Peruvian scenario has not been unaffected by the sector's reality. According to the most recent report by National Institute of Statistics and Informatics of Peru (INEI), the manufacture of plastic products has fallen by 1.5% during the first half of 2021. Although, this scenario is better than the previous year (-5.2%), there is still a gap in the sector's recovery. It has been reported that 64% of Peruvian companies currently use only 61%-70% of their installed capacity.

Likewise, profitability over sales has also been significantly affected, going from 6.2% in 2011 to 3.2% by 2019 [3]. Evidently, one of the most recurrent problems has been the delay in the delivery of orders caused by operational waste and inefficiencies in the manufacturing process [4][5][6].

Furthermore, according to what has been studied, this problem has a significant influence on the additional costs incurred by the company and its reputation and brand value. Given this, several solutions have been proposed. The first one establishes an improvement plan in the supply management area to reduce delivery time. The tools proposed for the development were, mainly, Pareto diagram, satisfaction surveys, supplier homologation, BCG matrix, Kraljic matrix, and sourcing plan. By applying the tools mention, the finish product delivery rate improved by 58% by reducing the delivery time from 17 days down to 10 days as it was the goal of the study. Within the same study, there was also a 23% reduction in sales costs [7]. Another research that also exhibits the issue with the delivery delay, will improve by applying other useful tools. In this case, the study of a plastic bag company relates the issue of delivery with production delay, and in addition, a non-compliance rate of 41.67%. The initiatives adopted in this case are related to the application of Lean tools such as Jidoka, Kanban, 5s, and TPM. As the result of that, this study showed a decrease of defective products down to 8%, and rework down to 4%; as well as an increase of order fulfillment rate up to 37% [8].

Consequently, this research will seek to contribute to the existing literature regarding the increasing rate of order delivery fulfillment, by reducing Lead Time and other idle times. Furthermore, this will seek to avoid incurring additional costs due to delay penalties and operational cost overruns. In addition, priority will be given to creating the best possible working conditions for employees. To this end, a dual-focus optimization model is proposed due to its nature of operational improvement and human capital development. Moreover, the novelty proposed would be an extra phase-oriented towards sustainability under a continuous improvement approach. In this way, the research will be able to transcend in time and would result in a perdurable improvement. Thus, the model will contain an initial assessment phase, followed by a phase related to the stabilization of the production process, to finally conclude with the optimization of maintenance times and

Digital Object Identifier (DOI):
http://dx.doi.org/10.18687/LACCEI2022.1.1.151
ISBN: 978-628-95207-0-5 **ISSN:** 2414-6390

equipment setup, as well as being able to maintain implementation sustainability.

The development of this article has been divided into six chapters. The first chapter has been this introduction to the subject matter. Followed by the second chapter in which it will be address the state of the art with all the literature consulted regarding the main problem; the development of Lean tools; plant layout redesign; proposed optimization model; and evaluation and diagnosis methodologies. As for the third chapter, the contribution of the present research, the most relevant components, and indicators will be developed. The fourth chapter presents the validation of the study showing the initial assessment, the design validation, and the final simulation of the proposal together with the pilot plan. Moreover, chapter five will compare and contrast the results obtained from previous studies in the researched area. Finally, chapter six will show the most significant conclusions within this research.

II. State of the Art

A. Delay and non-delivery of orders

The current manufacturing demands sector are becoming increasingly stringent so that factors such as the rate of delivery performance play a key role in maintaining competitiveness in the market [9]. In that sense, studies have shown the negative impact of late delivery on future sales and pricing [10]. For example, a change in the product delivery schedule from 2 to 7 days causes an approximate decrease in future demand of 6.87% to 10.99% [11]. Moreover, a previous study has determined the period in which late delivery negatively affects demand. It turns out that 15 days late deliveries have a maximum impact of 10% on the development of future sales and this effect could last on average between 3 to 4 weeks. In the case of 30 to 45 days delays, the impact could be between 15-20% and last approximately 4 to 6 weeks [7].

Different studies, due to these issues, have come up with diverse solution procedures and variable results rooted in the company's environment and particular case of this one [6][9][12][13]. One of the methodologies evaluated was Quick Response Manufacturing (QRM), which was unsuccessful due to an insufficient study of the root causes of the problem [9]. Ant Colony Optimization (ACO) and Genetic Algorithm (GA) methodologies were also applied giving favorable results in improving the flexibility of the production system. However, the complexity of these three methodologies was too high for daily use [12]. Finally, the application of Lean Manufacturing gave the best results in the long term, solving the problems related to delivery time within the supply chain. [4][14]. Therefore, this area of study can be identified as the most viable one for knowledge expansion and easy application.

B. Development of Lean Manufacturing tools

Currently, the methodology called Lean Manufacturing is widely used for its contribution to the efficient management of waste generated throughout a production process [15]. In addition, *Value Stream Mapping* (VSM) and *Just in Time* are tools that have shown the effectiveness in the initial assessment of the current situation [16][17].

