Setup Time Reduction in an Automotive Battery Assembly Line

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Abstract— Many manufacturers face cost-reduction and efficiency challenges in their manufacturing operations. To survive in today's highly competitive world, manufacturers need to find ways to reduce production time and costs in order to improve operating performance and product quality. Nowadays, targets of an increased productivity, operational availability and better overall efficiency of the production line are the most important goals for almost all manufacturing companies. The main objective of this study is to improve battery assembly line setup time and at the same time reduce the manufacturing costs. The specific objectives of the study are firstly to reduce setup time; secondly to identify existing and expected problems and implement and identify potential process improvements in the assembly line and thirdly to measure setup time reduction performance in terms of time and cost, productivity, quality and operational availability and flexibility. The result shows that this study has achieved more than the target 35% of setup time reduction. From setup time reduction, a total cost savings of RM168, 000 was achieved in assembly line A. Meanwhile the company level a total saving of RM1.11million was achieved for all assembly lines in Company X. Other various benefit also achieved from SMED implementation and this study also shows that tooling cost is not a major factor contributing to the increase in manufacturing costs for this company.

Keywords— bottleneck, cost saving, lean manufacturing, setup time, SMED

I. INTRODUCTION

Due to the complexity of market demand and competitiveness, many manufacturers are under pressure to produce and deliver products in shorter delivery times. In today's information era and globalize markets, new challenges emerge in the industrial environment of the entire world [1].

In recent years, companies have become increasingly focused on market demand and customers responsiveness. This has led to the implementation and adoption of lean manufacturing techniques in the automotive industry. Due to the complexity and demand behaviour from customers, the role of better change over or setup time reduction has become more critical because it can enable better response and small batch manufacture [2].

Applying lean principles represents a systematic method for identifying all the activities which contribute in the value stream of the decision making process and eliminating activities that generates losses [3].

In the past two decades, setup time reduction and quality improvement programs have become prevalent in manufacturing industry [4, 5]. They form fundamental elements of the lean manufacturing approach. These programs had contributed towards higher efficiency and agility needed by manufacturers. At present manufacturers must be able to manufacture a wide variety of highly differentiated and high-quality products in a cost-effective manner, and respond quickly to changes in the product designs and volumes in order to compete effectively [6].

The primary goal of any business enterprise is to make profit. In order to achieve more profits one can either increase its revenue or reduce the costs involved in manufacturing. Cost reduction is a better option than increasing revenue because capacity of plant is fixed and has to increase price, but due to the presence of competitors in the market it may not be possible. [7].

Single Minute Exchange of Die (SMED) is a scientific approach to setup time reduction that can be applied in any factory and also to any machine [8]. The ultimate goal of SMED is to perform machine setup and changeover operations in less than ten minutes. Several practitioners have proved that the SMED method really works in practice and in some situations reductions of higher than 90 percent setup time are achievable [9].

Cakmakci [10] had performed an investigational research to observe the relationship between SMED methodology and equipment design in the automotive industry. The results of this research had indicated that SMED is an appropriate method not only for manufacturing improvement but also for equipment and die design development. Other past researchers such as Gilmore and Smith [11], Enns et al. [12], and Van Goubergen and Lockhart [13] had conducted studies in setup time reduction.

This case study is concerned with reducing setup time and manufacturing costs for a battery manufacturing company. Faced with increasing production volume and a desire to increase capacity, operational availability, reduce battery cost and increase flexibility to meet demands from customers, Company X began evaluating these options and actions to cope with these issues by implementing setup time and manufacturing costs reduction. The proposed countermeasures were based on the company requirement to increase production output and to reduce the operating cost.

The four specific objectives of the study are to: reduce setup time; identify existing and expected problems; implement and identify potential process improvements in the assembly line; and measure setup time reduction performance in terms of time and cost, productivity, quality and operational availability and flexibility. In other words, the overall objective of this study is to improve battery assembly line setup time and reduce the manufacturing costs.

II. METHODOLOGY

This study was conducted in Company X. Only one battery assembly line was involved, which is known as the main assembly line A.

A. Data Collection

Statistical data collection methods for measuring machine setup time in assembly line A operation was used in this study to summarise and describe the data. Production process flow and standard operation procedure are reviewed briefly before setting up the data collection table is done. The next step is to create a data collection table prior to collecting data and the time taken was measured using a stopwatch. Based on the actual production, data was collected and recorded on a daily basis by different types of time loss from the assembly line A. Subsequently, a statistical bar chart was drawn to monitor and analyse the problems. These methods helps to identify the main contributor to high time loss in the battery assembly line A and help to visualise and better understand the root causes and finding possible solutions to the problems.

