

# **Managing Changeover Waste in Manufacturing Plants When Using Single Minute Exchange of Dies**

**Rushil Madhav, Annlize Marnewick, Hannelie Nel, Jan-Harm Pretorius**

Postgraduate School of Engineering Management

University of Johannesburg

Johannesburg, South Africa

Rbm89.rushil@gmail.com, amarnewick@uj.ac.za, hannelien@uj.ac.za, jhcpretorius@uj.ac.za

## **Abstract**

The research presented in the paper demonstrates the implementation of single minute exchange of dies whilst considering the critical success factors of lean to manage the waste and cost generated during changeover processes. The aim of the work is to ascertain whether the consideration of lean critical success factors during changeovers has an impact on waste and cost in manufacturing. The findings indicate that critical success factors provide a practical guide to achieve a fully integrated manufacturing management system with efficient changeover processes and reduced waste. Ultimately, the findings allow organizations to meet customer requirements for a differentiated product line since changeovers could take place more frequently with smaller batch sizes and lower inventory levels.

## **Keywords**

Changeovers, Lean, Critical Success Factors

## **1. Introduction**

Companies are expected to continuously improve efficiency due to rapid changes in customer requirements, with customers demanding a variety of products with better quality, improved delivery periods and affordable costs (Ferradás and Saloniitis, 2013; Seebacher and Winkler, 2014). This can only be achieved with greater flexibility in manufacturing since it allows companies to adapt to continuous changes in customer demands (Seebacher and Winkler, 2014). The diversity in customer products forces many manufacturing companies to produce multiple products resulting in frequent machine changeovers and resultant waste (Ferradás and Saloniitis, 2013; Hinkin, 2016).

A multiple cross-case study analysis approach was utilized for the research. Six case studies were conducted on two production lines in a manufacturing plant of one of the leading packaging organizations in South Africa; and the data was analysed employing the statistical package SPSS. The results are presented as documentation analysis, observational analysis, interview data analysis and statistical data analysis. Relevant statistical parameters were employed to ascertain the reliability of data and to test the research hypotheses.

The research determines how single minute exchange of dies (SMED) is implemented when considering the critical success factors (CSFs) of lean. The aim of the work is to determine the impact of CSFs on waste generated during manufacturing changeovers and the possible savings that could result from considering these factors during the implementation of SMED. The findings would determine whether lean CSFs form a part of SMED implementation and whether it could facilitate the success of SMED and waste reduction.

## **2. Changeovers**

Machine changeovers is the time required (TC) to prepare a machine, device or process to change from producing the last good product (A) from the previous production order to the first good product (B) of the following production order as indicated in Figure 1 (Ferradás and Saloniitis, 2013; Henry, 2012). The preparation for the changeover involves single or several changes, where numerous parameters, components and elements are changed to support the production of goods from the new production order (Vermaak, 2008). This process is often conducted on a single

machine but it could also be executed on several machines that are utilized to form a packaging or production line (Dave and Sohani, 2012). All manufacturing organizations must understand their changeover capability and ensure that the procedures utilized to conduct these changeovers are efficient and effective. Changeovers may be very time-consuming, and different manufacturing organizations adopt different procedures to reduce the time lost during changeovers, including cleaning, setting up and the run-up stages (Dombrowski and Mielke, 2014).

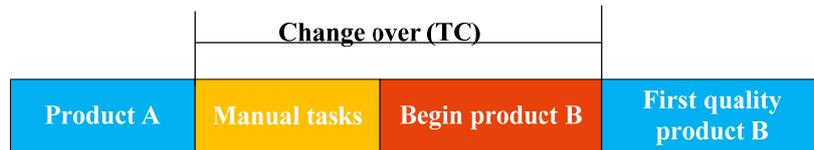


Figure 1. Changeover process

## 2.2 Changeover Waste

Reducing changeovers aims to eliminate the challenges experienced during the clean-up, set-up and run-up stages (Kemal, Cakmakci, Cakiroglu, Ayva and Demirel-Ortabas, 2014). These challenges result in the seven wastes of lean manufacturing and consequent unprofitable activities (*ibid.*, Guo, 2009). The waste and costs that accompany these changeovers stem from one or a combination of the factors listed in Table 1 (*Manufacturing Wastes, 2015*).

Table 1. Seven wastes of lean manufacturing

Overproduction	Overproduction refers to the production of products in larger quantities sooner and faster than the customer requires them.
Inventory	Any materials, supplies, parts or products in excess of the required amount inevitably results in waste.
Waiting	The idle time and/or downtime that is caused when any material, supplies, parts, information, planning and/or equipment is not available.
Motion	The unnecessary movement of materials, parts, equipment, machines and people that does not add value to the product or service.
Transportation	The irrelevant movement of materials, parts or equipment and the unnecessary movements made by people (e.g. walking) resulting in wasted time and costs (Yann, 2009)
Defects / Rework	The repetition or correction of certain tasks and processes due to incorrect procedures, errors, poor product quality or poor delivery performance (Yann, 2009).
Inappropriate Processing	Incorrect execution of processes, incorrect utilization of tools due to poor procedures and systems (Yann, 2009). Or it could involve processing beyond customers' required standard.