Moreover, Lean methodology can be used to develop initiatives for operational efficiency, optimization of time, and continuous improvement. For example, studies have demonstrated the usefulness of *Single Minute Exchange of Die (SMED)* in reducing set-up times within the production industry. Some of the most significant improvements reduced time by approximately 48% to 60% and increased *Overall Equipment Effectiveness (OEE)* by over 80% [18][19][20][21]. However, there were also cases where the improvement was not so considerable, by saving 20% of the preparation time [22]. On the other hand, the 5S tool has also been evaluated by several authors. After the application of this methodology, the time to search tools was reduced from 8.6 to 3.1 hours in a plastic machinery manufacturing company [23]. Furthermore, alternatives have been proposed to complement 5S, such as the inclusion of 2 additional "s" focused on the development of team spirit and safety. As a result, improvements of 30% to 50% have been achieved in 7S audit rates. [24]. In addition, the impact of *Total Productive Maintenance (TPM)* has been studied on problems related to machinery breakdown, low operating efficiency of equipment, and high rates of unscheduled shutdowns. Many of the investigated companies had an OEE below the world standard that is 85% [25]. In fact, these companies presented OEE levels within the range of 30% to 55% approximately, which exhibits a low utilization of equipment capacity therefore, of the manufacturing time. Thus, after the application of some of the TPM pillars companies have been able to achieve improvements between 12% and 27% by utilizing this tool alone [26][27][28].

After evaluating various application scenarios for Lean tools, most authors conclude that the tools alone are not entirely effective in achieving time optimization, cost reduction, and sustainability improvement. In the case of SMED, most experts recommend complementing the tool with options such as the Fuzzy Interference System (FIS), VSM, SIPOC, Taguchi Method or other quality improvement methods or tools [19][20][21][29]. In the same way, in the case of 5S, the authors highlight the importance of opting for complementary tools to maximize the application results. Some of the main ones that work well with the 5s method, are Kaizen, SMED, Poka-Joke, 3M and Jidoka. When combine effectively, some of the leading indicators, such as Lead Time, were reduced by 4.04% and delivery time compliance increased from 58% to 95% [30][31][32]. Furthermore, the evidence shows that TPM also works better when complemented with tools that filled the gaps of this methodology. Such is the case when the TPM works with *Reliability-Centered Maintenance* (RCM) and *Total Quality Management* (TQM), which proved its effectiveness in the food, beverage, electrical and electronics sectors [33][34].

C. Layout redesign of a manufacturing plant.

The appropriate location of the production units in the manufacturing plant is of vital importance to carry out efficient operations and increase productivity rates [35][36]. In this sense, the authors agree that the Systematic Layout Planning methodology is one of the most efficient since it considerably reduces the time spent moving between areas; reduces transportation and handling costs; creates safer and more comfortable (ergonomic) work environments; and maximizes the use of machinery [37][38]. The application of the methodology was evaluated in micro and small enterprises (MSEs) that had high transportation costs of approximately 177,372.7 rupees per month; obtaining a saving of 20,633.4 rupees or 11.63%, as a result [39]. Another study tested the complementation of the SLP methodology with an ergonomic approach to improve the quality of work perceived by the operator. This resulted in a 23.88% improvement in travel distance, reduced material handling cost by 22.92%, and employee fatigue [38].

Thus, it is concluded that the application of the SLP is effective in most scenarios; especially when it is a matter of adapting an existing production system to take advantage of the environment conditions. However, the methods used varied on the distribution proposal's choice and validation. One study chose to evaluate five design proposals using an analytical ranking process based on three validated criteria by a consistency ratio (CR) [40]. Likewise, it has been determined that the implementation of a table and a relational diagram of activities is an effective and simple method to apply. Since this application does provide specific, quantitative, and measurable information regarding the magnitude of the improvement presented by each scenario. This option would be especially effective and applicable in the case of small and medium-sized companies, due to the costs savings and the optimization of planning time [35][36][38][39].

D. *Time optimization model in the plastic manufacturing sector*

After determining the importance of productivity and time efficiency in plastics manufacturing, several sources have proposed improvement solutions. The first proposal studied the long lead times for a plastic chair production line. This has an OEE between 60% and 81%, which is below the standard industry, and is also unstable. Given the issue, it is proposed, by a study, an integrative linear programming model using MATLAB and multiple regression analysis. While using this method production increased considerably by improving 332 minutes per total shift activity nevertheless, this model it is complex to apply [41]. Similarly, a plastic packaging manufacturing company opted for a time reduction model that integrates SMED and 5S tools. The study's main objective was to reduce the time associated with set-up by eliminating non-value-adding activities and irregularities in the work area. The result of the combined application was a decrease of 44 minutes or 18% of mold change time [42].

In conclusion, it has been determined that the proposed models effectively counteract unproductive times and low efficiency rates however, there is still room for improvement. The gaps are due to the implementation complexity of the models in SMEs in view of the high degree specialization required. Nevertheless, Lean tools could be applied to most enterprises suitable for their low cost and straightforward implementation. For this reason, the application will be feasible as long as a correct study of the external and internal conditions of the target production system is carried out [6][41].

III. CONTRIBUTION

TABLA I
COMPARATIVE MATRIX OF MODEL OBJECTIVES AND STATE OF THE ART

Objectiv / Scientific Papers	Reduction of unnecessary movements	Reduced tool search time	Reduction of set up time	Reduction of unscheduled stops
D. Agung & H. Hasbullah, 2019		5S	SMED	
S. Gupta & P. Chandna, 2020		5S		
M. Mansur & A. Ahmarofi, 2020	SLP			
S. Nallusamy, V. Kumar, V. Yadav, U. Prasad & S. Suman, 2018				TPM
J. Singh, H. Singh & I. Singh, 2018			SMED	
B. Suhardi, E. Juwita & R. Dwi, 2019	SLP			
Z. Xiang & C. Feng, 2020		5S		TPM (Focused improvements and Autonomous maintenance)
Proposed Model	SLP	5S	SMED	TPM (Autonomous maintenance and Focused improvements)

A. *Model Basis*

The model proposed in this paper is a double focus optimization design aimed at improving both the production process, and the working conditions and welfare of workers. Moreover, the novelty of this research proposes to integrate a sustainability phase with a focus on continuous improvement over time by incorporating these tools as part of the company's routine.