B. Application of SMED techniques

This study methodology describes on the project implementation in the battery assembly line by using SMED techniques. The SMED method consists of eight techniques: (1) separate internal from external setup operations; (2) convert internal to external setup; (3) standardise function, not shape; (4) use functional clamps or eliminate fasteners altogether; (5) use intermediate jigs; (6) adopt parallel operations; (7) eliminate adjustments and (8) mechanisation.

C. Data Analysis

The analysis of data and information gathered led to significant improvement carried out in three categories such as mechanical improvement, electrical improvement and organisational improvement. Comparison result before and after SMED implementation was extensively reviewed. Total savings, other benefits and tooling costs are also discussed and explained.

III. RESULT & DISCUSSION

Basically, there are nine processes and machines involved in mould setup activities in assembly line A. Processes and machines involved are enveloping, cast on strap, polarity tester, spot welding, short circuit, shear tester, heat seal, post burning and air leak tester.

A. Current Setup Time

This data analysis is vital to observe the current setup time activities and performance and to identify which current setup processes need to be focused in this study before SMED can be implemented on mould setup in the assembly line A. The current setup time of nine processes involved in mould setup collected are shown in Figure 1. Data for setup times were taken daily from June to July 2009. The cycle time data for each process performed was taken to ensure data accuracy and to observe data variation in each cycle time reading.

The current setup time shows that cast on strap and heat seal machines take longer setup times compared to other processes. Over the past 2 months, averages of 52 minutes were taken to perform the cast on strap machine setups. On the other hand, averages of 32 minutes were used to perform the heat seal machine setups. From this analysis, cast on strap and heat seal machines were identified as major bottlenecks. These 2 setup processes approximately took about 59 percent of the total average time in minutes to complete the tasks.

