The Use of Lean Six Sigma Tools in a South African Multinational Organization

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Abstract

The Covid-19 has introduced a new set of challenges in the business environment. Companies are looking for a management philosophy that could help in identifying and remove non-value-adding activities. The paper presents the application of the Lean Six Sigma tools and techniques in the South African logistic company based in Durban. The company has reported the challenge in meeting its business commitment which was further amplified by the Covid-19 regulations which force the companies to operate with the reduced staff levels. The research used secondary data and questionnaires as data collection strategies. According to the findings, the company was unable to meet its availability target of 90 % to 100 %, with an average availability of 84 %, which was 6 % less than the threshold level. The number of defective vehicles ranged from 18 to 65 vehicles with and median of 40 vehicles per day. The company committed to keeping the number of defective vehicles under 10% of the total fleet size, and the results show that the company had an average of 16% defective vehicles, which was higher than 10%. Overall, the company was operating at a 2.45 sigma level with a quality level of 82.51 %, which meant 17.49% of the time was spent on defect repairs. The contribution of the research is the application of LSS to promote and encourage continuous improvement in the South African logistic industry.

Keywords

Continuous Improvement; Lean Six Sigma, Lean Manufacturing, Six Sigma

1. Introduction

The Covid-19 has introduced a new set of challenges in the business environment. Companies are looking for a management philosophy that could help in identifying and remove non-value-adding activities. Bhamu and Sangwan (2014), identify Lean Manufacturing (LM) as a management philosophy that is well recognized globally to deal with business challenges. The focus of LM is to identify waste in the business processes and other non-value-adding activities and remove them (Hussain *et al.*, 2019). Morgan and Brenig-Jones (2012), argued LM has run its course from the 1950s, and during the 1980s the concept of Six Sigma (SS) started to gain momentum as a quality improvement strategy. SS is a data-driven method that focuses on improving quality by identifying the root cause of variation in the processes. Sharma *et al.*(2021), maintain that LM is a knowledge-driven strategy while SS depends on data and statistical analysis. The authors recently discovered that LM and SS are compatible with each other and that using the combination maximizes the benefit (Snee, 2010; Morgan and Brenig-Jones, 2012; Hussain *et al.*, 2019; Bhaskar, 2020). Lean Six Sigma (LSS) which is the combination of LM and SS has established itself as one of the well-known practices in the industry to eliminate waste and deal with process variation (Snee, 2010; Shokri and Li, 2020). Lean six sigma uses a structured methodology call define, measure, analyze, improve and control (DMAIC) to identify defects and improve processes (Garza-Reyes *et al.*, 2016; Bhaskar, 2020). Shokri and Li (2020) maintain that LSS has demonstrated the ability to improve profitability, a safe working environment, effective utilization of resources, and customer satisfaction.

LSS has its origin in the manufacturing sector but over the years the strategy has found its way to different industries (Bhaskar, 2020; Sharma *et al.*, 2021). For example, Abner *et al.*(2020), cited more than ten studies conducted in the financial sector between 2003 and 2019 on the implementation of LSS and its benefits. Some of the advantages of LSS in the financial sector include defect reduction, improved customer satisfaction, increased utilization of human resources, and a better business image. The study of 38 Mexican hospitals (Peimbert-García *et al.*, 2019) and the savings of $ 530 thousand per annum as a result of LSS reported in (MVijaya and Kunnath, 2020) demonstrated a good adoption of LSS in the healthcare environment. Garza-Reyes, Al-Balushi, *et al.*, (2016) reported the case study of the implementation of the LSS project in the ship loading environment in the Pelletising Industry which resulted in a savings of $ 300 thousand per annum. The cited studies provided evidence that LSS is applicable across different industries. However, the authors (Abner *et al*., 2020) reported a disproportion in LSS adoption across continents, with European, Northern, and Southern American countries being among the top LSS practitioners and African countries being among the slow users. The primary goal of this research is to demonstrate the use of LSS as a continuous improvement strategy in a South African logistics company. The study was designed to provide answers to the following questions based on the case study:

a) What are the current performance levels of the South African logistics company?
b) What are the defects rates of the South African logistics company?