The purpose of the proposed model is to increase the fulfillment rate of order delivery, by reducing the productions process total cycle time. The timely delivery will aid to avoid penalty charges for delays and reduce production cost overruns. It also seeks to improve working conditions and the work environment, providing safer processes and motivated operators.

On the other hand, one of the advantages of the proposed model is that it can be easily adapted to different scenarios. In this sense, this study will allow SMEs from different sectors and with a delivery delay problem to apply the model, in this way optimizing their processes while providing better working conditions to their operators.

Table 1 shows a comparative matrix with the objectives of the case study and the usage of relevant scientific articles to construct the contribution of our model.

B. Model Components

The proposed model consists of 4 phases: (1) Initial Assessment, (2) Production Process Stabilization, (3) Preparation and Maintenance Time Optimization and, (4) Implementation's Sustainability.

1) Phase 1: Initial Assessment

The aim of this first phase is to identify the main causes that led to the problem. For this purpose, historical sales and production data are used for a minimum period of 1 year. A detailed analysis is then carried out using tools such as FMEA, AVA, ABC-PQ and VSM. As a result, the main causes are obtained and based on them the objectives are set.

2) Phase 2: Production Process Stabilization

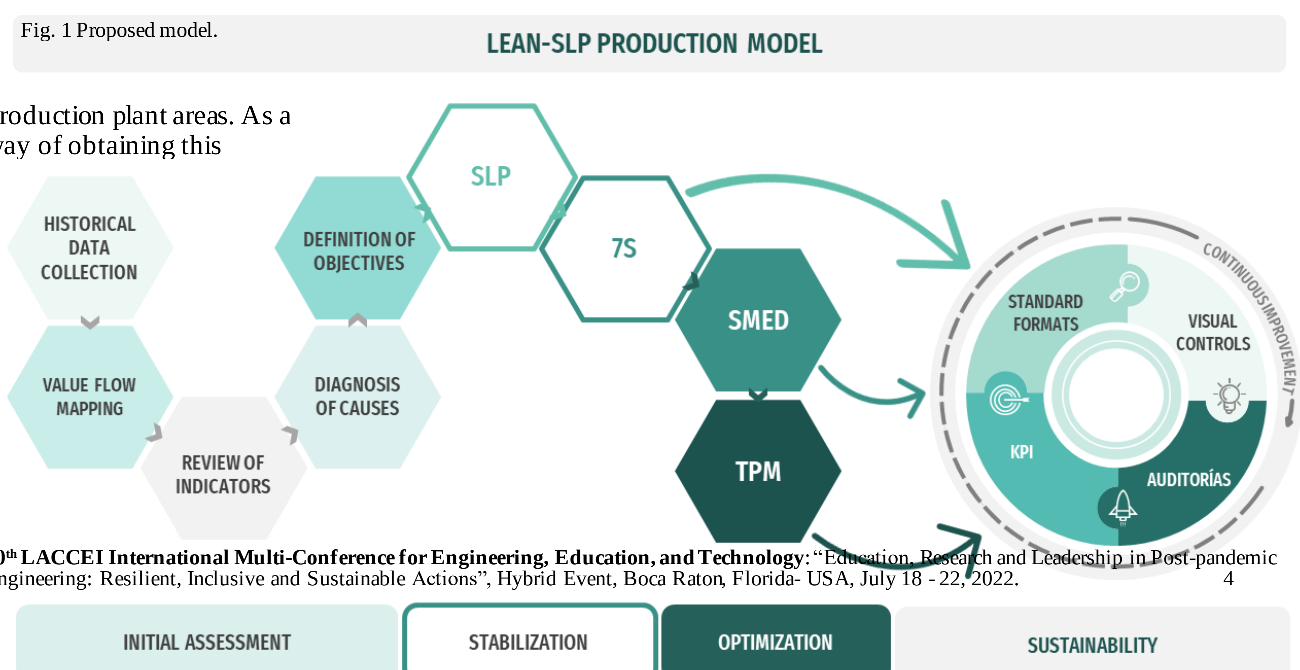
This second phase aims to reorganize and order the diverse production plant areas. As a way of obtaining this new structure it is proposed to integrate two highly effective methodologies. The first is Systematic Layout Planning (SLP), which allows to redesign the distribution of facilities by analyzing the production flow, thus reducing resources and efforts. On the other hand, 7S it is applied, as a modification of the already known Lean 5S which adds the two additional "S " alluding to occupational health and safety, and team spirit. Ones the redistribution is implemented it will keep work areas organized with the necessary tools properly identified, which will increase the safety and welfare of workers.

3) Phase 3: Preparation and Maintenance Time Optimization

The main objective of this phase is to reduce the time allocated to mold change in the injectors. Likewise, to maximize the production volume by keeping the machines and equipment in optimal conditions, avoiding unexpected breakdowns and quality defects.

Single Minute Exchange of Die (SMED) is implemented, as well in this phase, with the pillars of Autonomous Maintenance and Focused Improvements of the TPM methodology.

Fig. 1 Proposed model.