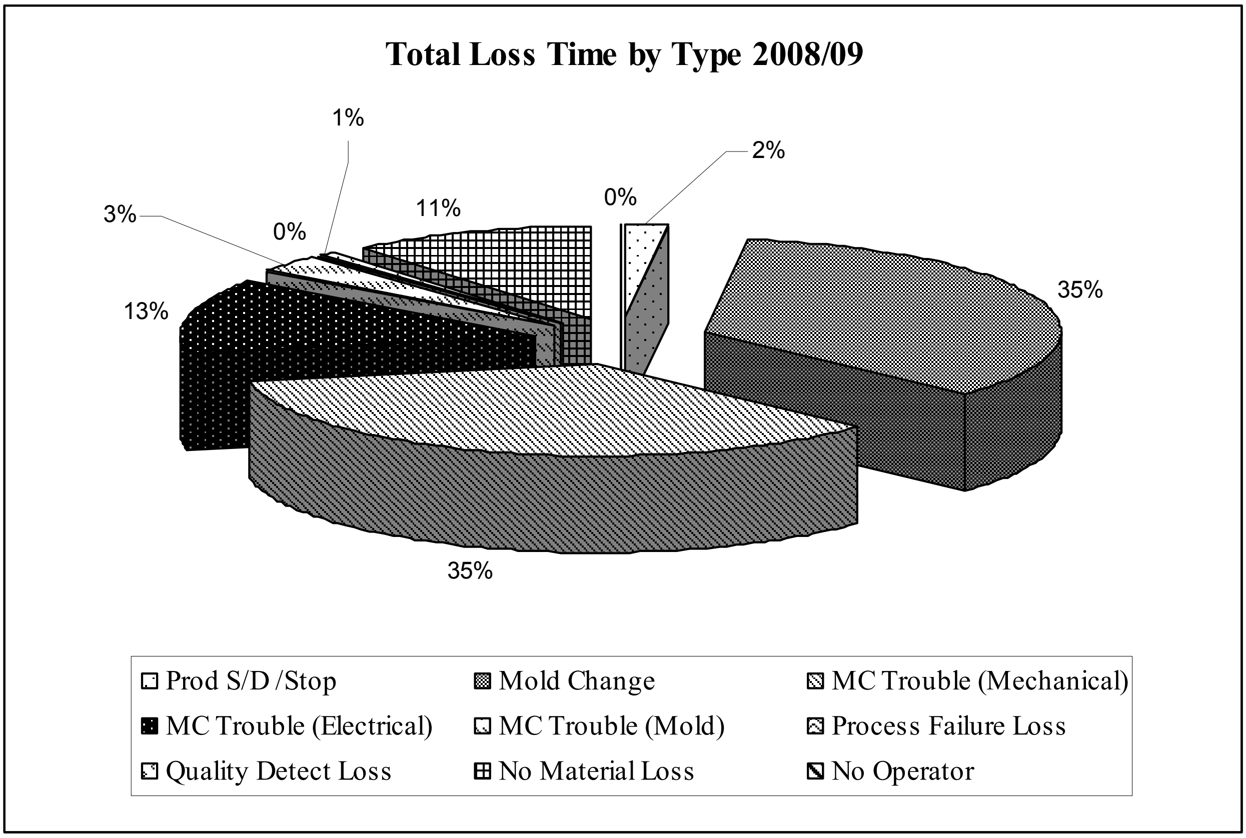

Figure 1: Total production loss time in assembly line A

B. SMED implementation on bottleneck process

Setup time reduction

SMED helps to reduce machine setup times by eliminating wastes and unnecessary setup processes and also helps to improve current setup processes and manufacturing flexibility.

There are 13 tasks involved in the cast on strap setups on mould changing at the assembly line A. Data analysis on setup data was used to identify which current cast on strap activities delayed the setups processes and contributes to longer setup times.

After SMED methodology and approaches had been applied in the cast on strap setup activities, the number of setup tasks with respect to cast on strap were drastically reduced from 13 to seven 7 tasks only. Figure 2 shows the new tasks after successful implementation of SMED methodology.

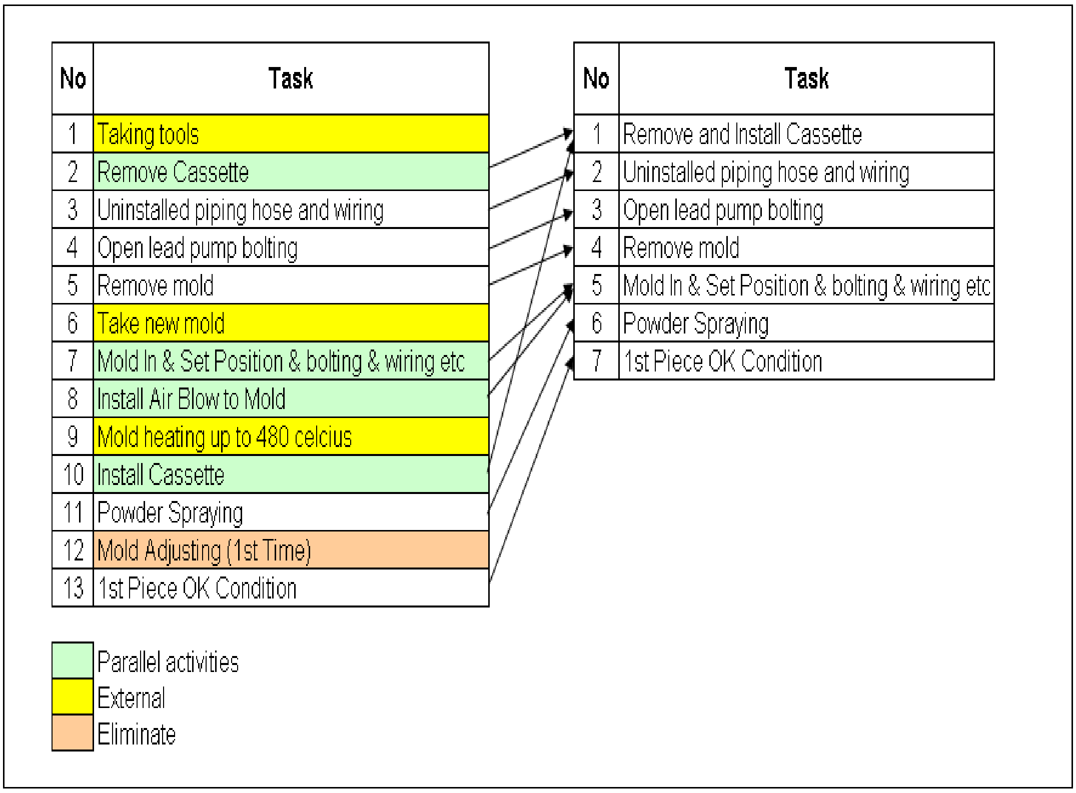

Figure 2: Tasks after SMED implementation in cast on strap

The overall setup time was reduced from 52 minutes to 24 minutes. A total of 28 minutes or 54% of setup time were reduced in the cast on strap setup operations. Figure 3 shows the time comparison before and after SMED implementation in cast on strap.

