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Application of the SMED methodology through folding references for a bus manufacturing company

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ABSTRACT

Bodywork assembly in bus manufacturing is a task that involves several operations. In Mexico, many bus manufacturing companies have non-flexible production lines, which makes model change very problematic. In response to this situation, the SMED methodology was applied to make more flexible production lines in terms of setup reduction for model changing. In this paper, the urban bus assembly line was studied, which is composed of sub-assembly stations that subsequently feed the station that assembles the unit, and that joints all the frames of the required model, the aim of the paper is to propose an approach to reduce the production time through the use of folding references. With the application of the SMED, it was observed that the production line improved in the transition from one body structure model to another, obtaining results of 56.2% in the time reduction.

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1. Introduction

Currently, the global market for the transport industry raises the need to prepare for competition and thus integrate the new parameters of opening, integration, and trade regulations, both in local and international markets, considering the existence of the great number of players improving and maintaining their position in this market. Highlighting the weight that this sector represents within the economy, whose main and strategic function lies in the fact that it is the automotive vehicle that moves the activity of the countries. In this global competition, several bus companies such as Bus, Zhengzhou Yutong, Xiamen King Long Motor, Toyota, Tata Motors, Volkswagen, BYD, Marcopolo, Anhui Ankai Automobile, CNH Industrial Daimler, Ashok Leyland Blue Bird, Hyundai, Navistar, stand out as key players. Who operate, on different fronts, usually classified in the following blocks: North America (the United States, Canada, and Mexico), Europe (Germany, France, United Kingdom, Russia, Italy, and the Rest of Europe), Asia-Pacific (China, Japan, Korea, India, Southeast Asia, and Australia), South America (Brazil, Argentina, Colombia and the rest of South Amer-

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ica), Middle East and Africa (Saudi Arabia, United Arab Emirates, Egypt, South Africa and the rest of the Middle East and Africa).

The international environment generates a change in the vision that was previously presented, where the production batches had the characteristic of being long and continuous. In the 1970s and 1980s, there were only two suppliers in Mexico (Masa Somex and DINA), who defined prices and delivery times. This ended in 1994 with the North American Free Trade Agreement allowing global openness for international companies to enter the Mexican bus market, which generated the arrival of manufacturers with an international presence such as Volvo, Mercedez Benz, Scania, and Neobus among others.

One of the characteristics that distinguish the bus manufacturing industry is its high production volume, specifically when their products are aimed at customers who manage fleets for different routes in a region of the country, normally meeting large orders that imply high production requirements, causing companies to adopt methodologies that can facilitate demand satisfaction on time. Added to this surge in demand, the manufacturers usually present different production configurations. This is due to the fact that the bus unit will be used in several contexts, for example, in urban routes, tourism, foreign travel, and school routes. Each of these options has a particular design requirement. Another characteristic of this industry is the delivery schedule, where it is common to present a mix of different models. This is reflected in the staff who do the production schedule. It is common to observe that such schedules do not use high production runs. Due to globalization in the current market, there is great competition among the main bus manufacturers, demanding flexibility and shorter delivery times and so on-time satisfaction of the demand required by customers, which occasionally presents changes in production demand. From the above-presented context, the need for smaller batch production runs causes accelerated line setup frequency, and the necessity to perform rapid model changes. Another factor that intervenes in the bus industry is the quality of the product, leading the organization to implement productivity resources that can contribute to these quality requirements.

Derived from this context, the production need arises to implement tools that facilitate manufacturing and meet the needs of the market. An ideal tool to improve this business environment is Lean Manufacturing (LM) developed by the Toyota company in 1973. James Womack and Daniel Jones are the experts with the clearest vision of Lean, in their books they reveal 5 basic principles: the first one implies specifying the value and identifying the value stream of each of the products. The second principle requires eliminating all unnecessary steps (waste or change) in each value stream. In the third principle, one must make value flow (which requires a redesign of the workflow of the entire organization). In the fourth principle, all activities must be customer driven. And in the fifth, the company must seek perfection. All of this is documented in his book Lean Thinking [1].

Within the strategies to facilitate the principles established by LM, the Single Minute Exchange of Die (SMED) methodology, is one of the most used successful techniques [2]. SMED is a group of tools created to vastly improve operational efficiency in the installation and assembly of machinery in less than ten minutes [2]. This range of time is not always reached in all types of configurations or preparation of the machinery, but time savings can be observed. Therefore, this technique has a substantial impact on rapid availability, causing operations to become more flexible, with an increase in productivity and a notable improvement in competitiveness [2].

