Reduction of changeover time through SMED with RACI integration in garment factories

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Abstract:

Objective:

Shorter lead time with low price and quality product demand is pivotal in the garment industry. Pressure on production lead time stresses the importance of reducing style changeover time in manufacturing factories, and this paper contributes to solving the challenge by showing how the Single Minute Exchange of Die (SMED) methodology in practice can be adapted to garment factories in developing countries.

Methodology:

The paper investigates three cases of SMED implementation integrated with RACI (Responsible, Accountable, Consulted, Informed) matrices in garment factories in an action research approach. Both quantitative and qualitative methods are applied.

Findings:

The study shows reduction of 50% to 64% of changeover time with SMED implementation measured with two key indicators – throughout time and time to reach peak production. Moreover, the implementation depends on application of the RACI matrix for distribution of responsibility as well as integration with the basic production flow before and after application of SMED.

Practical Implication:

The study can guide better SMED implementation in garment factories with limited investment by stressing the need to adapt to the specifics of the garment industry, secure the division of responsibility, and integrate SMED in the production flow before and after the changeover.

Originality/ Value:

Limited research on application of SMED in the garment industry. This paper contributes to understanding the specific conditions for the successful implementation in the garment industry in developing countries and addresses additional activities that help secure a sustainable implementation process.

Keywords: Changeover time, SMED, RACI, Lean tools, Garment.

1. Introduction

The ready-made garments industry is truly global in nature. Garment manufacturing being labor-intensive, has migrated from the high-wage developed world to developing countries the last decades before the Millennium (Gereffi, 2003). The garment industry in developing countries is now in a position to retain competitiveness with improved supply chain and manufacturing operations (Nuruzzaman, 2015). Currently, this industry is challenged by the trend towards smaller order quantities and high volatile fashion trends with shorter lead time (Bruce *et al.*, 2004; Hamja *et al.*, 2021; Štefko and Steffek, 2018). The production of a large variety in small lot quantities is a condition that requires frequent changeover. Style changeover time delays production time due to occupation of the sewing line (Kordoghli and Moussa, 2013). A large number of the factories are losing sewing floor efficiency due to mismanaged changeovers (Hamja, Maalouf, *et al.*, 2018), and practitioners tell about productivity loses due to small lots and frequent changeovers. In this situation, rapid changeover becomes a critical economic factor for a garment factory's profitability, and quick changeover is therefore key to satisfying customer demand and remaining competitive and profitable (Khan, 2016).

The most common approach to reduce changeover time is to use the lean manufacturing tool Single Minute Exchange of Dies (SMED). The methodology developed by Shigeo Shingo, denominate setups to be carried out within a maximum of a single digit of time (Shingo, 1985). The method was originally developed for well-established and managed automotive components manufacturers, and SMED has since then proved to be an efficient tool to reduce changeover time in many different industries such as IT, pharmaceuticals, and electronics (Fonda and Meneghetti, 2022; Godina *et al.*, 2018; Da Silva and Godinho Filho, 2019). The applicability of SMED in a developing country with more limited economic and human resources has been scarcely studied in the literature. The garment industry constitutes such an example of an industry mainly located in developing countries, which potentially could benefit from SMED. A few published examples indicate the potential for application of SMED in garments (Bajpai, 2014; Kordoghli and Moussa, 2013; Senthil Kumar *et al.*, 2012). However, case studies suggest the direct implementation of SMED in garment manufacturing to be challenging due to multiple variables (Zerin *et al.*, 2019). Some of the key challenges that make it challenging to adopt SMED in the garment industry have been studied by Hamja, Rabbi, *et al.*, (2018) and Khan (2019), indicating poor management planning, lack of proper training and coordination, inappropriate technology and lack of skilled operator issues. Additional organizational constraints can be limited access to learning opportunities, weak knowledge management systems and lack of appropriate organizational capabilities. Such constraints are likely to impede the implementation of SMED in the garments industry in developing countries.

Hence, the evidence about how to meet the technical and organizational challenges is limited, and more systematic knowledge is needed to secure that SMED can be applied on a broader scale in the garment industry in developing countries. To address this gap, this study contributes to the literature by showing how to fit the SMED methodology to the specific requirements of the garment industry in a developing country context and how to manage the application of SMED to secure the organizational sustainability of the methodology.