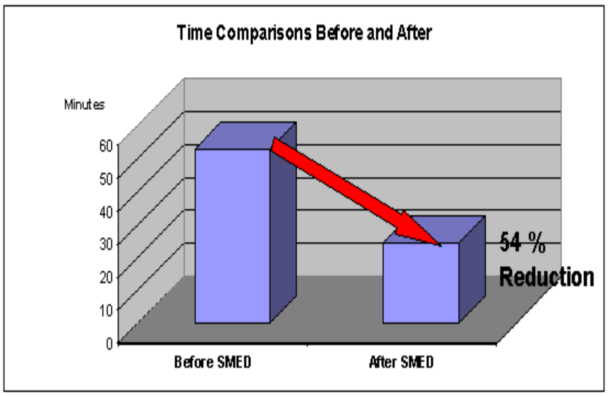

Figure 3: Time comparison before and after SMED implementation in cast on strap

There are basically 12 processes or task for battery heat sealing. In current practice, all the internal activities involved during the setup for a battery heat sealing machine are performed while the machine is not running. Setup time data for each activity involved in battery heat sealing setups were collected and analysed. After SMED methodology and approaches were applied in the heat seal setup activities, the number of setup tasks for heat seal processes were drastically reduced from 12 to 5 tasks. Figure 4 shows the new tasks after successful implementation of SMED methodology.

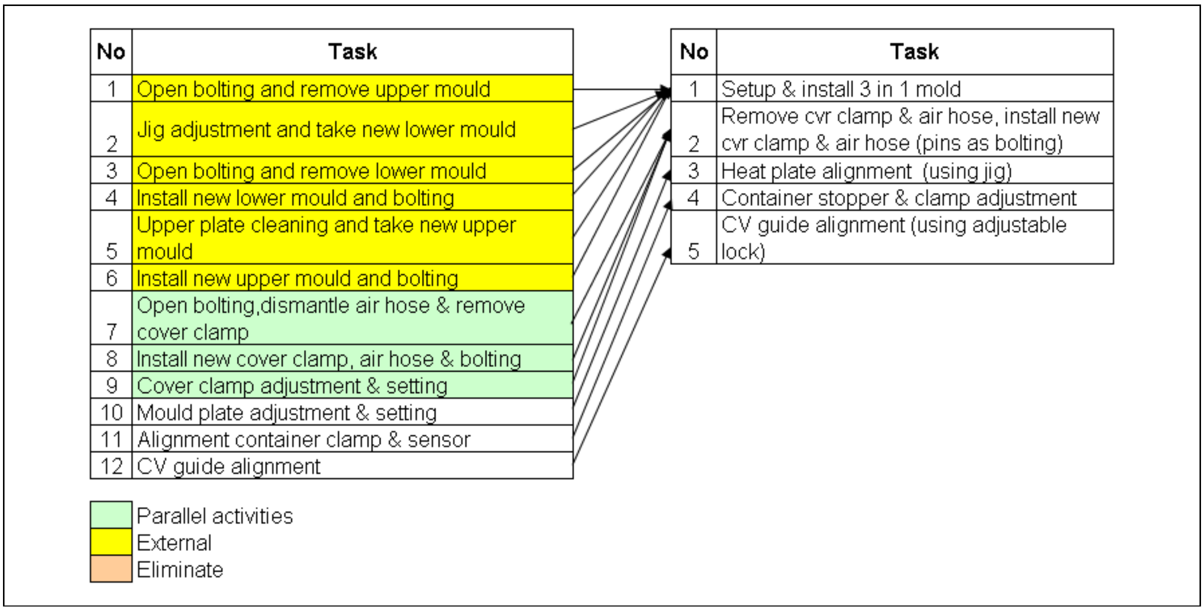

Figure 4: Tasks after SMED implementation in heat seal setup process

The overall setup times were reduced from 36 minutes to 19 minutes. A total of 17 minutes or 47% were reduced in the heat seal setup operations. Figure 5 shows the time comparison before and after SMED implementation in heat seal.