The concept of SMED states that any model change should always take a specific time, and the tasks should be standardized for that change. Therefore, when there is a planned change to the available models, the time for setup is known and the resources required are quantified. This allows time to be taken into account and included in the scheduling of the production lines. Generating the inclusion of certain improvements to reduce the time required to change the machine, reduce the assigned resources, or both [3]. Other authors have reported the gains that can be achieved with the application of the SMED methodology, mainly the time saved, time that can be translated into money, or the use of that time in other tasks that also bring profit [4]. Many Mexican companies still do not apply the joint SMED tools to make faster setups, it is clear that with its application they can obtain a competitive advantage, following the methodology in a sequential manner [4].

In this paper, we have worked with a bus assembly company, which had a planning methodology with only empirical methods based on experience. However, the application of the SMED methodology implies several challenges such as: not considering model setups, not all the necessary devices included in the original production line, shift changes, etc. Specifically, there was a lot of time lost in the model setup and there was not enough communication. Seeing this problem, the purpose of this work is to determine the application of the SMED technique to complement the planning methods and make it more robust, to ensure that the bus assembly line allows faster setups and satisfies the proposed demand. This setup planning required both administrative and organizational changes as well as modifications in the layout of the assembly line that will be explained in detail in the paper. The case study that is analyzed in this work shows the pre-planning methodology, it specifies the activities that had to be done, but not the method, causing a longer time in the model changes, what is proposed is the SMED tool to execute the change more agile, through the use of collapsible references.

With this investigation, the following was obtained:

- 56.2% reduction in the time spent changing bus body structures.
- That the company under study improve times to meet customer demand.

The document is organized as follows. In section 1, an overview and context of the application of the tool are presented in order to familiarize the reader with the topic of the paper. In section 2, some previous research on the SMED tool is presented. In section 3, the methodology to demonstrate the SMED stages by recording the times of model changes is shown. Section 4 describes the results obtained. Section 5 presents the conclusions and future work.

2. Literature review

SMED is one of the lean manufacturing techniques used to reduce machine setup times. The purpose of SMED is to make setup times less than ten minutes. The SMED literature provides us with a large number of applications in various fields. Currently, organizations seek to obtain greater profitability in the sector in which they are operating. Productivity is an indicator that allows them to know what conditions they are in and how competitive they are when buying from the market that demands their products. Lean manufacturing (LM) was projected as a set of principles, slowly became a manufacturing strategy, and finally emerged as a manufacturing philosophy. The main focus of the LM philosophy is to reduce non-value-adding activities in the industry to improve customer value and thus become more competitive [5].

Some applications that have been developed for LM in various fields have demonstrated its effectiveness in their processes. For example [6] propose in their research, the use of SWOT (strengths, weaknesses, opportunities, and threats) to control and analyze the information they collected, in the implementation of LM in the Portuguese industry. At the same time, [7] developed a self-assessment model to verify the level of preparation of organizations to implement Green Lean initiatives, which serves as a reference as a diagnosis of the requirements for its implementation. In addition, [8] related, within their study, the influence of four different organizational cultures, as well as a hybrid culture and the ability of a company to be culturally ambidextrous, in the relationship between operational performance and Lean, concluding that making quality improvements from lean is particularly sensitive to organizational culture. [9] used SMED to solve the growing quality problems of a small drone assembly company, showing results that show a reduction in delivery time and an increase in the Lean level from 23% to 60%. The rate of multifunctional workers increased from 75% to 83% and movement waste was reduced by almost 50%. Applying line balance and simulation. Small and medium-sized enterprises (SMEs) are lagging in the implementation of LM, propose four sequential stages of implementation that include 23 essential components to adapt to the characteristics of SMEs. Using the PDCA cycle approach (Plan-To-Check-Act) aligns it with the company's work approaches. This approach can help SMEs to practice Lean in their LM implementation process systematically and improve organizational performance [10].