2. Background

2.1 Single minute exchange of Dies (SMED)

Single Minute Exchange of Die (SMED) is a lean tool for reducing setup time in a manufacturing process (Shingo *et al.*, 1985). The conventional SMED – as proposed by Shingo – provides a quick and efficient way to convert a manufacturing process from running the current product to running the following product. Shingo showed how to perform equipment setup (changeover) operations within single-digit minutes in the automotive industry. He characterized it as a scientific approach for reducing setup times, which can be applied in any industrial unit and any machine (Khan, 2016; Meredith, 1998; Shingo *et al.*, 1985). Shingo explained SMED methodology in three stages (see in Figure 1): 1. Separating internal and external setup, 2. Converting internal setup to external set up and 3. Streamlining all aspects of the setup process and, as a result, dramatically reduce the setup time (Kemal Karasu *et al.*, 2014).

The main steps of changeover operation start with separations of internal and external activities. Setup tasks are differentiated based on whether they can be performed internally or externally. External activities (E) can be conducted during the machine's regular operation when it is still running. Internal activities (I) are the ones that can only be performed when the machine is shut down. The internal and external activities involve different operations, such as preparation, after-process adjustment, material checking, mounting, and removing tools, settings, calibrations, measurements, trial runs, adjustments. At the second phase, internal activities are converted to external activities via in-advance preparation of operation conditions, standardizing essential functions (like standardizing clamping heights of the molds and centering mechanisms), and using intermediary jigs that lets preparation of preceding mold on an assistive tool while the machine is running. At the third stage, the remaining elements are reviewed to streamline and simplify to be completed in less time. All aspects of setup operations are streamlined by using multiple operators working parallelly.

[Figure 1 near here]

The traditional SMED method is fitting one machine and one worker. Today most industrial systems contain several machines and a team of operators. The efficacy of the traditional SMED method in its most basic form needs to be adapted for multivariate machines with different types of work processes. Fitting SMED to the technical and organizational context of a specific industry is therefore a prerequisite for successful application, and studies of SMED have since the Millennium continuously appeared in the literature (Da Silva and Godinho Filho, 2019). A few studies point towards the risk for failure of SMED implementation if the development of SMED does not fit the context. For example, McIntosh et al. (2017) argue that one possible cause of failure might be the strict application of this methodology, and that the three stages pathway might not be the most efficient way to reduce setup times in all situations. Indicatively, some companies emphasize transferring changeover internal tasks to external, missing the importance of minimizing or streamlining both internal and external activities by design improvements (Patel *et al.*, 2001). In addition, the same authors show that poka-yoke, resistance to change from the supervisor, and lack of training are the main obstacles to SMED implementation. Supplementary organizational measures may therefore be needed to apply SMED in such a setup with many machines and workers.

2.2 Application of SMED in the garment industry

The prospect for application of SMED in the textile industry was pointed out right after the Millennium (Mahajan, S. D., & Joshirao, 2002; Moxham and Greatbanks, 2001) and continues doing so with new case studies (see for example Bukhsh *et al.*, 2021; Prasad and Panghal, 2022) but empirical studies of SMED in the sewing garment industry have so far been scarce (Bajpai, 2014; Kordoghli and Moussa, 2013; Senthil Kumar *et al.*, 2012; Zerin *et al.*, 2019). While the studies support the prospects for benefits of application of SMED, they also emphasize the importance of integration with additional tools. An Indian case study (Bajpai, 2014) shows successful changeover time reduction in a garment manufacturing factory where value stream mapping was used to complement SMED. The entire process of style changeover was mapped and recorded from the time when the previous style reached completion, and the new style reaches a perfect flow of production using the VSM tool before applying SMED. Another study from Malaysia (Ibrahim *et al.*, 2015) proves the benefit of using 5S and a specific jig was used in mold alignment in a textile factory to reduce the changeover time by around 26% with the SMED method amplifying the success of SMED. A study from the Tunisia garments industry (Kordoghli and Moussa, 2013) found the appropriate working process, workers' skill level, and efficiency of mechanics to be critical for SMED success. Hence, the literature suggests that the implementation success of SMED particularly in textile and garments industry can be enhanced by supplementing with proper tools and organizational measures. Tools such as VSM and 5S are important to assist the reduction of changeover time with SMED due to the substantial number of machines and operators in production line in the garments industry.