## 2.3 SMED

SMED is one of the many lean tools employed for improving changeover processes (Alves and Tenera, 2009). The methodology was developed by Shingeo during the 1950s in the Japanese Toyota Production System to improve and reduce waste (*ibid.*). Shingeo defined SMED as "the minimum amount of time necessary to change the type of production activity, taking into consideration the moment at which the last piece of a previous lot was produced *visa vis* the first piece produced by the subsequent lot" (King, 2009; Tilkar, Nagaich and Marwah, 2013). SMED is an approach that reduces changeover periods, and it can be applied in any industrial organization on any machine (Alves and Tenera, 2009; Massa, 2010). Shingeo developed four stages that utilizes nine techniques to reduce the duration of changeover periods (Ferradás and Salonitis, 2013; Joshi and Naik, 2016; Massa, 2010; Trietsch, 2016). Shingeo described these four stages as follows (Ferradás and Salonitis, 2013):

**The preliminary stage: differentiate between internal and external setups.** The lack of clarity between internal and external setups leads to extended changeover periods (Ferradás and Salonitis, 2013; Trietsch, 2016).

**Stage 1: separate internal and external setups.** Once each setup procedure has been categorized by the preliminary stage, each setup is divided into either an internal or external setup (Ferradás and Salonitis, 2013). This assists in

isolating the internal activity from external activities and it would ideally measure the length of the setup period as the internal setup determines the length of the changeover setup time period (Trietsch, 2016). This stage can aid in reducing the setup time by as much as thirty to fifty percent (*ibid.*).

**Stage 2: convert internal setup steps to external setup steps.** Shortening or converting the internal setups that were identified in Stage 1 would further reduce and simplify the changeover process. Such an analysis would lead to the utilization of intermediary jigs, dies, settings and standards (Trietsch, 2016).

**Stage 3: streamline both internal and external setups.** Stage 3 reduced the effort required within the final internal and external setups (Ferradás and Salonitis, 2013).

Attainment of these benefits with successful implementation of the different stages requires several prerequisites to manage, master and reduce each stage of the changeover. These prerequisites were identified and later compared with the Critical Success Factors of lean in order to determine if these prerequisites were part of the factors.

## 2.4 Critical Success Factors for the Implementation of Lean

The implementation of lean is believed to bear difficulty and challenges. Thus, the identification of the CSFs for any continuous improvement initiative is important since it allows organizations to focus their efforts on these factors for success.

Table 2 outlines the critical success factors for the successful implementation of lean, and it compares these factors with the prerequisites for SMED.

Table 2. CSFs for the implementation of lean

Lean Critical Success Factors	Prerequisite for SMED	Reference
Front Line Employees	✓	Alaskari et al., 2016; Palanisamy and Siddiqui, 2016; Quinlan, 2011
Top Managements Commitment	✓	Dave and Sohani, 2012; Massa, 2010; Alaskari et al., 2016; Palanisamy and Siddiqui, 2016; Quinlan, 2011; Sreejesh, Mohapatra and Anusree, 2014; Bhasin, 2012
Allocation of Resources	✗	Dave and Sohani, 2012; Alaskari et al., 2016
Strong Communication	✓	Dave and Sohani, 2012; Dombrowski and Mielke, 2014; Alaskari et al., 2016; Bhasin, 2012
Structural Methodology	✓	Dave and Sohani, 2012; Alaskari et al., 2016
Integration	✓	Alaskari et al., 2016
Continuous Performance Measurement	✗	Alaskari et al., 2016; Bhasin, 2012
Finance Capabilities	✓	Dombrowski and Mielke, 2014; Alaskari et al., 2016; Massa, 2010; Palanisamy and Siddiqui, 2016; Sreejesh, Mohapatra and Anusree, 2014; McIntosh et al., 2007
Leadership	✓	Yann, 2009; Dombrowski and Mielke, 2014; Massa, 2010; Alaskari et al., 2016; Palanisamy and Siddiqui, 2016; Sreejesh, Mohapatra and Anusree, 2014; Bajpai, 2016
Specific Goals and Objectives	✓	Tilkar, Nagaich and Marwah, 2013; Alaskari et al., 2016
Organizational Culture	✓	Dombrowski and Mielke, 2014; Massa, 2010; Alaskari et al., 2016; Palanisamy and Siddiqui, 2016
Roles in the Change Process	✓	Alaskari et al., 2016;
Lean Office	✓	Alaskari et al., 2016; Sreejesh, Mohapatra and Anusree, 2014; Hines et al., 2008
View Lean as a Long Term Journey and Philosophy	✗	Dave and Sohani, 2012; Sreejesh, Mohapatra and Anusree, 2014
Training, Skills and Expertise	✓	Dave and Sohani, 2012; Massa, 2010; Alaskari et al., 2016; Palanisamy and Siddiqui, 2016; McIntosh et al., 2007; Hines et al., 2008

Lean Critical Success Factors	Prerequisite for SMED	Reference
Change Management	✓	Dave and Sohani, 2012; Dombrowski and Mielke, 2014; Massa, 2010; Alaskari et al., 2016; Palanisamy and Siddiqui, 2016; Hines et al., 2008
Kaizen	✓	Alaskari et al., 2016; Taylor and Brunt, 2000
Customer Focus	✓	Alaskari et al., 2016; Hines et al., 2008
Information and Knowledge	✓	Manufacturing Wastes, 2015
Rewards and Incentive System	✗	Alaskari et al., 2016; Hines et al., 2008; Mileham et al., 1999
Strategy and Alignment	✗	Yann, 2009
Behaviour and Engagement	✗	Yann, 2009

The comparison indicates that the majority of SMED prerequisites form part of the CSFs; and hence it is important to consider the lean CSFs during the implementation of SMED. The researchers conducted several case studies to determine whether CSFs were indeed considered during SMED implementation.