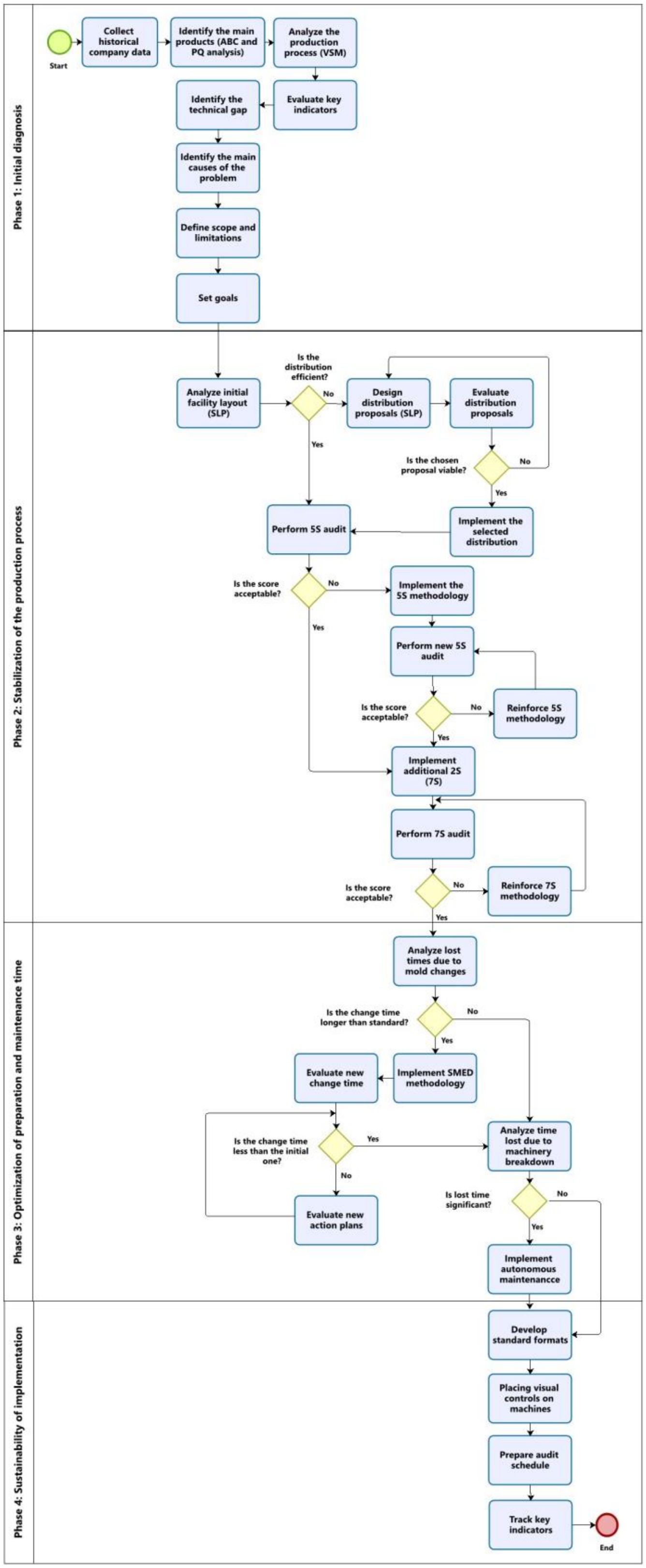


Fig. 2 Flowchart of the proposed model.

4) *Phase 4: Implementation's Sustainability*

The main objective of this last phase of the proposed model is to ensure the transcendence and permanence of previous implementations. Therefore, standard formats are developed for optimized processes, visual controls are placed on different parts of the machines, visual aids are developed for the correct location of tools, a monthly calendar of audits is prepared, and the key indicators are constantly monitored.

C. *Proposed Process*

Figure 2 details the implementation process of the proposed Lean-SLP model. The four phases are illustrated in a flowchart as: (1) Initial Assessment, (2) Production Process Stabilization, (3) Preparation and Maintenance Time Optimization and, (4) Implementation's Sustainability.

IV. VALIDATION

The development of the validation is carried out in a medium-sized company, which is mainly engaged in the development and manufacture of plastic injection molding products. Its 3 main products are Gin glasses, Wine glasses and Kero Corto glasses, which account for 81.84% of total annual production. The main manufacturing processes are injection molding, screen printing, packaging, and picking, in that order.

This company is selected because it presents problems in order delivery with a fulfillment rate below 60% in 2020. Due to this, economic losses of around S/. 669'711.8 were incurred, which represents 16% of the company's annual revenues.

A. *Validation Scenario Description*

The proposed Lean-SLP optimization model's validation was developed in two parts. The first one carries out a pilot plan with the goal of verifying the effectiveness of the 7S methodology. Followed by the second part that performs a discrete event simulation (DES). In this section, the necessary information is collected from the case study to build the simulation model that validates the SLP, SMED and TPM tools. In addition, Arena 14.0 was the software used to develop the simulation. Some of the main inputs for this purpose are the number of operators, number of machines, process time, breakdown, set-up time, among others.

B. *Initial Assessment*

The results obtained from the initial assessment phase identified the orders delivery delay as the company's main problem. The technical gap in this regard is quite wide, since the company currently has a delivery compliance level of approximately 57.6%, while the average for the sector is 95%. In addition, it is known that 11% of the late delivered orders were set back by more than one week. This situation had an impact also on the company's costs, generating penalty losses of 115,851 PEN and 553,860 PEN in operating cost overruns. Likewise, the causes identified by the methodology were determined as 59.22% of unproductive times, 26.43% of unnecessary movements and transfers, and 14.36% of reprocesses due to final product's quality failure.

The following table shows the initial status of the selected indicators to measure the real impact and the expected improvement for each of them.