In this LM methodology, one of the tools by which the current status is evaluated is the VSM (Value Stream Map) in which the wastes and processes that do not allow the organization to achieve its goals can be clearly observed. [11] used the Kaizen tool to correct these processes and achieve the desired objective. Today, in the industrial environment, the elimination of waste, such as downtime, is an important issue, since it is an activity without added value that represents costs and lack of productivity. At the same time, the diversification of products and increasingly smaller orders lead companies to optimize the preparation times associated with processes and machinery, [12] highlighting the importance of integrating the principles of lean manufacturing and ergonomics in organizations to increase productivity and improve working conditions simultaneously. The integrated application of SMED and ergonomic analysis in a metallurgical factory. They highlight the 55% reduction in preparation time and the extreme attenuation of the risk level of musculoskeletal disorders in workers. Likewise, [13] presented a case study in a bearing manufacturing company to reduce the setup time of the machine in the turning line using the SMED. The main results obtained from the study indicate that the preparation times of the machines were reduced by more than 45% for the turning line. Similarly, [14] applied SMED, in an oil and gas company. The findings achieved in this work showed that the preparation time was improved by 91.6%, from 1 h 44 min 56 s to 8 min 52 s, and the OEE increased by 44.6%. Also, [15] studied the effect of the implementation of SMED in the bean packing operation, in agribusiness. The implementation of this methodology allowed to reduce the preparation time by about 58%, and the distance traveled by the operators in the process by about 50%, in addition to gains in production capacity of 14%. Likewise, [16] state that the Human-Centric SMED (H-SMED) is an evolution of the classic methodology introduced by Shingo to manage the installation process, which is especially suitable for companies where the installation involves activities with a high human content, which can hardly be transformed into external operations to be carried out during the machine's activity time. It has presented results of a 44% reduction in installation duration. On the other hand, [17] proposed an alternative approach to improve manufacturing setup time and time between failures. It focuses on eliminating outliers related to manufacturing setup times and time between failures. Using simulations to compare the effect on the delivery time of both improvement strategies with the traditional strategies of reduction of the mean or variability. Furthermore, [18] studied the production performance of the stamping process in the Malaysian automotive industry. The presented method decreased the change processes from the beginning from 1509.5 seconds to 750.75 seconds, then further reduced to 569.75 seconds, with a net time reduction of 62.2%. The result shows that the daily output gradually increased from 1,100 pieces to 1,500 pieces, further increasing to 2,145 pieces. In addition, [19] developed in the electronic components industry, the acceleration of the product changeover process by developing an automated non-contact inspection method in the assembly area using a vision system. The results of the study illustrate that it can be done in 7 minutes, or reduced by 81%, and the speed of switching activities between operators is the same. Also, [20] developed a novel SMED model that integrates the traditional SMED and diffuse failure modes and effects analysis (fuzzy FMEA) methods. The new approach is applied to set up a plastic injection mold for a pen manufacturing company. Preparation time is reduced from 71.32 to 36.97 min, achieving a 48% improvement. Furthermore, [21] developed a method that reduces the intensity levels of the factors that affect the time of change. He proposed the Taguchi-based SMED methodology for this. In his study, he compared the Taguchi-based SMED with the traditional SMED method. Gaining an additional 216-minute improvement in total setup time. However, [22] combine SMED with Center lining in complex production environments with numerous changes in format, product, raw materials, and tools. This implies an initial application of Center lining and, once the machinery and the process are stabilized, the subsequent implementation of SMED. The most important general conclusion is that a successful application of SMED must always be accompanied by another type of tool or technique to maximize the results of its application. Likewise, [23] presents a case study on injection machines of a company that manufactures test and assembly parts in the automotive and electrical sectors. They also performed a 5S study before the SMED study. As a result, installation durations have been observed to be reduced from 65.30 minutes to 23.62 minutes. Adding to the above, [24] applied it to the stamping process of metal components in the automotive industry, achieving a reduction in configuration time (45%). On the other hand, [25] proposed a fuzzy inference system application for parameter adjustment during changes in plastic injection molds. They integrated this system into SMED applications to reduce production lot size. Similarly, [26] proposed a new hybrid method that integrates the original SMED and the analytical hierarchy process. Likewise, [27] implemented SMED in the high-speed circuit board assembly configuration. Of which, they made an annual profit of $1.5 million and were able to reduce setup time at a rate of 80%.

In the application of the SMED tool, the support of additional tools such as 5's (Order and cleanliness) is required, in addition to poka joke devices to facilitate the processes in the reduction of preparation times of the tooling for the different configurations in the body models. Here it is observed that the SMED methodology continues to be widely used to streamline and improve industrial processes, meeting the expectations and constant changes in the market, which presents a greater tendency to the variety of products demanded by users. In a summarized way, Table 1 shows the previous investigations.

Taking into account globalization requires producing small batches more frequently, which demands a significant increase in the assembly fre-