### 3. Case Study Research Approach

A multiple cross-case study analysis approach was utilized since it provides a more rigorous and robust approach than single case studies (Khan and Van Wynsberghe, 2008; Rowley, 2002; Yin, 2013). Six case studies were conducted on two production lines in a manufacturing plant of one of the leading packaging organizations in South Africa. The manufacturing site comprises two manufacturing lines referred to as Line 1 and Line 2 respectively. Line 1 produces three different products, namely product 1, product 2 and product 3. Line 2 also produces three different products that shall be referred to as product 4, product 5 and product 6 as illustrated in Figure 2.

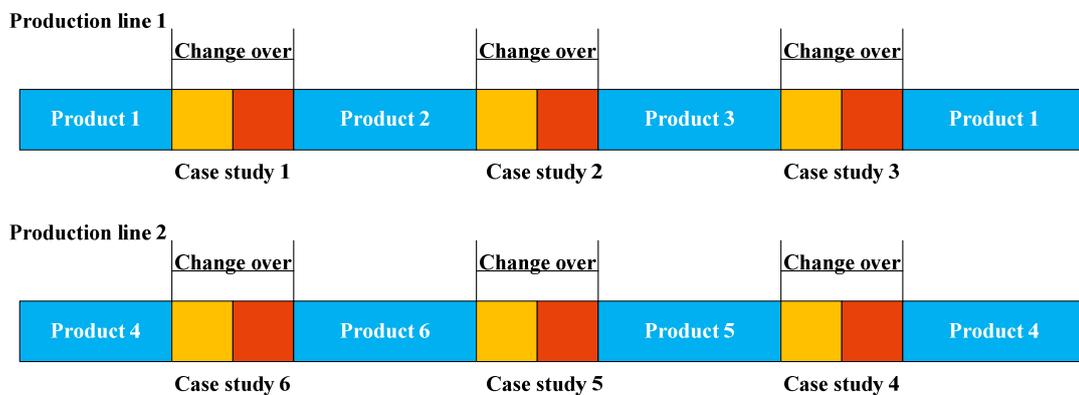


Figure 2. Changeover case studies

Each machine undergoes changeovers to produce the different products and different sizes of the products. Table 3 presents the different types of changeovers that take place per line.

Table 3. Changeovers and case studies on lines 1 and 2

Line 1	Case study	Line 2	Case study
Changeover from product size 1 to 2	1	Changeover from product size 4 to size 6	6
Changeover from product size 2 to size 3	2	Changeover from product size 5 to size 4	4
Changeover from product size 3 size 1	3	Changeover from product size 6 to size 5	5

The case study research methodology enabled the researchers to accumulate knowledge, refine and develop concepts, and to build or test the theory (Hines, Found, Griffiths and Harrison, 2008; Taylor and Brunt, 2000). Different data collection protocols were utilized to collect evidence and to conduct the case studies. Documents, archival records and direct observations were cross-referenced to ensure triangulation; and structured interviews were utilized to attain

additional data, eliminate bias and confirm the findings. These interviews were held with personnel who conducted and managed the changeovers per line. Confidentiality prescription precludes the researchers from identifying the organization and its products.

#### 4. Results

The results are presented in four sections, namely (4.1) Documentation Analysis; (4.2) Observational Analysis; (4.3) Interview Data Analysis and (4.4) Statistical Data Analysis. Section 4.1 presents the desktop analysis conducted on production reports, documented changeover downtimes, waste and cost statistics, settings and procedures. Section 4.2 presents the observational results which indicated how actual change overs were performed compared to the three stages mentioned in Section 2.3. The last two sections (4.3 and 4.4) provide descriptive and statically analysis of data collected during interviews of employees.

#### 4.1 Documentation Analysis

Documentation included production reports, changeover downtime, waste and cost statistics, settings and procedures. Table 4 summarizes the production statistics for each case study and it includes the changeover waste, costs and changeover time periods per case. The recommended changeover time per line and product is three hours across both production lines.

Table 4. Production statistics for each case study

Statistics	Line 1				Line 2			
	Case 1	Case 2	Case 3	Average	Case 4	Case 5	Case 6	Average
Efficiency	47 %	54 %	28 %	43 %	0 %	1 %	14 %	5 %
Waste (Pieces)	1 500	1 468	8 258	3 742	12 043	13 464	15 419	13 642
Changeover Time Period	2.6 hrs	3.5 hrs	3.3 hrs	3.13 hrs	9 hrs	11 hrs	10.1 hrs	10.03 hrs
Cost of each Changeover	R 13 380	R 17 394	R 24 098	R 18 291	R 53 988	R 64 579	R 62 719	R 60 429

Figure 3 and 4 illustrate the moving average and the linear trend lines for changeover time and waste pieces before and after the implementation of SMED on Lines 1 and 2. Figure 3 indicates that the changeover time on Line 1 has been decreasing slightly before the implementation of SMED. However, these improvements were inconsistent but the implementation of SMED ensured that the improvements remained constant. The changeover time periods on Line 2 also improved with the implementation of SMED, although these improvements seemed to be more inconsistent. The difference in the improvements between the two lines is also significant and it is clear that Line 2’s progress is less than that of Line 1. The changeovers on Line 1 have improved substantially and seem to have stabilized on an average of 3.13 hours, whereas Line 2 is at an average of 12.5 hours.