2.3. Supporting organizational measures

Next to the importance of supplementing SMED with other lean tools, the overall experience with lean implementation in the garment industry points towards organizational constraints for implementation, including change of staff and loss of commitment during change process (Hamja *et al.*, 2021; Hoque *et al.*, 2020). In particular maintaining clear responsibility for the implementation of change and subsequent daily operations of the changes is crucial (Hasle and Vang, 2021). One possible measure to facilitate an organizational process to secure a sustainable application of SMED is the Responsibility Assignment Matrix (RAM) (Stackpole, 2011). RAM provides a way to plan, organize and coordinate work that assigns different degrees of responsibility to the members of an organization for each activity undertaken. In the context of RAM, the various responsibilities that may be transferred to action are usually called roles or task duties (Cabanillas *et al.*, 2012).

In some studies, RAM is expressed by RACI matrices (Cabanillas *et al.*, 2012; Tealeb *et al.*, 2016). RACI stands for Responsible, Accountable, Consulted, Informed and each letter refers to the particular roles of team members, and it ensures that all stakeholders know who oversees completing a job or receiving feedback on deliverables (Haughey, 2017). RACI is proved to be an efficient tool to manage stakeholder responsibility especially in process-oriented organizations (Cabanillas *et al.*, 2012).

RACI/RAM is initially developed for project management and software development (Khan and Quraishi, 2014) and has since spread to many other fields, including the manufacturing industry in combination with kaizen (Rossini *et al.*, 2019) and construction sites (Shrahily *et al.*, 2020). The main idea is to solve challenges for coordination and responsibility in a cross-functional team to avoid dysfunction and failure (Marle and Cardinal, 2010; McGrath and Whitty, 2018).

Application of SMED in the garment requires control of a large number of operation variables (product variation, machine variation, machine sequence, materials, and workers); these variables are managed by different people in production and production planning, and there is a need to secure coordination both for implementation and sustainable operations of SMED. RACI can be a relevant tool and to our knowledge has not been applied and studied in the garment industry before.

3. Methodology

SMED is scarcely applied in the garment industry in Bangladesh and RACI is not known at all. Case studies comparing companies with and without SMED are therefore not applicable. The best possibility for the study of the possibilities for application in the industry is therefore action research with interventions to introduce change in real-life situations (Coughlan and Coghlan, 2002; Greenwood J. and Levin, 2007). Action research has been widely used in operations management (Shani and Coghlan, 2019; Soni and Kodali, 2012). Action research is especially relevant to study real-life changes, which are highly context-dependent (Coughlan and Coghlan, 2002). In this study, we used action research to introduce and test SMED implementation with the integration of RACI charts and basic lean tools, and we use the often used five-step model for action research, developed by Susman et al. (1978) for the : 1) diagnosing, 2) Intervention planning, 3) Intervention, 4) evaluation, and 5) specifying learning. The target group was garment factories in Bangladesh, and the goal was identify the conditions for application of the integrated SMED implementation to reduce changeover time and increase productivity.

3.1. Selection of factories for interventions

The first author contacted ten factories in his network and from these factories, we have selected three factories based on the following criteria:

- Willingness to engage in the intervention and granting access to the researchers.
- Export- focused on sewing basic ready-made garments as the main activity.
- Availability of one production line for the SMED intervention.
- More than 1000 workers in the factory.
- Woven, knit and lingerie factories to ensure some degree of process similarities for comparison.

In each factory, the management and researchers selected a pilot line for SMED implementation. Table 1 presents the basic information of the three factories, including the pilot line.

[Table 1 near here]

3.2. Intervention Procedure:

Intervention planning: This step started with an introductory meeting with the factory's management to align expectations and commitments from both sides. It was agreed with management to establish a core management team responsible for the overall supervision and an operational team responsible for carrying out tangible changes according to RACI. The operational teams included industrial engineers (IE), production managers, quality managers, human resource and compliance managers, line supervisors and workers' representatives. One production line was selected as a pilot to implement changeover time reduction with SMED & RACI in each factory.