TABLA II
INITIAL INDICATORS AND IMPROVEMENT EXPECTATIONS

Indicators	Initial value	Expectation
Level of order fulfillment	57,65%	95%
Effort level for material transfer (kg-m/month)	1'892,782.48	656,186.31
Tool search time	5,80%	0,12%
Mold change time (min)	175,2	76
Overall Equipment Effectiveness (OEE)	20,78%	28%

C. *Validation Design and Comparison via Initial Assessment*

Initially it is developed the discrete event simulation model. To do so, a series of steps will be followed and explained in Figure 3.

The graphic representation was prepared taking into consideration the table of entities, attributes, and activities. In addition, it was necessary to identify controllable and non-controllable variables. To cite some examples, the controllable variables were the number of operators available, for the job; the number of machines, that are being used; and the downtime of the injectors, for maintenance. Likewise, some of the non-controllable variables were the injection times and the human productive activities times.

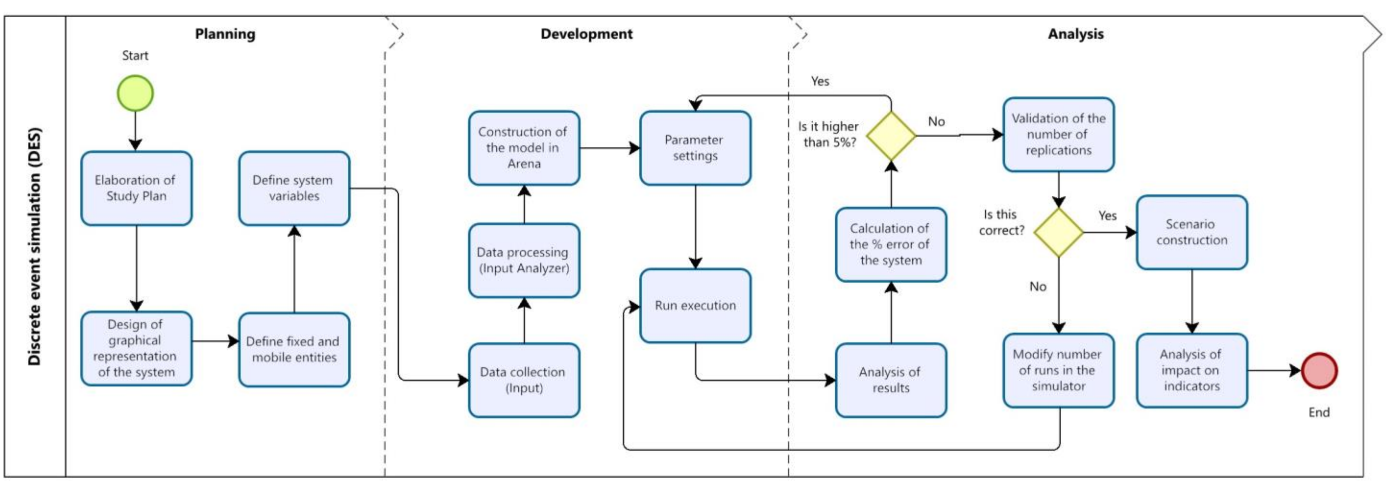
In the same way, the data input is processed by the Input Analyzer tool complementary to Arena software. From this, it is obtained the statistical distribution for the data that will give sense to the simulation model. The results obtained were as follows.

TABLA III
STATISTICAL DISTRIBUTION OF DATA INPUT

Process	Statistical Distribution
Plastic injection	Triangular (3,72;5,20;6,00)
Cups deburring	Normal (1,96;0,359)
Silk-screen printing	Normal (4,03;0,414)
Bagging	Normal (2,99;0,296)
Packaging	Normal (4,02;0,393)

Furthermore, the simulator is configured with the established data collection parameters, and it is obtained the final simulation model. The simulator is configured to run eight hours a day for a total of 264 days, which is equivalent to one year of working time. The initial sample is taken based of one hundred production batches. Subsequently, the sample size needs to be validated; once the number of samples is confirmed as sufficient for the data, it is proven to be valid for the study. It is also worth noting that the simulation will consider only one shift per day. In figure 4 it is shown the example that was followed in the process of the configuration of the simulator.

On the other hand, the pilot plan for the application of 7S was carried out only in the injection molding area. In this way, it could be implemented without major inconveniences which resulted on greatly reduced cost. The five proposed stages were executed in detail. First, the audit application forms were designed, printed, and applied, obtaining an initial score of 39/96. Subsequently, a training period was held for the operators since they are a fundamental part for the tool to successfully produce an improvement. Among the most important initiatives implemented there are the red card, to eliminate dispensable elements; the delimitation of areas with yellow tape, to assign the areas to each task; and the establishment of colored garbage cans, to recycle appropriately.



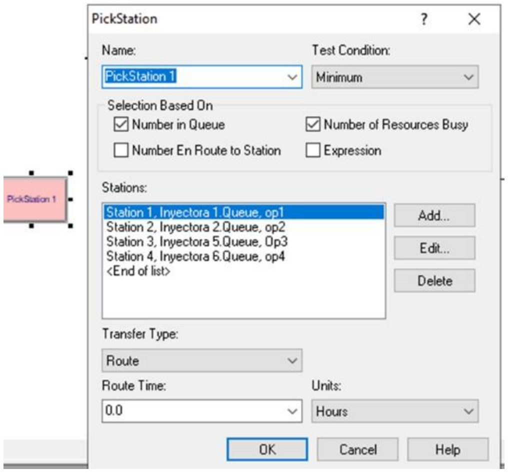


Fig. 4 Configuration of the PickStation of the injector.

Fig. 5 Implementation of red card.