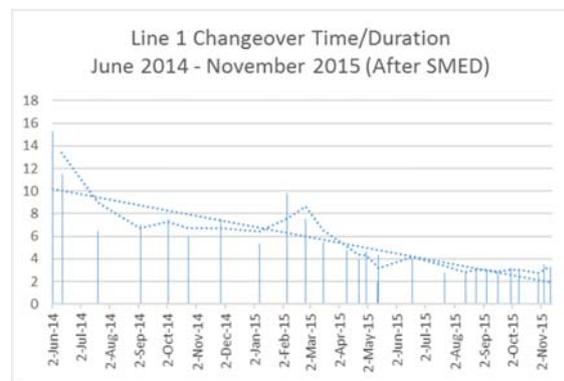
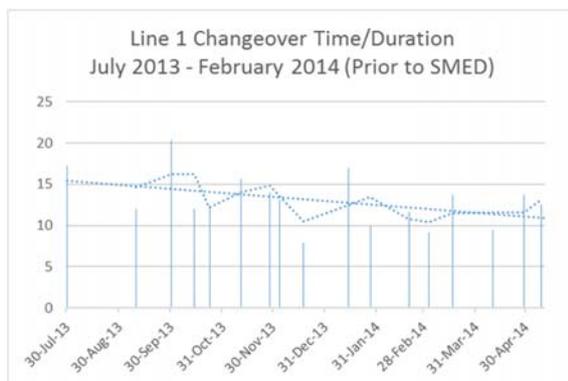




Figure 3. Changeover Time for Lines 1 and 2

Figure 4 provides an analysis of the waste identified in the production reports for the changeovers that had been conducted in the same period. The reduction in waste on Line 1 after the implementation of SMED was significant, whereas the waste on Line 2 remained high albeit a decrease was noted. The decrease in the changeover times and waste has a direct impact on the cost of each changeover; and the utilization of SMED indicated improvements on both production lines.

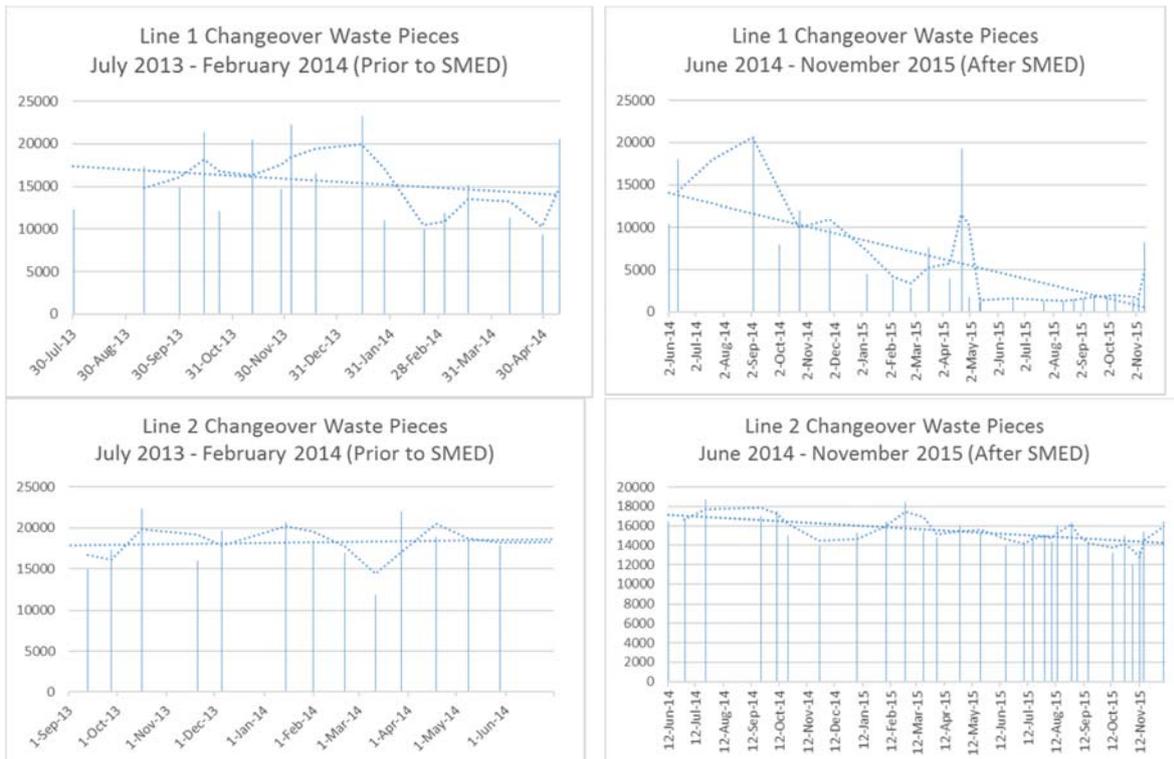


Figure 4. Changeover Waste for Lines 1 and 2

#### 4.2 Observational Analysis

Observational analysis focused on the consideration of lean CSFs in the implementation of SMED. The entire changeover process was analyzed in the time frame within which each changeover had taken place. The analysis included note taking, observation, listening, monitoring and interacting with employees. These interactions promoted understanding of the changeover operation, and it provided relevant information presented in Tables 5 to 7. The findings are presented with reference to the SMED process, the CSFs of lean and the seven wastes of lean

manufacturing for each case. The findings presented in Table 5 refer to the SMED process and were obtained during each changeover.