Subsequently, the researchers assessed the factory's knowledge of lean processes and organized training focused on lean tools important for SMED implementation support. Building capacity involved formal and on-the-job training. The formal training covered basic lean tools total preventive maintenance, throughput time, root cause analysis, 5S, Time and Motion Study (TMS), and ergonomics to support SMED activities

Intervention: The researchers in cooperation with the management core team tailored the actual change process to each factory depending on needs and priorities. The factory's operational teams supported by the researchers implemented the change process.

All factories worked with SMED implementation as the primary change according to the RACI matrices set by the core management team. Focused training of the core management team on SMED was followed by the incorporation of RACI matrices. In addition, line feeding preparation activities pre-plan, VSM, time and motion study, 5S, and lean flow were included to support the SMED application.

Evaluation: The intervention process was completed by assessing the effects, which included measurements of Key Performance Indicator (KPI). The measurements were used to compare before and after, and the evaluation results were subsequently used for feedback to the companies. The whole intervention process was carried out from January 2018 to December 2020.

3.3 Data Collection:

In the changeover process, the focus is to capture clean up, set up, and start-up time which make up the cycle time. As the primary SMED intervention, we identified the internal (I) and external (E) activities from the process flow chart. The clean-up, set up and start-up time was then measured to find the cycle time.

Then, to understand the RACI matrix, management, supervisors, and workers interviews were carried out. 5S were used to ensure machine cleanliness as well as the machine layouts. The throughput time was calculated as the sum of all operations cycle time. The below table 2 gives an overview of the data collection method:

[Table 2 near here]

4. Results

Table-1 represents the data provided by the factories consisting of information about all the production lines. The changeover time has been recorded in the pilot line, as stated in table 3. The throughput time is recorded from the first material input in the production pilot line to the first finished product output. And the time to reach peak production after the throughput time is also measured to reflect the learning curve. The total changeover time is the sum of both.

[Table 3 near here]

The operational team assisted by the researchers observed two changeovers (current practice and after intervention) in the pilot lines. The team classified the activities as internal and external, respectively (see table 4). Changeover activities are classified into three categories: 1) during the understanding stage when the style change is scrutinized, 2) before the style change and 3) after the style change. The intervention was used to reclassify internal and external activities, and the table shows that many internal activities could be reclassified as external activities. The complete list is included in appendix A.

[Table 4 near here]

In the first category, style analysis and understanding changeover, 2 out of 9 activities were internal (I). After SMED second step intervention, all of them became converted to External (E). In the second category, during the changeover preparation before the intervention, 9 out of 12 activities were internal (I), which is one of the reasons for a longer time used for changeover. Still, after the intervention, we have converted 100% of the task into external in all three factories. The third category was significant for the setup time called execution and monitoring activities of changeo-ver. Considerable time was involved in this category; F-1, F-2, and F-3 were doing 30, 17, and 24 activities out of 41 Internally (I). Still, SMED intervention converted 44 activities out of 71 internal activities to external in the third category (total in the 3 factories). Out of the 27 internal activities left 1 activity (during the style change) could not been entirely converted to external work (reported in the appendix as both internal and external).

During this process, RACI served as the tool to clearly define responsibility for each changeover activity. The operational team assisted by the researchers carried out this allocation of responsibility. The before situation was marked by indecision and lack of clarity in changeover activities as the tasks were obscurely defined. As a result, most of the changeover activities were treated as internal consuming added time. But after the implementation of RACI, the tasks and responsibilities have been well defined, making the changeover activities more visible. Hence, it was possible to reclassify most of the changeover activities as external. Another important observation is the relatively substantial number of different staff involved in changeover activities, stressing the importance of RACI.

The operational team applied 5S to secure a foundation for the SMED activities before the process. The main activities included:

- 5S team formation
- Training up team on 5S
- Create 5S audit habit as part of daily work.

We compare the before and after observed changeovers. The operational team tried to keep almost similar products and near SMV for ease of comparison in all the three factories (Table 5). Finally, the percentage (%) change in total changeover time after RACI integration in the intervention was 50%, 64% and 51%, respectively, in the three factories.