Fig. 6 Delimitation of spaces and assignment of codes.

Regarding the two additional "S" to be implemented the proposed procedure was followed by applying the hazards' signaling and risks' control. In this way, we hope to keep the work environment incident free and increase employees' satisfaction. In terms of team spirit, a soccer championship was created to build unity among the operators, which was successfully carried out. As a result, it was evident the work environment improvement, which was shown by motivated employees that work in collaboration with each other due to the emotional ties strengthening produced by the exercise.

Fig. 7 Application of safety signage within the plant.

After applying the simulation as well as the pilot plan the indicators' assessment is repeated which would allow to determine the effectiveness of the proposal. The results obtained are shown below.

TABLA IV
INITIAL SITUATION VS. IMPROVED SITUATION AFTER APPLICATION OF THE PROPOSED MODEL

Indicators	Initial situation	Post-application situation	% Improvement
Level of order fulfillment	57,65%	70,4%	13,4%
Effort level for material transfer (kg-m/month)	1'892,782.48	711,049.66	62%
Tool search time	5,80%	0.14%	98%
Mold change time (min)	175,2	76	57%
Overall Equipment Effectiveness (OEE)	20,78%	28.03%	7%

V. Discussion

A. Scenario vs. outcomes

The results after the stabilization phase execution obtained were 62% of operator effort reduction and 98% of tool search reduction time. As the study conducted by Suhardi, Juwita & Dwi that have shown positive results regarding material transfer times and traveled distances, which are factors directly related to the operator's workload. Their study also showed 23% to 24% distant reduction and 34% decrease of material transfer time [38]. Therefore, the results obtained in this research are consistent with previous studies, such as the one mention.

This paper showed 57% of mold change time reduction, from 175.9 to 79 minutes, by SMED implementation. On the other hand, studies performed in similar industries showed a range of 48% to 60% set-up time improvement [18][19][20][21]. As showed by Yazıcı, Hatice and Boran in which they concluded on an approximate time of 71.32 to 36.97 minutes reduction for an injection molding machine's preparation time [21]. This investigation is consequent with their findings and the other three studies above, thus the validity of the obtained set-up time results is evident. Moreover, the Overall Equipment Effectiveness (OEE) improved from 20% to 28% during the implementation of Total Productive Maintenance's (TPM) first quarter. However, when the OEE is applied in the long run it is expected to reach a significant improvement up to 54% after the first year of implementation. In contrast, previous studies have determined an improvement of approximately 12% to 27% after applying some of the main pillars of TPM [26][27][28]. Such is the case of the article published by J. Singh, H. Singh and V. Sharma, where the Mobile Maintenance strategy is developed, which achieves only a 17.08% OEE improvement [26]. Once again, the investigation shows that the results of this study are not far from the industry reality, therefore valid.

VI. CONCLUSION

This research has contributed to the existing literature with an alternative solution to the problem of order delivery delays in the plastics sector. This has been achieved through the integration of Lean and SLP methodologies that have demonstrated a high level of complementarity. As a result, the following conclusions can be drawn:

- The application of 5S and SLP in the initial stabilization phase of the production process has succeeded in reducing the effort made by the operators in 62%. Likewise, the indicator of time spent searching for tools is now almost non-existent, since everything is assigned to its appropriate place, and constantly monitored. As a result, there was a 98% reduction in the indicator mentioned above.
- The SMED and TPM approach to optimize machine setup and maintenance has been effective. Mold change time was reduced by 57%, from 175.2 minutes to only 76 minutes. In addition, the OEE of the injection molding machines increased by 7%, which improves availability and optimizes production flow.
- The order fulfillment rate, which was the main reason for the study, was properly addressed providing positive results. As a result, a significant improvement of 13.4% was achieved in this indicator in a short period of time. Although this is still below the industry standard, it is an important improvement for the company towards achieving operational excellence.
- The motivation and empowerment of the operators increased considerably due to their constant involvement in the new activities developed in each phase of the proposed model. Activities such as training, review of the hazard assessment matrix, creation of cleaning and inspection standards, identification of anomalies in machines, even the soccer championship, contributed to the development of skills such as teamwork, communication and integration. of all levels.
- For future research it is recommended to integrate the pillars of (1) Education and Training, and (2) Preventive Maintenance of TPM. The first one will provide the necessary support to periodically reinforce the knowledge and skills of the operators; as the second one will collaborate with the Autonomous Maintenance pillar used in this investigation, thus allowing gradual progress towards the zero machine failures goal.

REFERENCES

[1] PlasticEurope, "Plastics – the Facts 2020 (2020)", PlasticEurope, Brussels, Belgium, 2020 [Online]. Available: https://plasticseurope.org/es/wp-content/uploads/sites/4/2021/11/Plastics_the_facts-WEB-2020_versionJun21_final-1.pdf.

[2] Grand View Research, "Injection Molded Plastics Market Size, Share & Trends Analysis Report by Raw Material (Polypropylene, ABS, HDPE, Polystyrene), by Application (Packaging, Automotive & Transportation, Medical), by Region, And Segment Forecasts, 2021 – 2028", Grand View Research, San Francisco, EEUU, 2021 [Online]. Available: https://www.grandviewresearch.com/industry-analysis/injection-molded-plastics-market.

[3] D. Carhuavilca, "Situación del Sector Plástico en el Perú Aspectos cuantitativos", INEI, Perú, Tech, 2021 [Online]. Available: https://www.inei.gob.pe/media/MenuRecursivo/boletines/presentacion-iii-congreso-internacional-plasticos.pdf.