Table 5. Analysis of the SMED process

Production Line 1			Production Line 2		
Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Preliminary Stage: Differentiate between internal and external setups			Preliminary Stage: Differentiate between internal and external setups		
<ul style="list-style-type: none"> <li>▪ Clear distinction between the internal and external tasks.</li> <li>▪ Specific tasks are performed prior to the changeover and specific tasks were only conducted when the machine had stopped.</li> </ul>			<ul style="list-style-type: none"> <li>▪ No distinction between internal and external tasks.</li> <li>▪ Tasks are conducted only when the machine stops. No external tasks observed prior to the machine stopping.</li> </ul>		
<b>Stage 1: Separate internal and external steps</b>			<b>Stage 1: Separate internal and external steps</b>		
<ul style="list-style-type: none"> <li>▪ Preparation and cleaning of changeover parts and tools prior to the machine stopping for each changeover.</li> <li>▪ Tools, changeover parts, changeover trolleys and work instructions with settings were brought to the machine prior to every changeover.</li> <li>▪ Specific parts cleaned and loaded next to the machine prior to the machine stopping</li> <li>▪ Operators did not do any cleaning or walk around aimlessly looking for any tools or parts in this time.</li> </ul>			<ul style="list-style-type: none"> <li>▪ Every changeover conducted on line 2 had only prepared, collected and cleaned there spare parts during the changeover. Operators continuously searched for changeover parts and tools.</li> <li>▪ In some cases tools were borrowed and parts only cleaned at the time of installation.</li> <li>▪ Changeover settings had not been provided with work instructions.</li> <li>▪ Operators were expected to know what must be done and the settings for each changeover had been stuck onto the frame of the machine.</li> </ul>		
<b>Stage 2: Convert internal setup to external setup steps</b>			<b>Stage 2: Convert internal setup to external setup steps</b>		
<ul style="list-style-type: none"> <li>▪ Internal changeover tasks on line 1 had not been converted but had been totally eliminated.</li> <li>▪ Eliminating these tasks reduced the amount of labour required and simplified the operations.</li> <li>▪ Operators capable of conducting all the tasks without any assistance from any artisans.</li> </ul>			<ul style="list-style-type: none"> <li>▪ The available information and interaction with operators had indicated that all tasks are still conducted.</li> <li>▪ Operators had indicated that some tasks have been reduced and the changeovers have only improved slightly since the implementation of SMED.</li> <li>▪ Operators had pointed out that this is due to the lack of, communication, training, managerial support and the issues amongst senior and junior management from Line 2.</li> </ul>		
<b>Stage 3: Streamline both internal and external setups</b>			<b>Stage 3: Streamline both internal and external setups</b>		
<ul style="list-style-type: none"> <li>▪ Line 1 has already started with the implementation of stage 3 with the full support and presence of higher management.</li> <li>▪ Waste, machine and material centre-lining, design optimization and the utilisation of jigs, spacers and quick fasteners are a part of line 1's processes. This resulted in quick start-ups with reduced waste, stops, variability and adjustments.</li> </ul>			<ul style="list-style-type: none"> <li>▪ Line 2 has started streamlining its processes with the use of jigs and quick fasteners. The number of stops and the large amounts of waste had been present on all three case study start-ups.</li> </ul>		

Table 5 provides a detailed analysis of the SMED processes across both production lines and a significant difference exists between the two processes. The observations indicate that Line 1 is more efficient than Line 2 and that SMED was implemented effectively with minimal waste. The lean CSFs presented in Table 2 were analyzed in each case to determine whether they had an influence during the implementation of SMED. Some factors were unidentifiable and team members were consulted to determine whether these factors were considered. The comparative presence of CSFs per case study is presented in Table 6.

Table 6. The presence of the CSFs of lean when implementing SMED

Line 1			Line 2		
Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
95%	95%	95%	18%	27%	23%

Table 6 indicates that Line 1 considered CSFs 95% of the time when compared to Line 2. The CSFs that were considered in the implementation of SMED on Line 1 form part of the prerequisites that are required for the successful implementation of SMED; whereas Line 2 considered a smaller number of these factors. Table 7 provides insight to the seven wastes of lean manufacturing which were identified per case study. The types of waste that were easily identified throughout the six changeover processes included defects, rework, motion, waiting and inappropriate processing. These wastes were dominant on Line 2.

Table 7. Analysis on the 7 wastes of lean

7 Wastes of Lean	Line 1			Line 2		
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Overproduction	✓	✓	✓	✓	✓	✓
Inventory	✓	✓	✓	✓	✓	✓
Waiting	✗	✗	✗	✓	✓	✓
Motion	✗	✗	✗	✓	✓	✓
Transportation	✗	✗	✗	✓	✓	✓
Defects / Rework	✓	✓	✓	✓	✓	✓
Inappropriate Processing	✓	✗	✗	✓	✓	✗

### 4.3 Interview Data Analysis

The administration of research questionnaires was utilized to eliminate researcher bias. The questionnaires were completed by the employees who were involved in the implementation of SMED for the improvement of the changeovers across the two production lines. 53% of the respondents on Line 2 indicated that the CSFs were not considered; 31% of the respondents were indecisive; and 16% of the respondents replied that the factors were not considered at all. Furthermore, 57% of the respondents on Line 1 indicated that waste is not an issue on Line 1, whereas 44% and 30% indicated that waste is often and always present on Line 2.