[Table 5 near here]

In more detail, from the throughput report, F-2 starts with a much better throughput time and thus has less scope to improve. F-2 also ends up with less than half the total changeover time compared to the other 2 factories. It clearly suggests that there are large scopes of improvement for F-1 and F-3. A key indicator of the effects of SMED is the learning curve indicating how long time it takes to reach peak production (second column, table 5). The three factories achieved significant changes in this category, also for this indicator that F-1 and F-3 have a large scope for further improvements.

Next to the reclassification of external and internal activities, applying the additional lean tools constitutes a critical supplement. These activities included RACI responsibility assignment, 5S, visual control, work in progress control, and time and motion studies (see oversight in appendix B). Distributing responsibilities as per RACI matrix was a challenge due to the silo orientation of the organizations hindering the practice of coordination, sharing, team-work and the sense of participation (Waal *et al.*, 2019). Again, the RACI matrix distribution of responsibilities is quite extensive with a level of details, which the staff is not used to. The major challenge in implementing RACI was the knowledge gap in the industry. The workers and supervisors were only aware of Responsibility but not on the practice of Accountability, Consultation and sharing Information, which are key elements in the RACI matrix. As a result, after the first introduction of the RACI model to the workers and supervisors, there was an inertia among them to share, consult and inform any difficulties to their peers. However, after practicing, many of their uncertainty gradually disappeared and the efficiency of changeover activities increased.

After a positive result in changeover time reduction, management needs to verify the sustainability of positive trend. We followed the total line efficiency outcome for a whole month after the changeover; all factories improved their line efficiency minimum of 15% to a maximum of 19% shown in table 6. To maintain sustainable efficiency growth or retain mature efficiency in line we have tracked nonproductive time data, sometimes need to rearrange workstation and method improvement with team integration.

[Table 6 near here]

5. Discussion

This study aims to assess the potential for the application of SMED to reduce changeover time in the garment industry and to figure out how to adapt the basic Shingo guidelines to fit the conditions for the garment industry. The variety of products with different specifications, diversity of raw material, and the labor-intensive work with different skill sets makes SMED a complex phenomenon in the garments industry compared to many other industries. The increasing product diversity with smaller lot numbers makes style changeover more frequent and constitute a great challenge in the production process.

Garment factories in Bangladesh are often marked by relatively chaotic, unstructured work processes and a silo organizational culture, making application of systematic SMED difficult. Yet, the results show considerable improvements in the three intervention factories both in the changeover time and in the general efficiency of production. Considering these results alongside the earlier published case studies of SMED, the evidence points towards a considerable potential for application of SMED in the garment industry. The potential benefits are large compared to a relatively low investment in terms of working hours for the staff during the transition period. No capital investments are required.

The intervention presented in this paper builds on a comprehensive and integrated strategy with the addition of a RACI matrix and the application of additional lean tools. The results thereby add to the understanding of SMED compared to the original SMED method focused on the die change process with a dedicated team operation of on one machine as the point of departure. The garment industry's special conditions with long production lines with many workers and machines, a very flexible raw material, small batches, and short lead time make the RACI addition essential to manage the series of work task involved in SMED in a multi-stakeholder environment.

Furthermore, the lack of qualified industrial engineers and other professionals is a well-known constraint for the garment industry in developing countries. This constraint also appeared in the intervention. Yet, the results indicate that it is possible to introduce SMED, RACI, and a few basic lean tools to staff with practical experience but limited formal education. Together with the practical experience, the introduction proved sufficient to secure the implementation of SMED and the additional tools. For example, the application of 5S assisted in identifying and eliminating non-value-added activities from the changeover tasks. TPM supplemented the conversion of maintenance tasks from internal to external. Combination with other tools amplified the SMED results considerably.

The reluctance to share across responsibilities constituted a major organizational constraint for coordination in the included factories, and the RACI matrix proved to be a valuable tool to cope with this constraint. RACI ensured the specialization of responsibility and delegation of activities among the supervisors and workers according to their capability and duties. Top management support is proved to be pivotal for the sustainability of the change as their bold initiatives are the only pressure factor for the industrial engineers and floor operators after the intervention project is finished.