Table 1. Previous investigations

Authors	Contribution
Afonso, Gabriel & Godina (2022)	They highlight the importance of integrating the principles of LM and Ergonomics in organizations to increase productivity and improve working conditions simultaneously. [12]
Sahin & Kologlu (2022)	They presented a case study at a bearing manufacturing company to reduce machine setup time on the turning line using the SMED. [13]
Junior, Inácio, da Silva, Hassui & Barbosa (2022)	They applied SMED, in an oil and gas company. [14]
Fonda, & Meneghetti (2022)	They state, the Human-Centric SMED (H-SMED) is an evolution of the classic methodology introduced by Shingo to manage the installation process, it involves activities with a high human content, which can hardly be transformed into external operations. [16]
Utiyama, Godinho Filho & Oprime (2021)	They propose an alternative approach to improve manufacturing lead time and time between failures. Using simulations to compare the effect on delivery times of both traditional strategies of reduction of the average or variability. [17]
Basri, Mohamed, Nelfiyanti & Yusoof (2021)	They studied the production performance of the stamping process in the Malaysian automotive industry. [18]
Herlambang, Fitri Ikatrinasari, & Kosasih (2021)	They developed in the electronic components industry, the acceleration of the product change process by developing an automated non-contact inspection method in the assembly area using a vision system. [19]
Yazıcı, Gökler, & Boran (2021)	They developed a novel SMED model that integrates traditional SMED and fuzzy failure modes and effects analysis (Diffuse FMEA) methods is applied to set up a plastic injection mold for a pen manufacturing company. [20]
Çelik (2020)	I develop a method that reduces the intensity levels of the factors that affect the time of change. In his study, he compared the Taguchi-based SMED with the traditional SMED method. [21]
Lozano, Saenz-Díez, Martínez, Jiménez & Blanco (2019)	They combine SMED with Centerlining in complex production environments with numerous format, product, raw material and tooling changes. The conclusion reached is that a SMED application should always be accompanied by another type of tool to maximize the results of its application. [22]
Zeki & Eren (2019)	They present a case study in injection machines of a company that manufactures test and assembly parts in the automotive and electrical sector. [23]
Bidarra, Godina, Matias, & Azevedo (2018)	They applied it to the process of stamping metal components in the automotive industry. [24]
Karasu & Salum (2018)	They proposed a fuzzy inference system application for parameter tuning during changeovers in plastic injection molds. They integrated this system into SMED applications to reduce production batch size. [25]
Soberi, & Ahmad (2017)	They proposed a new hybrid method that integrates the original SMED and the analytical hierarchy process. [26]
Trovinger & Bohn (2005)	Implemented SMED in high-speed circuit board assembly configuration. [27]
Contribution of this research work	Most of the previous investigations are based on the combination of SMED with other tools that can assist it in its operation, some of these investigations only apply some of the steps of the classical methodology and the other steps are handled as future investigations. In this case study, the application of the methodology was carried out all the steps. Until now, it has not been implemented in bus assembly companies in Mexico or sp ecifically in the planning of the assembly of structures for the bodies, which describe this particular problem, or if it has been used it is limited in the manufacture of components with direct suppliers and it is where this work pays in the knowledge.

quency, causing the reduction of production times for each batch. Hence the importance that setups must be performed in a shorter period so that the flexibility of response to demand is not affected. SMED has been widely used, and it brings many advantages, but so far it has not been implemented in bus assembly companies in Mexico or specifically in the planning of the assembly of structures for the bodies, which describe this particular problem, or if it has been used it is limited in the manufacture of components with direct suppliers and this is where this work pays off in knowledge. Therefore, the problem that is presented in this paper fits well with this methodology.

3. Problem statement

The solution applied in the present work was used in a company dedicated to the assembly of urban buses, specifically in the bodywork area, which had a planning methodology where empirical methods based on experience were used. However, this empirical methodology caused several problems such as: not considering model setups, not all the necessary devices including shift changes, etc. Specifically, there was a lot of time lost in the model setup and there was not enough communication. With this problem, the company could not meet the demand, since they needed a faster model changeover, with the time that was being handled it was impossible to make the setup in a satisfactory time, it was required that such setups were conducted in hours, but normally it was conducted in days. It was sought to complement the planning method and make it more robust, to achieve a bus assembly line that would allow faster setups to be made and meet the proposed demand. This planning included both administrative and organizational changes as well as changes at the physical level in the assembly line layout. In the pre-planning methodology, it specifies the activities that had to be done, but not the method, causing a longer time in the model changes. Therefore, an alternative was sought to solve this problem and it was decided to apply the SMED methodology. Figure 1 shows the problems that the company has with the time spent in changing tools and the solution by reducing these times and covering the constant changes in customer needs.

One of the factors for which the implementation of the SMED tool is chosen is due to the fact that when monitoring the production rates, at least 30% of the time established was exceeded in each of the operations that were carried out during their workday. As a consequence, more than the resources programmed for production were used. Its representation can be seen in Table 2.

Table 2. Representation of the production index in the manufacture of bodywork before SMED

Activities	Parameters	Index
Left side	Time	Decrease 30%
Right side	Time	Decrease 30%
Flat	Time	Decrease 30%
Awning	Time	Decrease 30%
front structure	Time	Decrease 30%
rear structure	Time	Decrease 30%
Principal structure	Time	Decrease 30%
Transfer of change personnel to the line	Time	Decrease 30%
Transfer of tools and devices to the line	Time	Decrease 30%