### 4.4 Statistical Data Analysis

The testing of relevant statistical parameters confirmed the robustness of the research methodology as indicated in the analysis below. Interview data was collected, organized and analyzed with SPSS. Cronbach's alpha analysis was employed to determine if the interview data was reliable, and independent samples t-test, and a Mann-Whitney U tests were employed to determine whether a significant difference exists in the consideration of the CSFs and the levels of waste during changeovers on Lines 1 and 2.

Cronbach's alpha analysis was conducted to determine the reliability of the data. Cronbach's alpha coefficient ranges from 0 to 1 and values at 0,7 or above are desirable (Hassan, 2016; Hinkin, 2016; Saneifard, 2016). Questions two and three were analyzed in SPSS using Cronbach's alpha coefficient, and Table 8 provides the Cronbach's alpha coefficient for both the CSFs and the waste. Cronbach's alpha was 0.985 and 0.976 for the CSFs and the waste respectively; indicating reliability of data (Hinkin, 2016).

Table 8. Cronbach's alpha coefficient

	Cronbach's Alpha	Cronbach's Alpha based on standardized items	No of items
CSFs	0.985	0.985	22
Waste	0.976	0.978	7

In order to understand the consideration of the CSFs on each line with reference to the waste levels on each line, the data obtained from Questions 2 and 3 were presented on the scatter graphs as per Figure 5. Question 2 read: *During machine changeover processes, how would you rate the consideration of the following CSFs of lean manufacturing when implementing SMED?* Question 3: *During changeovers, which of the following waste issues were present in your changeover process?* The figure on the left presents the scatter plot for the CSFs vs. Waste on Line 1, and the figure on the right presents the scatter plot for the CSFs vs. Waste on Line 2. On both production lines the responses were grouped into three. Group 1 from Line 1 indicates that the individuals believed that the CSFs were considered and that the waste was low. Group 2 indicated that the CSFs were highly considered with a moderate amount of waste. Group 3 indicated that with higher waste levels there was an increase in the consideration of the CSFs.

Group 1 from Line 2 has a moderately high waste score with a low consideration of the CSFs. The majority of the individuals in Group 2 indicated a high level of waste with a moderate consideration of the CSFs. Group 3 indicated an increase in the consideration of the CSFs; however the waste levels remained high.

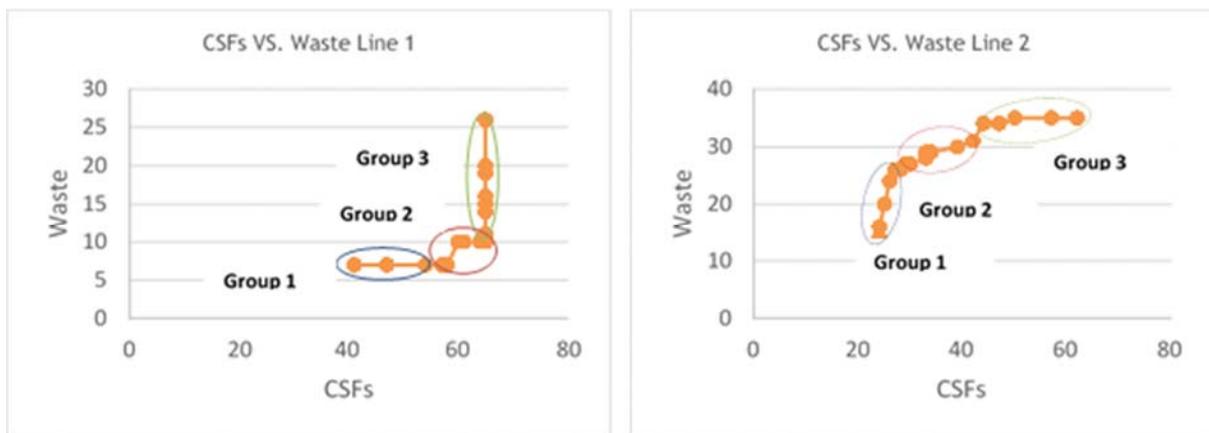


Figure 5. CSFs and waste for lines 1 and 2

An independent sample t-test compares the differences in means of two independent or unrelated groups and it is necessary that these two groups are measured on two sets of variables that have their own scores. One variable is the test variable for one group and the other is the test variable for the second group. This allows the t-test to evaluate if the mean value for the test variable of one group differs from the other (Lazar, Feng and Hochheiser, 2009). SPSS was utilized to conduct Levene's test for equality of variances and the t-test for equality of means (*ibid.*). Where the level of significance is used to test the assumption of homogeneity of variance, and if the level of significance is greater than 0.05 then the assumption is valid. This in turn would determine the level of significance for the t-test which in turn reveals whether there is a significant difference between the two groups (*ibid.*). Independent sample t-tests were conducted to determine whether a significant difference exists between the means of Lines 1 and 2 for the CSFs and the waste. The results are presented in Table 9. The data indicates that the variance between the lines are significant since alpha is less than 0.05 for Levene's test. This in turn reflected an alpha value (0.00) less than 0.05 for the t-test. The scores computed indicated a significant difference exists in the average means reported per line (Lazar *et al.*, 2009). The significant difference in means between Lines 1 and 2 indicates that the CSFs across Line 1 were considered whereas the CSFs on Line 2 were rarely considered. It also indicates a significant difference in the waste. A Mann-Whitney U test was then conducted to compare the means across the lines for the CSFs and the waste.