It was only possible to observe sustainability of the implemented changes for approximately one month, and long-term sustainability and the possibility of securing sustainability is obviously a subject for further research. The strongest results were achieved in the factory with the most qualified industrial engineers, and competent staff may be one indicator of future sustainability. We also must take reservations due to the limited number of cases in one single country. Repetition of the intervention in more factories and countries will be helpful to build up stronger evidence for a more widespread application of SMED.

7.1 Practical implications

For practitioners, the findings have several important learnings:

1) Application of SMED has potential for significant reduction of changeover time, which any company in the garment industry can benefit from. Application of related lean tools such as 5S, TPM and TMS increase the benefits form implementation of SMED.
2) SMED with related basic lean tools can be applied in factories with limited industrial engineering expertise although the access to such expertise will strengthen the results. However, a committed top management and dedicated project will be prerequisites for successful application.

3) Yet, to secure implementation and longer-term sustainability commitment and responsibility need to clear, and the RACI matrix proves as an important tool for a transparent division of responsibility, which can secure that all concerned staff and workers are aware of the tasks in the SMED application.
4) Implementation of SMED with the full program of related lean tools and the RACI matrix will be important for any individual garment company for increasing productivity and securing competitiveness – both in terms of meeting delivery and price requirements from buyers.

6. Conclusion

This paper highlights a great potential to apply SMED in the garments industry to reduce change-over time and improve productivity. The method can thereby contribute to meet the fashion industry's requirements to suppliers regarding competitive prices, smaller lot size and shorter lead time. The benefits are large compared to the relatively limited investment. The results emphasize the need to adapt SMED to the specific context of garment industries in developing countries. SMED cannot be applied in the pure original form but needs to be accompanied with related simple lean tool to secure those gains from SMED. It is particularly important to secure organization commitment, which require a clear division of responsibility. The RACI matrix has in this context proved to be a useful tool coordinating and adhering to responsibilities. Our results do not indicate any overall adverse effects of the application of SMED and RACI in the three RMG factories. For practitioners, the findings imply that implementing basic SMED with careful consideration of RACI can be a way forward to increase productivity in the garments industry. Further research is needed to confirm the applicability of the results in other factories and countries, and more research to study constraints and possibilities to secure long term responsibility. With the increasing digitalization also in garment in developing countries further research could study the possibilities to integrate SMED in the general planning systems to secure a standardized use across production lines and departments in the factories.

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Figure 1: Three major phases in SMED (Shingo et al., 1985)

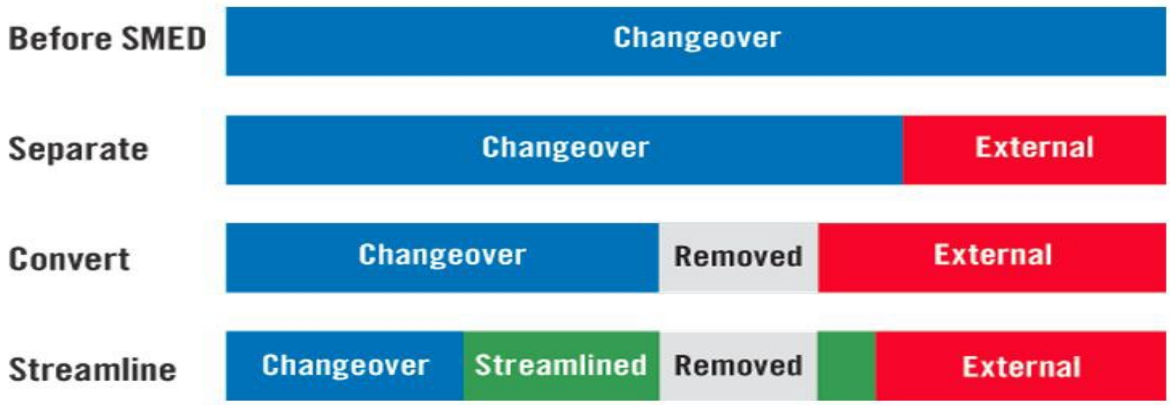

Table 1: Context of the three factories (Source: Author's own creation)