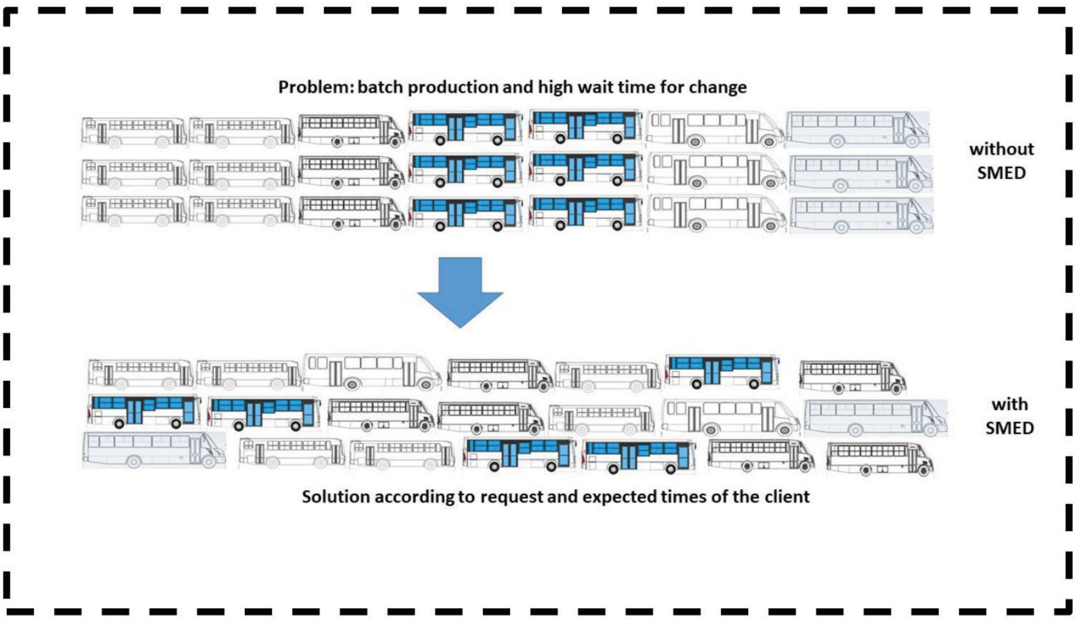

Figure 1. Iconic representation of the problem

SMED is one of many Lean Production methods to reduce waste in a manufacturing process. It provides a fast and efficient way to convert a manufacturing process from the current product to running the next product. This rapid changeover is key to reducing the size of production batches and thus improving flow. SMED or quick changeover, is the practices of reducing the time it takes to change a line or machine to go from one product to another [28].

The basic idea of SMED is to reduce the setup time of a machine. There are two types of settings: internal and external. Internal configuration activities are those that can be performed only while the machine is stopped, while external configuration activities are those that can be performed while the machine is running. [29] states that "SMED can be applied in any factory to any machine". Mainly in the application of design changes to the process of changing and balancing production lines by minimizing setup.

SMED process:

(1) Observe the current methodology: Current procedures are generally videotaped of the entire change process. It covers the complete change from one model to another model.
(2) Separate internal and external activities: Internal activities are those that can only be performed when the process is stopped, while external activities can be performed while the last batch is being produced or after the next batch has been started.
(3) Streamline the change process: For each iteration of the above process, a substantial improvement in setup times should be expected, so it may take several iterations to cross the ten-minute line.
(4) Continuous training: After the first successful iteration of the SMED application, the main requirement becomes the training of all cell operators.

Knowing the context of the company's problems and the reason for being of SMED, it was applied as described below.

3.1 Application of the SMED to the assembly of bodyworks

This section outlines the phases of the implementation of the SMED methodology in the body assembly process in an urban bus assembly plant. By analyzing the internal and external operations of SMED, to know the preparation times and minimize them, which contributes to the efficiency of production during hours of operation.

3.1.1 Observe current methodology

The body assembly line was made up of 7 assembly processes, 1. Side, Left, and Right, 2. Floor and Awning, 3. Front Structure, 4. Rear Structure, 5. Main Structure, 6. Detailed Welding and 7. Body-Chassis Assembly. The first four processes are assembled at the same time in their station and later they are transferred to process 5, where they are assembled in a single structure, once the process is finished the line is advanced to process 6 where the welding is detailed so that it finally advances to process 7 where the structure is assembled with the chassis. The above described can be visualized in Figure 2, which shows the layout of the bodywork area.