Table 9. Independent samples t-test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
CSF Score	Equal variances assumed	6.440	.016	8.133	36	.000	25.105	3.086	18.844	31.365
	Equal variances not assumed			8.133	29.377	.000	25.105	3.086	18.795	31.415
Waste Score	Equal variances assumed	.327	.571	-8.44	36	.000	-15.578	1.843	-19.318	-11.839
	Equal variances not assumed			-8.44	35.057	.000	-15.578	1.843	-19.321	-11.836

The Mann-Whitney U test is considered to be the nonparametric alternative to the independent t-test (Pallant, 2007). If the *p*-value is less than 0.05 then the null hypothesis is rejected and the means across the two groups are considered to be different (*ibid.*). Table 10 provides the Mann-Whitney U test for the data that was obtained from Questions 2 and 3 to determine if a difference exists in the means across the two production lines for the CSFs and the waste.

Table 10. Mann Whitney U-Test for CSF and Waste

Test Statistics <sup>a</sup>		
	CSF Score	Waste Score
Mann-Whitney U	16.000	13.500
Wilcoxon W	206.000	203.500
Z	-4.863	-4.891
Asymp. Sig. (2-tailed)	.000	.000
Exact Sig. [2*(1-tailed Sig.)]	.000b	.000b
a. Grouping Variable: Line		
b. Not corrected for ties.		

Table 11 indicates that the mean ranks for the CSF Score for Line 1 (28.16) and Line 2 (10.84) are considerably different with a Mann-Whitney U test value of 16 for which the *p*-value is 0.000 (Pallant, 2007). The *p*-value indicates that the means across Lines 1 and 2 are different and hence the null hypothesis that assumes the means are equal is rejected. The implication is that the CSFs are more likely to be considered on Line 1 than Line 2.

The mean rank for waste for Line 1 (10.71) and Line 2 (28.29) were different and have resulted a Mann-Whitney U test value of 13.5 for which the *p*-value is less than 0.05 (*ibid.*). The means across Lines 1 and 2 are therefore significantly different for the waste. Consequently, the null hypothesis which assumes that the means would typically be equal, is rejected. Therefore Line 2 has higher levels of waste than Line 1, confirming the results from the independent samples t-test for both the CSFs and the waste.

Table 11. Ranks from Mann Whitney U-Test for CSF and Waste

Line	N	Mean Rank (CSF)	Mean Rank (Waste)
Line 1	19	28.16	10.71
Line 2	19	10.84	28.29

## **5. Conclusion**

The research aimed to determine how SMED is implemented in practice when considering the CFSs of lean. It also determined the effect of these factors on waste generated during the changeover process; and the potential savings that could result from considering these factors during the implementation of SMED.

A multiple case study research strategy was implemented in a packaging plant that conducted machine changeovers on two production lines that utilized SMED. The data was obtained through observations, documentation review and interviews; and the data from the interviews was imported and analyzed by SPSS.

The analysis indicated that the critical success factors of lean are practical guidelines for an effective integrated strategy towards the successful implementation of SMED which allows management of waste and cost reduction during changeovers. It also offers organizations the required flexibility to satisfy customer requirements and to move towards the adoption of efficient manufacturing principles and systems. The research could further investigate the importance of the soft issues in the implementation of SMED and/or other lean tools and techniques.

## **References**

- Alaskari, O., Ahmad, M.M., Dhafr, N., and Pinedo-Cuenca, N., Critical Successful Factors (CSFs) for Successful Implementation of Lean Tools and ERP Systems, WCE2012, pp. 1627-1632, 2016.
- Alves, A.S., and Tenera, A. Improving SMED in the Automotive Industry: A case study, in POMS 20th Annual conference. Orlando, Florida, pp. 1–27, 2007.
- Bajpai, J.D., SMED (Single-Minute Exchange of Die) methodology in Garment manufacturing Industry: Case study in reducing Style Change over Time, SMED (single-minute exchange of die) methodology in garment manufacturing industry: Case study in reducing style change over time, 2016.
- Bhasin, S., An appropriate change strategy for lean success, *Management Decision*, vol. 50, no. 3, pp. 439–458, 2012.
- Dave, Y., and Sohani, N., Single Minute Exchange of Dies: Literature Review, *International Journal of lean thinking*, vol. 3, no. 2, pp. 27–37, 2012.
- Dombrowski, U., and Mielke, T., Lean leadership – 15 rules for a sustainable lean implementation, *Procedia CIRP*. Elsevier BV, pp. 565–570, 2012.
- Ferradás, P.G., and Salonitis, K., Improving changeover time: A tailored SMED approach for welding cells, *Procedia CIRP*. Elsevier BV, vol. 7, pp. 598–603, 2012.
- Guo, H., *Head & Base Production Optimization: Setup Time Reduction*. THES, 2009.
- Hassan, G., Factors influencing undergraduate students' motivation to study science, 2016.
- Henry, J., No Title, in *Achieving lean changeover: Putting SMED to work*. Boca Raton: Productivity Press, 2012.
- Hines, P., Found, P., Griffiths, G., and Harrison, R., *Staying Lean, striving not just surviving*. RPRT. Cardiff, 2008.
- Hinkin, T.R., A brief Tutorial on the development of measures for use in survey questionnaires, *Organizational Research Methods*. SAGE Publications, vol. 1, no. 1, pp. 104–121, 2016.
- Joshi, R.R., and Naik, P.R.G., Reduction in Setup Time By SMED A Literature Review, *International Journal of Modern Engineering Research Journal of Modern Engineering Research*, vol. 2, no. 1, pp. 442–444, 2016.
- Kemal, K.M., Cakmakci, M., Cakiroglu, M.B., Ayva, E., and Demirel-Ortabas, N., Improvement of changeover times via Taguchi empowered SMED/case study on injection molding production, *Measurement*. Elsevier BV, vol. 47, pp. 741–748, 2014.
- King, P.L., SMED in the process industries, improved flow through shorter product changeovers, the need to reduce changeovers – SMED and its origins, *IE Magazine*, pp. 1–8, 2009.
- Lazar, J., Feng, J.H., and Hochheiser, H., *Research methods in human-computer interaction*. Chichester, United Kingdom: John Wiley & Sons, 2009.
- Manufacturing Wastes, i. Available at: <http://leanmanufacturing.org/71/muda-mura-and-muri-lean-manufacturingwastes/mura>, 2015. Accessed 12.12.2016.
- Massa, R.F., SMED: SIXTY MINUTE EXCHANGE OF DIAPER. THES, 2010.
- McIntosh, R., Owen, G., Culley, S., and Mileham, T., Changeover improvement: Reinterpreting Shingo's "SMED" methodology, *IEEE Transactions on Engineering Management*, vol. 54, no. 1, pp. 98–111, 2007.
- Mileham, A.R., Cully, S.J., Owen, G.W. and McIntosh, R.I., Rapid changeover a prerequisite for responsive manufacture, *International Journal of Operations & Productions Management*, vol. 19, no 8, pp. 785-796, 1999.
- Palanisamy, S., and Siddiqui, S., Changeover time reduction and productivity improvement by integrating conventional SMED method with implementation of MES for better production planning and control,