[4] G. Nawanir, K.T. Lim, T. Ramayah, F. Mahmud, K.L. Lee and M.G. Maarof, "Synergistic effect of lean practices on lead time reduction: mediating role of manufacturing flexibility", *Benchmarking: An International Journal*, vol. 27, no. 5, pp. 1815-184, 2020. doi: 10.1108/BIJ-05-2019-0205.

[5] T. Niemi, A.-P. Hameri, P. Kolesnyk and P. Appelqvist, "What is the value of delivering on time?", *Journal of Advances in Management Research*, vol. 17, no. 4, pp. 473-503, 2020. doi: 10.1108/JAMR-12-2019-0218.

[6] P. Ribeiro, J.C. Sá, L.P. Ferreira, F.J.G. Silva, M.T. Pereira and G. Santos, "The Impact of the Application of Lean Tools for Improvement of Process in a Plastic Company: a case study" *Procedia Manufacturing*, vol. 38, no. 2019, pp. 765-775, 2019. doi: 10.1016/j.promfg.2020.01.104.

[7] C. Delgado and E. Olivos, "Reducción de tiempo de entrega de productos terminados basado en la implementación de mejora en la gestión de abastecimiento en una empresa fabricante de productos plásticos", degree tesis, Universidad Ricardo Palma, 2019 [Online]. Available: http://repositorio.urp.edu.pe/handle/URP/3087.

[8] K. Guillén and K. Umasi, "Modelo LEAN para la optimización del proceso de fabricación de bolsas plásticas en una empresa del sector de plásticos" degree tesis, Universidad Peruana de Ciencias Aplicadas, 2019 [Online]. Available: http://hdl.handle.net/10757/651571.

[9] B. Cheng and K. Eng, "Implementing Quick Response Manufacturing to Improve Delivery Performance in an ETO Company", *International Journal of Applied Science and Engineering*, vol. 7, no. 2, pp. 38 – 46, 2018. doi: 10.14419/ijet.v7i2.28.12879.

[10] D. Xiaosong and G. Lu, "Exploring the Impact of Delivery Performance on Customer Transaction Volume and Unit Price: Evidence from an Assembly Manufacturing Supply Chain", *Production and Operations Management*, vol. 26, no. 5, pp. 880-902, 2017. doi: 10.1111/poms.12682.

[11] G. Marino, G. Zotteri and F. Montagna, "Consumer sensitivity to delivery lead time: a furniture retail case", *International Journal of Physical Distribution & Logistics Management*, vol. 48, no. 6, pp. 610-629, 2018. doi: 10.1108/IJPDLM-01-2017-0030.

[12] X. Hao Luo and X. Yang, "A synchronized production-warehouse management solution for reengineering the online-offline integrated order fulfilment", *Transportation Research Part E*, vol. 122, no. 7, pp. 211-230, 2019. doi: 10.1016 / j.tre.2018.12.010.

[13] J. Zhang, S. Onal, R. Das, A. Helminsky and S. Das, "Fulfilment time performance of online retailers – an empirical analysis", *International Journal of Retail & Distribution Management*, vol. 47, no. 5, pp. 493-510, 2019. doi: 10.1108/IJRDM-10-2017-0237.

[14] D. Seth, N. Seth and D. Goel, "Application of Value Stream Mapping (VSM) for Minimization of Wastes in the Processing Side of Supply Chain of Cottonseed Oil Industry in Indian Context", *Journal of Manufacturing Technology Management*, vol. 19, no. 4, pp. 529–550, 2008.

[15] J. N. Malpartida, "Importancia del uso de las herramientas Lean Manufacturing en las operaciones de la industria del plástico en Lima", *Llamkasun*, vol. 1, no. 2, pp. 77–89, 2020. https://doi.org/10.47797/llamkasun.v1i2.16.

[16] D. Seth, N. Seth and P. Dhariwal, "Application of value stream mapping (VSM) for lean and cycle time reduction in complex production environments: a case study", *Production Planning & Control*, vol. 28, no. 5, pp. 398-419, 2017. doi: 10.1080/09537287.2017.1300352.

[17] I. Sultana and I. Ahmed, "A state of art review on optimization techniques in just in time", *International Journal of Optimization Techniques in Manufacturing*, vol. 2, no. 1, pp. 15–26, 2013.

[18] M. Martins, R. Godina, C. Pimentel, F.J.G. Silva and J. Matias, "A Practical Study of the Application of SMED to Electron-beam Machining in Automotive Industry", *Procedia Manufacturing*, vol. 17, no. 2018, pp. 647-654, 2018. doi: 10.1016/j.promfg.2018.10.113.

[19] L. Alvarado, G. Quispe and C. Raymundo, "Method for Optimizing the Production Process of Domestic Water Tank Manufacturing Companies", *International Journal of Engineering Research and Technology*, vol. 11, no. 11, pp. 1735-1757, 2018.

[20] C. Ekincioglu and S. Boran, "SMED methodology based on fuzzy Taguchi method", *Journal of Enterprise Information Management*, vol. 31, no. 6, pp. 867– 878, 2018.

[21] K. Yazıcı, S.H. Gökler and S. Boran, "An integrated SMED-fuzzy FMEA model for reducing setup time", *Journal of Intelligent Manufacturing*, vol. 32, no. 1, 2020. doi: 10.1007/s10845-020-01675-x.

[22] J. Singh, H. Singh, and I. Singh, "SMED for quick changeover in manufacturing industry – a case study", *Benchmarking: An International Journal*, vol. 25, pp. 2065 – 2088, 2018. doi: doi.org/10.1108/BIJ-05-2017-0122.