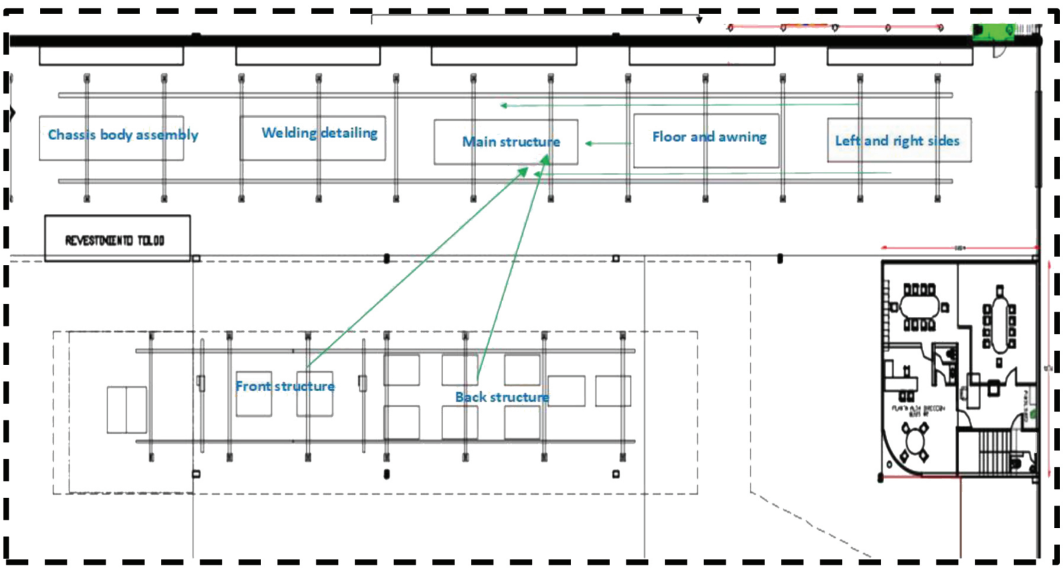

Figure 2. Layout of área

When the model setup occurs on this line, normally until process number seven is finished, it is when the Tooling department is notified to carry out the model setup and is able to start its activities. Times of up to 18.25 hours (1095 min) are recorded to completely complete the setup of the model on the line, derived from the fact that when the line stops, it is when the tooling washing process begins and changes of references according to the following model. In addition to only working one shift, so the model setup process continues until the next day. Moreover, the tooling area is outside the warehouse where the model setup is made, as a consequence of not having planned for this setup, there is a constant lack of tools and devices for the setup and the personnel constantly moves from the workshop to bring the tools that he uses, consuming a time up to 2 hours (120 min). These time requirements can be seen in Table 3.

Table 3. Initial system SMED analysis

Activities	Before (min)
Left side	90
Right side	90
Flat	150
Awning	120
front structure	30
rear structure	30
Principal structure	420
Transfer of change personnel to the line	45
Transfer of tools and devices to the line	120
TOTAL	1095

During the observation period, operators were found to be standing still on all setting steps until their station was released by the tooling crew. The results of the analysis revealed that 15% of the total configuration time was consumed by external configuration activities. The remaining 85% of the total configuration time consisted of internal configuration activities. This can be visualized in Figure 3.

3.1.2 Separate internal and external activities.

Firstly, it was necessary to have a list of sequential activities carried out during the change of model and identify which are internal (carried out during a stoppage of operations at the station) and external (carried out during normal operation at the station). Route diagrams were used. and video filming of the line recording the times of each operation.

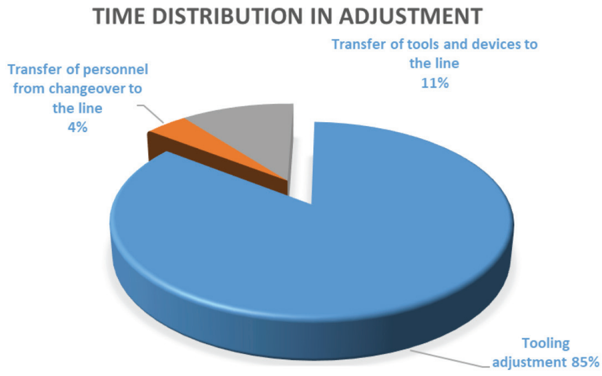

Figure 3. Pie chart of time loss of car bodies

Once the classification was complete, the implementation team, based on their experience, converted some of the internal operations to external ones. One of the first points addressed was the planning of the tools that would be used in the adjustment. Previously, it took up to two hours (120 min) just to get from the area to the line where they were needed. For the above, a cart was implemented, where the necessary tools were placed to execute the necessary operations in the adjustment, in addition to ensuring the organization of the tools during the assembly and disassembly of the references handled in each tooling and enabling the movement of the tools. This allowed the transfer time to be reduced from 120 to 10 minutes. This cart can be seen in Figure 4, where its design is shown.