Factory	Product of this factory	Production Pieces/Month	Number of workers	Pilot Line information	Major Machine type	Experience in Lean Tools
F-1	Woven Tops	500000	2553	Workstation- 60 nos SMV- 18 minutes, Average monthly changeovers - 4, Average efficiency- 49%, Average batch size - 8000 pcs, Female-male worker- 75%-25%, No of Supervisors-2	Single Needle, Double Needle, Feed of Arms Multi Needle Chain Stitch	Factory has industrial engineering department but limited knowledge on Lean, SMED, TPM, 5S, RACI.
F-2	Women Intimate Items	1100000	1250	Workstation- 26 nos SMV- 3.94 minutes, Average monthly changeovers - 5, Average efficiency- 55%, Average batch size - 10000 pcs, Female-male worker- 85%-15%, No of Supervisors-2	Overlock, Flat Lock, Feed of the Arm	Factory has industrial engineering department with operational knowledge on Lean, SMED, TPM, 5S but RACI.
F-3	Woven Bottom	550000	3500	Workstation- 78 nos SMV- 20 minutes, Average monthly changeovers - 4, Average efficiency- 48%, Average batch size - 10000 pcs, Female-male worker- 70%-30%, No of Supervisors-2	Single Needle, Double Needle, Feed of Arms Multi Needle	Factory has industrial engineering department but no operational knowledge on Lean, SMED, TPM, 5S, RACI.

Table 2: Method of data collection (Source: Author's own creation)

Tools	Method of Data Collection
Process flow chart	List out all tasks in the changeover process distributed on external and internal tasks
Throughput time	Line feeding report provides total time to get the first pieces of output after changeover
Total preventive Maintenance TPM	Before and after the changeover, how all machines are maintained according to TPM, to reduce machine breakdown time in the time of changeover with four types of maintenance (Autonomous Maintenance, Planned Maintenance, Quality Maintenance, Focused Improvement) activities carried out as a part of SMED.
5S audit including OHS assessment	All parameters assessed on a score from one to five. The assessment included unnecessary items, transport area, workstation design, labels, signs, color-coding, and cleanness. Photos were taken before and after 5S implementation
Time and motion study	Measure time of each task five times and check which cycle operator makes a good piece. This is the first input to the line feeding report.
Qualitative interviews	Interviews with management, supervisors, and workers to identify the challenges and barriers of SMED implementation, toolbox meeting, worker responsibilities etc.

Table-3: Baseline Data (Source: Author's own creation)

Factory	Throughput time (first material input to first finished good output) (Hr)	Time to reach peak production after throughput (Hr)	Total changeover time (Hr)
F-1	18.0	46	64
F-2	8.87	26	32.87
F-3	15.5	36	51.5

Table 4: Summary of change over activity (Source: Author's own creation)

Changeover Activity	**F-1**				**F-2**				**F-3**			
	Before		After		Before		After		Before		After	
	I	E	I	E	I	E	I	E	I	E	I	E
Understanding style change	2	7	0	9	2	7	0	9	2	7	0	9
Before style change	9	3	0	12	2	10	0	12	3	9	0	12
During style change	19	1	9	10	13	7	9	10	19	1	9	10
Total	30	11	9	31	17	24	9	31	24	17	9	31

Table 5: Summary of changeover activity (Source: Author's own creation)

Factory	Throughput Time Hr.				Time to reach peak production after throughput Hr.				Total Changeover Time Hr.			
	Before	After	Total Hr. Saved	% Reduction of time	Before	After	Total Hr. Saved	% Reduction of time	Before	After	Total Hr. Saved	% Reduction of time
F-1	18	14	4	22	46	18	28	61	64	32	32	50
F-2	8.87	4.3	4.4	51	26	8	18	69	34.87	12.3	22.4	64
F-3	15.5	9.5	6	39	36	15.6	20.4	57	51.5	25.1	26.4	51

Table 6: Production efficiency Improvement (Source: Author's own creation)

Factory	Efficiency (%)			Activities done in the time of changeover						
	Before (%)	After (%)	Change (%)	Time and motion studies	Nonproductive time control	Operator skill enhancement	Rearranging workstation	Auxiliary Items attachments with machines	Method improvement	Different inter department team involvement
F-1	42	49	17	Y	Y	N	N	N	N	Y
F-2	54	64	19	Y	Y	Y	Y	Y	Y	Y
F-3	46	53	15	Y	Y	N	N	Y	Y	Y