[23] A. Dhanjibhai and G. Shankarrao, "Strategic implementation of 5S and its effect on productivity of plastic machinery manufacturing company", *Australian Journal of Mechanical Engineering*, vol. 13, pp. 2204-2253, 2019. doi: 10.1080/14484846.2019.1676112.

[24] N. Sukdeo, K. Ramdass and G. Petja, "Application of 7S methodology: a systematic approach in a bucket manufacturing organization", *South African Journal of Industrial Engineering*, vol. 31, pp. 178-193, 2020. doi: 10.7166/31-4-2283.

[25] S. Nallusamy, V. Kumar, V. Yadav, U. Prasad and S. Suman, "Implementation of Total Productive Maintenance To Enhance The Overall Equipment Effectiveness In Medium Scale Industries", *International Journal of Mechanical and Production Engineering Research and Development*, vol. 8, pp. 1027-1038, 2018.

[26] J. Singh, H. Singh and V. Sharma, "Success of TPM concept in a manufacturing unit – a case study", *International Journal of Productivity and Performance Management*, vol. 67, pp. 536-549, 2018. doi: 10.1108/IJPPM-01-2017-0003.

[27] O. Bataineh, T. Al-Hawari, H. Alshraideh and D. Dalalah, "A sequential TPM-based scheme for improving production effectiveness presented with a case study", *Journal of Quality in Maintenance Engineering*, vol. 25, pp. 144-161, 2019. doi: 10.1108 / JQME-07-2017-0045.

[28] Z. Xiang and C. Feng, C, "Implementing Total Productive Maintenance in a Manufacturing Small or Medium-Sized Enterprise", *Journal of Industrial Engineering and Management*, vol. 14, pp. 152-175, 2020. doi: http://dx.doi.org/10.3926/jiem.3286.

[29] M. Karasu and L. Salum, "FIS-SMED: a fuzzy inference system application for plastic injection mold changeover", *International Journal of Advanced Manufacturing Technology*, vol. 94, pp. 545-559, 2018. doi: 10.1007/s00170-017-0799-7.

[30] J. Randhawa and I. Ahuja, "An investigation into manufacturing performance achievements accrued by Indian manufacturing organization through strategic 5S practices", *International Journal of Productivity and Performance Management*, vol. 67, pp. 754-787, 2018. doi: 10.1108/IJPPM-06-2017-0149.

[31] H. Shukla and K. Ganvir, "Implementation of Kaizen and 5S in Plastic Pipe Manufacturing Unit", *International Journal of Applied Science and Engineering*, vol. 6, pp. 11 – 18, 2018. doi: 10.30954/2322-0465.1.2018.2.

[32] K. Guillen, K. Umasi, G. Quispe and C. Raymundo, "Lean Model for Optimizing Plastic Bag Production in Small and Medium Sized Companies in the Plastics Sector", *International Journal of Engineering Research and Technology*, vol. 11, pp. 1713-1734, 2018.

[33] M. Braglia, D. Castellano and M. Gallo, "A novel operational approach to equipment maintenance: TPM and RCM jointly at work", *Journal of Quality in Maintenance Engineering*, vol. 25, pp. 612-634, 2019. doi: 10.1108/JQME-05-2016-0018.

[34] S. Sahoo, "Assessment of TPM and TQM practices on business performance: a multi-sector análisis", *Journal of Quality in Maintenance Engineering*. vol. 25, pp. 412-434, 2019. doi: 10.1108 / JQME-06-2018-0048.

[35] E. Maina, P. Muchiri and J. Keraita, "Improvement of Facility Layout Using Systematic Layout Planning", *Journal of Engineering*, vol. 8, pp. 33-43, 2018.

[36] M. Mansur and A. Ahmarofi, "Designing the Re-layout of the Production Floor Using Integrated Systematic Layout Planning (SLP) and Simulation Methods", *International Journal of Industrial Management*, vol. 6, pp. 50-57, 2020.

[37] Z. Zhang, X. Wang, X. Wang, F. Cui and H. Cheng, "A simulation-based approach for plant layout design and production planning", *Journal of Ambient Intelligence and Humanized Computing*, vol.10, pp. 1217-1230, 2019. doi.org/10.1007/s12652-018-0687-5.

[38] B. Suhardi, E. Juwita and R. Dwi, "Facility layout improvement in sewing department with Systematic Layout planning and ergonomics approach", *Cogent Engineering*, vol. 6, 2019. doi: 10.1080/23311916.2019.1597412.

[39] O. Potadar and G. Kadam, "Development of Facility Layout for Medium-Scale Industry Using Systematic Layout Planning", *Proceedings of International Conference on Intelligent Manufacturing and Automation*, pp. 473-483, 2019. doi: 10.1007/978-981-13-2490-1_43.

[40] A. Qamar, O. Meanazel, A. Alalawin and H. Almomani, "Optimization of Plant Layout in Jordan Light Vehicle Manufacturing Company", *Journal of The Institution of Engineers (India)*, pp. 101, 721-728, 2020. doi: 10.1007/s40032-020-00576-5.

[41] S. Nwanya, J. Udofia and O. Ajay, "Optimization of machine downtime in the plastic manufacturing", *Cogent Engineering*, vol. 4, pp. 1-12, 2017. DOI: 10.1080 / 23311916.2017.1335444.

[42]D. Agung and H. Hasbullah, "Reducing the product changeover time using SMED & 5S methods in the injection molding industry", *Applied Econometrics*, vol. 23, pp. 199-212, 2019. doi: 10.22441/sinergi.2019.3.004