Figure 4. Trolley for moving tools and devices

Based on the new plan, the staff of the tooling area is informed of the exact moment of station stoppage one day in advance, this information was generated based on the times that the process of each station normally takes. In addition to the above, the moment in which the process stops is sequentially, first, the sides, left and right, are stopped, then the front and rear. When this happens, the tooling personnel (4) wash the tooling and proceed to make the adjustments, immediately, for the floor and awning, these are attended to by the personnel who are in the front and rear. This is because these structures are different tables and for each model, there is one. When the sides are finished, the staff moves to the main structure, which takes approximately 5 to 10 minutes to complete, and that is when they start their configuration, after finishing the floor and awning adjustments, the staff moves to reinforce the fit of the main structure. An important note is, when the stations are released, it is when the production of the new model is started, the first to start is the front structure and the rear structure, and in this same sequence the other stations that are configured. The flow of these operations can be better understood in Figure 5, which shows the action sequences of the tooling area in model changes.

3.1.3 Streamline the change process.

To speed up the adjustment processes, modifications were made to the structures (tooling), one of them was to identify the references with a color for a specific model, intending to clearly indicate which references should be adjusted and which do not cause interference with the others. This implementation can be seen in Figure 6.

Figure 6. Reference identification

Another of the changes that were made was, the current process of fastening the references is using Allen screws, whose tightening/loosening operations require the greater part of the process. Also, some must be welded to the structure. This process caused a long time the adjustment. For this process, folding references were implemented, which, when executing the model adjustments, the operator only moved towards the back of the tooling, facilitating the adjustment in the models that are welded. In addition to these changes, as mentioned in the tooling adjustment sequence, time is reduced, so that even with the

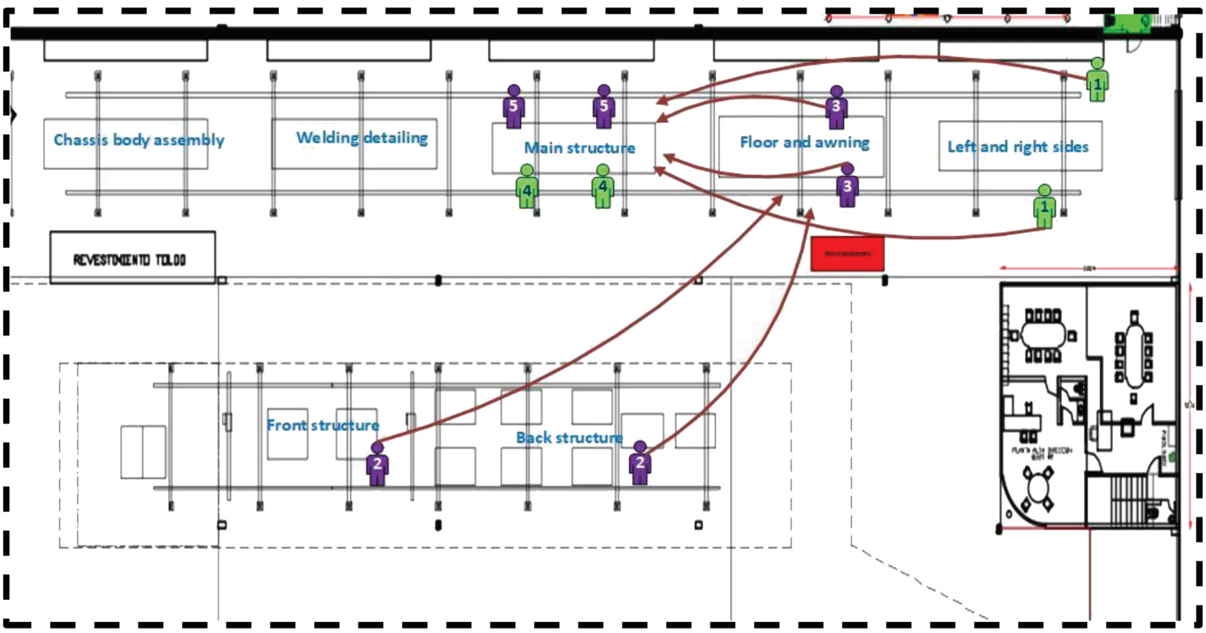

Figure 5. Layout of área

last stations being adjusted, the first ones can already start with the new model. These mentioned changes can be visualized in Figure 7.

Figure 7. Folding references

Once these adjustments were implemented in the company's bodywork line, a record of the times of the identified operations was made, to evidence them and subsequently compare them. The breakdown of the operations and registration after the implementation of SMED can be seen in Table 4.

Table 4. SMED analysis modified system

Activities	With SMED (min)
Left side	25
Right side	25
Flat	75
Awning	60
front structure	15
rear structure	15
Principal structure	240
Transfer of change personnel to the line	15
Transfer of tools and devices to the line	10
TOTAL	480

3.2 Continuous training

To execute all the proposed activities, the personnel of the areas involved in these changes were trained, and the personnel in charge of this was the continuous improvement department, starting with the tooling area, in the concept and mode of operation of the SMED methodology. The operational staff did the following, they were trained to be able to provide facilities in the production line and support if necessary. Training is constant in this methodology. It is considered the first stage implemented, due to the strict sense of the methodology that seeks to reach changes in less than 10 minutes. This process generated a decrease in the setup time that had been handled, but it is still high. It is recommended that it be improved every year and reduced the times as more experience is gained.