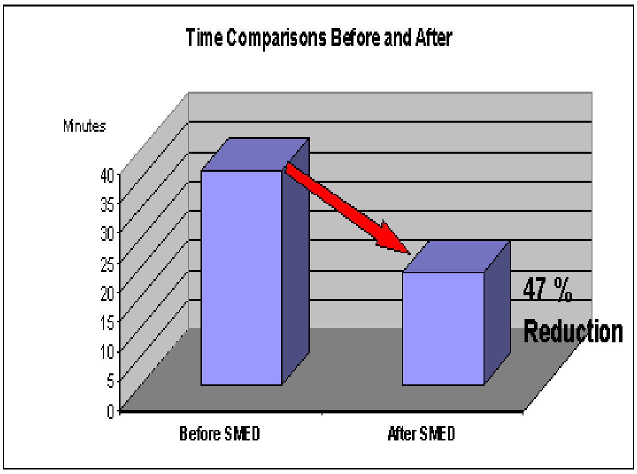

Figure 5: Time comparison before and after SMED implementation in heat seal

After the SMED technique was applied in the 2 bottleneck processes (cast on strap and heat seal), the total time taken to perform cast on strap setup activities at assembly line A was decreased by 54 percent from 52 minutes to 24 minutes, while heat seal machine setup was decreased from 36 minutes to 19 minutes, resulting in a 47 percent reduction in setup process time.

Saving and cost reduction

The biggest financial impact of the new improvements on the set up methods is the total machine down time reduction during the setup activities.

Both scheduled and unscheduled loss times are valued at RM2, 600 per hour or RM43 per minute. A total of 29,913 minutes are lost per year due to the mould setup activities and 575 setups per year (based on 52 minutes per setup) with setup costs averaging about RM1.1 million per year. Table 1 shows the detailed calculations of total savings for all the assembly lines.

Meanwhile, if we zoom in to the details of total saving for assembly line A, it shows that a total of RM168, 000 could have been saved during the setup. Total savings with respect to cast on strap and heat seal setup processes in the assembly line A are shown in Table 2. This calculation method is based on the past data information in which about 87 setups per year has been performed in assembly line A. This total saving is estimated in term of cost and cost savings in assembly line, which is valued at RM2, 600 per hour or RM43 per minute respectively.

The highest total savings for total assembly lines shows that it is critical to apply the SMED or setup reduction techniques into manufacturing plant to reduce the setup times and costs. The study also shows that the setup and manufacturing costs could have been reduced a long time ago if the SMED principles were applied in the setup operations.

Table 1: Total saving for all assembly lines in Company X

No	Process	Time (s)		Minutes +/-	% Change	RM Saving/Year with 575 setups/Year
		Before	After			
1	Cast on Strap set up loss time	52 minutes	24 minutes	28	-54%	692300
2	Heat Seal set up loss time	36 minutes	19 minutes	17	-47%	420325
					Total	1112625

Note: Estimated RM2600/hr @ RM 43/minute

Table 2: Total savings for assembly line A

No	Process	Time (s)		Minutes +/-	% Change	RM Saving/Year with 87 setups/Year
		Before	After			
1	Cast on Strap set up loss time	52 minutes	24 minutes	28	-54%	104748
2	Heat Seal set up loss time	36 minutes	19 minutes	17	-47%	63597
					Total	168345

Note: Estimated RM2600/hr @ RM 43/minute

Other benefits

SMED techniques were applied in the assembly line A to reduce machine setup time. There are various other benefits of applying SMED and reducing a number of machine downtimes or setup time such as follows;

i. SMED has helped Company X to respond quickly to customer demands. This has opened the possibility and ability to further increase the responsiveness to customers' demand by implementing the *heijunka* (mix model) approach. This can help the company to further increased manufacturing flexibility to produce a variety of products a day.

ii. The workers' motivations increased due to the setup tasks had been simplified and reduced from 13 tasks into 7 tasks. By using special equipment and devices such as a standby trolley and special tools during the setup activities, setup works become much easier.

iii. SMED principles are not only reduced cost and improved quality but also improved safety and health of workers in the workplace during the production and setup activities. For example, workers who are exposed to hot working environment are provided with special gloves and hand sleeves which have high resistance against temperature.

iv. Parallel operations system has increased production flexibility. Since many setup activities had been done in parallel and more operators were assigned to different setup processes, these operators were fully-utilised and none of the operator was left idle and waiting for job during the setup observation.

Line leader and line maintenance personnel are responsible to monitor the operators' work and know each of the operator's job functions. This has created an effective and productive work environment.

Tooling cost analysis

Setup time reduction improvements were conducted over the course of more than five months. During its implementation in the assembly line A, a thorough discussions and decisions had been made to consider the tooling or equipment costs that were likely to be incurred in these activities. All the designs of tooling must be standardised and can be used to reduce setup time and manufacturing costs in the other assembly lines.