- International Journal of Innovative Research in Science, Engineering and Technology (An ISO Certified Organization), vol. 12, no. 2, pp. 7961–7974, 2016.
- Pallant, J., *SPSS survival manual: A step by step guide to data analysis using SPSS for windows (version 15)*. 3rd edn. Australia: Allen & Unwin, 2007.
- Quinlan, C., *Business research methods*, 1st Edition. United Kingdom: Cengage Learning Business Press, 2011.
- Saneifard, R., Exploring factors affecting mobile commerce B2C adoption in Iran, Exploring factors affecting mobile commerce B2C adoption in Iran. THES. Available at: <http://epubl.ltu.se/1653-0187/2009/088/LTU-PB-EX-09088-SE.pdf>, 2016.
- Seebacher, G., and Winkler, H., Evaluating flexibility in discrete manufacturing based on performance and efficiency, *International Journal of Production Economics*. Elsevier BV, vol. 153, pp. 340–351, 2014.
- Sreejesh, S., Mohapatra, S., and Anusree, M.R., *Business research methods*. Springer Science + Business Media, 2014.
- Taylor, D.L., and Brunt, D., *Manufacturing operations and supply chain management: The LEAN approach*. London: Cengage Learning EMEA Higher Education, 2000.
- Tilkar, A.K., Nagaich, R., and Marwah, A.K., Improving Productivity of a Manufacturing Plant using Single Minute Exchange of Die, *International journal of advanced scientific and technical research*, vol. 1, no. 3, pp. 12–19, 2013.
- Trietsch, D., Calhoun: The NPS institutional archive some notes on the application of single minute exchange of die (SMED). RPRT. California USA, 2016.
- Vermaak, T.D., Critical success factors for the implementation of lean thinking in South African manufacturing organisations. THES, 2008.
- What is changeover time? Definition and meaning, *Business dictionary*. BusinessDictionary.com. Available at: <http://www.businessdictionary.com/definition/changeover-time.html>, 2013.
- Yann, K.L., *The Wiley encyclopedia of packaging technology*, *The Wiley Encyclopedia of Packaging Technology*. Wiley, pp. 47–6003, 2009.

## **Biography**

**Rushil Madhav** has an Engineering Management Master Degree and a Bachelor's Degree in Mechanical Engineering from the University of Johannesburg, South Africa. As a result, Rushil has completed research projects with Nampak and Osborn Engineering. He also completed a management graduate development programme with distinction at the Gordon Institute of Business School (University of Pretoria). His interests include lean manufacturing, systems engineering, and project management.

**Dr Annlize Marnewick** is a senior lecturer at the Postgraduate School of Engineering Management, Faculty of Engineering and the Built Environment, University of Johannesburg where she focuses on the supervision of research master's and doctoral students. Before joining the academia she has been involved in the industry with a technical record of 15 years in architecture, design and the implementation of system and software engineering projects with specialisation in requirements engineering. She is a registered professional engineer (Pr Eng) with the Engineering Council of South Africa (ECSA).

**Dr Hannelie Nel** is a Research Associate at the Faculty of Engineering and the Built Environment, University of Johannesburg and a Visiting Associate Professor at North-West University, South Africa. She holds a Doctorate in Engineering Management with twenty years' experience in both industry and academia. Dr Nel is a Fellow of the Southern African Society for Industrial Engineering and currently serves on the Boards of the Society for Engineering Education and the Metal Casting Technology Station of the University of Johannesburg. She is an Associate Member of the Institute of Directors in South Africa; and a Member of the International Women's Association.

**Prof Jan-Harm Pretorius** was a senior consulting engineer at the South African Atomic Energy Corporation, technology manager at the Satellite Applications Centre at the CSIR, and is currently Head of the Post-Graduate School of Engineering Management at the University of Johannesburg. He is involved in measurement and verification of energy saving for Eskom and Nampower. He has authored 120 research papers and supervised over 20 PhD and 120 Master's students.