The application of SMED to the bodywork line allows us to observe that the main structure station is more complex due to the number of references that it contains when grouping the subassemblies that arrive from the previous stations. Therefore, this station is the one that requires the most considerable amount of resources to reach its objective, in addition to complementing it with the application of other LM tools.

4. Results

In this case study, both analysis-implementation cycles carried out favored the reduction of the necessary setup time, in addition to also reducing the movement of the workers involved. Consequently, the reduction in tooling preparation time contributed to an increase in the company's productivity, since part of the time required for setup was available for production.

The main attribution to the efficiency of the SMED implementation would be the time for each work sequence in the seven identified assembly processes, 1. Side, Left, and Right, 2. Floor and Awning, 3. Front Structure, 4. Structure Rear, 5. The main structure, 6. Detailed welding and 7. Body-Chassis Assembly. By establishing times in the planning, the notice of change directed to the tooling area is informed in advance. In addition, the implementation of the tool cart, lead to reduce in 120 min used in the transfer of tools. Working with a sequence in the intervention of the tooling personnel to carry out the setup of the new model, as well as to implement the folding references, shows a decrease in the time spent on the model changeover of 615 minutes, equivalent to 56% of the total time spent. The comparison of the times can be observed in detail in Table 5 SMED analysis, showing the before and after implementation.

The main focus of the study was to observe the model setup activities that are performed while the stations were running, during the study it was discovered that the workers had to wait a long time to complete the work sequence. Using the SMED approach, it is necessary to identify and separate the external and internal work distributions at all stations. Howev-

Table 5. SMED analysis

Activities	Original system (min)	With SMED (min)	Improvements (min)	Percentage of profit per activity
Left side	90	25	65	72.2
Right side	90	25	65	72.2
Flat	150	75	75	50.0
Awning	120	60	60	50.0
front structure	30	15	15	50.0
rear structure	30	15	15	50.0
Principal structure	420	240	180	42.9
Transfer of change personnel to the line	45	15	30	66.7
Transfer of tools and devices to the line	120	10	110	91.7
TOTAL	1095	480	615	56.2

er, most of the work procedures of the stations were recorded as internal activities.

When SMED was introduced in the company, operators initially resisted its implementation, believing the changes would entail an increased workload. However, as the methodology was implemented, the operators began to realize the benefits that SMED brought to assembling operations and that there would not be an increase in workload. They realized that it was convenient for their work shifts, for their organization, finishing their activities faster, it was easier for them to work and they quickly got involved in accepting it and adapting the assembly line to have the change, which also brought advantages in the work environment. The foregoing produced a result that the change was well accepted, helping the SMED methodology to be accepted more quickly.

5. Conclusions

This work presented the implementation of the SMED tool in the body assembly in Mexico, strengthening planning methods and allowing greater productivity by reducing model setups on the production line. The problem of the company is that there was no efficient setup model, and so with in order to fill this gap, the SMED methodology was applied. In particular, in the SMED methodology, the line was modified so that the tools were ready to be used when needed, using a car that had all the necessary tools to accelerate the setup and also it was used a folding reference device. In addition, the synchronization of the intervention of the personnel was also adjusted. The advantages of applying SMED techniques presented a reduction of 56% of the time needed for setups, Furthermore, it was observed a rapid assimilation of the proposed activities of the operating personnel. Therefore, so far the methodology was successful.

5.1 Managerial insights and practical implications

Within these perspectives, there is the constant change in demand in the short term for the products that customers request, so the organization's production system must adopt tools that help them minimize the impacts that they cause, where the SMED is a solution that reduces these impacts by reducing changeover times between the models that are manufactured. The foregoing brings economic benefits that favor customer satisfaction in delivery times, for this specific case, it was possible to reduce 56.2% of the time that had been used. Which favors the fulfillment of the objectives that managers seek; which is to meet customer requirements, optimize resources and generate value for the company.

5.2 Limitation and proposal for future work

In the implementation of this SMED tool, several issues have been disregarded such as online stoppages due to machinery failures, absenteeism of tooling personnel, power outages, product validations by quality, and the lack of materials for the manufacture of tools.

In future work, such issues could be addressed and also SMED tools could be combined with TPM (Total Productive Maintenance), which would help to reduce some of the limitations or as mentioned by [12] at integrating the principles of Lean Manufacturing and Ergonomics. Similarly, it can be combined SMED with the Kanban tool to ensure material supplies. All of the above options will provide significant results for the company. It is planned for the following investigation to use the sensitivity analysis. In addition to developing a mathematical model.

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