For example, a preheat trolley used for cast on strap and heat seal mould was fabricated to suit with other production lines requirements. By doing this, it reduced the costs to implement SMED techniques and only one time investment would be needed. Table 3 and 4 show the tooling costs for cast on strap and heat seal.

Table 3: Tooling costs for cast on strap

No	Item	Qty	Cost (RM)
1	Pre Heat System - Electrical	1 unit	2600
2	Installation	1 lot	1250
3	Trolley (adjustable height)	1 unit	4500
4	Mould clamp	4 pcs	120
5	Cooling water piping system	1 set	450
6	Mold jigs	2 unit	85
		Total	9005

Table 4: Tooling costs for heat seal

No	Item	Qty	Cost (RM)
1	Pre Heat System - Electrical	1 unit	2600
2	Installation	1 lot	1250
3	Trolley (adjustable height)	1 unit	5500
4	Conveyor guide lock	2 pcs	240
5	Quick pin lock (mould)	2 pcs	780
		Total	10370

Table 5(a,b,c,d) shows that the total costs incurred during tools improvements for both processes are about 11.5 percent of total cost saving. The tooling cost for cast on strap is about 8.6 percent of the total cost saving for all the 8 processes. Meanwhile, heat seal tooling costs is 16.3 percent. This analysis shows that tooling cost is not a major factor contributing to the increase in manufacturing costs because tooling modifications and improvements can be implemented to reduce setup time since the total costs are far lower than the total saving costs per year and moreover, the return of investment for both processes is only 1.4 months. The details calculation on the tooling costs and return on investment (ROI) are shown in Table 5(a,b,c,d).

Table 5(a): Total cost for cast on strap

1	Cast on Strap (COS)	Unit	Total	Remark
a	Total investment cost (tooling)	RM	9005	
b	Total cost saving	RM	104748	
c	Percentage	%	8.6	

Table 5(b): Total cost for heat seal

2	Heat Seal	Unit	Total	Remark
a	Total investment cost (tooling)	RM	10370	
b	Total cost saving	RM	63597	
c	Percentage	%	16.3	

Table 5(c): Total cost for both processes

3	Overall (both processes)	Unit	Total	Remark
a	Total investment cost (tooling)	RM	19375	
b	Total cost saving	RM	168345	
c	Percentage	%	11.5	

Table 5(d): Return on saving (ROI)

4	Return On Investment (ROI)	Unit	Total	Remark
a	Total saving per year	RM	168345	
b	Average monthly saving	RM	14029	[a/12mth]
c	Total investment cost	RM	19375	
d	ROI	Mth	1.4	[c/b]

IV. CONCLUSION

Based on a series of time study data collected during the setup activities in the assembly line A, a comparison of results and achievements before and after the SMED implementation were made to measure the effectiveness of SMED to reduce setup time. Some of the improvements have been made to the setup operations using the eight SMED techniques. The study aims to reduce set up time by exploring the efforts on assembly line improvements, the required further improvements, and factors that can contribute to further reducing set up time in battery assembly. The SMED techniques were implemented in the two bottleneck processes, in cast on strap and heat seal. The goal to reduce machine downtime during the setup operations and reduction in setup times makes it possible to increase manufacturing system flexibility to manufacture a variety of products. By implementing the eight SMED techniques, the total time taken to perform cast on strap setup activities at assembly line A was reduced by 54% or from 52 minutes to 24 minutes. Meanwhile, the heat seal machine setup was reduced from 36 minutes to 19 minutes, resulting in a 47% reduction in setup process time. In this study, the system benefits achieved through the decreased lead time on the bottleneck processes, set up reductions on processes are also valuable. As a result to setup time reduction, a total savings of RM168, 000 was estimated in term of cost and cost savings in assembly line A and a total saving of RM1.11 million was estimated for all assembly lines in Company X. Other benefits achieved from SMED implementation are quick response to customers demand, increase workers motivation, improved workers' safety and health and parallel operation system. Through this analysis also shows that tooling cost is not a major factor contributing to the increase in manufacturing costs. However, the results from this study need to be treated with caution because the SMED techniques were not applied to the other three main assembly lines, B, C and D. Therefore, the authors had strongly recommend the company to implement the SMED techniques in main assembly lines B, C and D, so that the total assembly loss time due to setup or mould changeover could be reduced and thus improves their production efficiencies and total cost savings.

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