2. Lean and Six Sigma

LSS is defined in a variety of ways. For example, Bhamu and Sangwan (2014) define LSS as a management philosophy for reducing cost without adding resources. Others (Albliwi *et al*., 2014) saw LSS as an improvement strategy intended to reduce the cost of poor quality while also increasing customer satisfaction and improving the business image. Timans *et al*.(2012) and Gupta, Modgil and Gunasekaran (2020) maintain that LSS is an operations management model that contributes to the continuous improvement of businesses for both manufacturing and service industries. LSS is a defect reduction, process improvement, and customer focus quality management set of tools and techniques, according to the authors (Al-Aomar, 2012; Antunes, Sousa and Nunes, 2013). LSS benefits from the continuous improvement tools and techniques developed by LM and SS over the years (Immonen, 2016; Saleeshya *et al*., 2017; Bhaskar, 2020). Both strategies have a long history, with LM dating back to the 1900s and SS dating back to the 1920s (Figure 1)(Pepper and Spedding, 2010; Morgan and Brenig-Jones, 2012; Bhaskar, 2020).

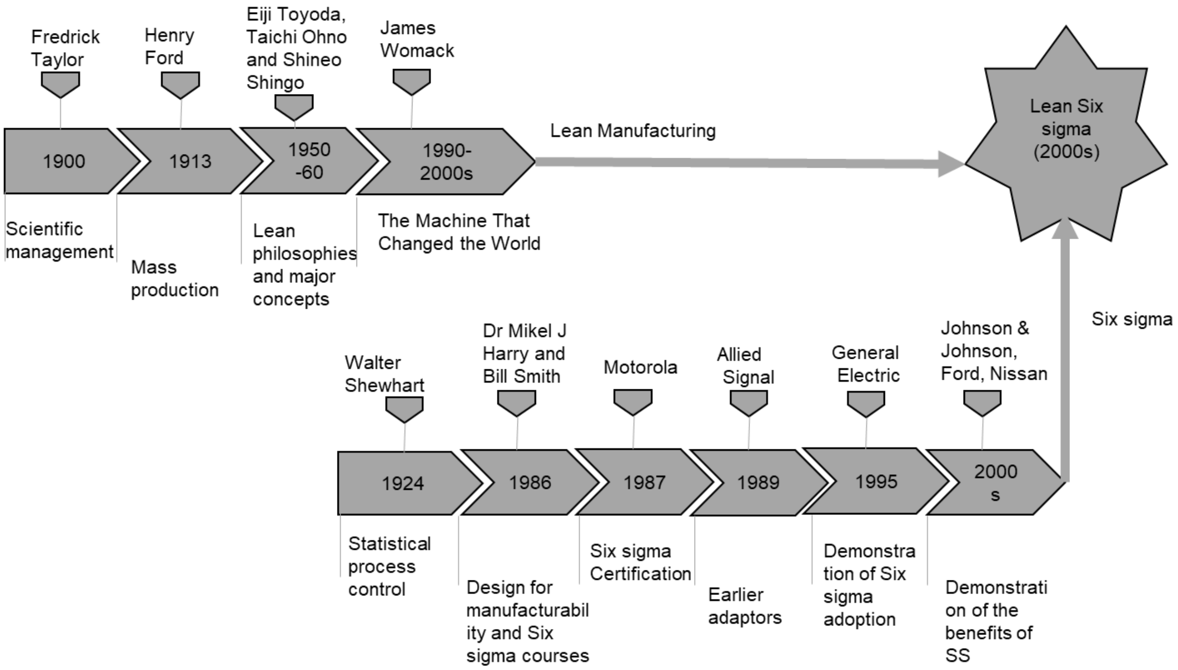


Figure 1. LM and SS Timelines

LM can be traced back to Frederick Taylor's job design, time studies, and collapsing work into manageable packages in the early 1900s and Henry Ford's mass production (Khlat, Harb and Kassem, 2014). Toyota developed the Toyota Production System after the second world war, based on Frederick Taylor and Henry Ford's teachings, to eliminate activities that had no direct contribution to the product or customer needs (Pepper and Spedding, 2010; Resende de Carvalho *et al*., 2017). According to experts, the primary goal of LM is to reduce waste and produce only when requested by the customer (Bhamu and Sangwan, 2014; Resende de Carvalho *et al*., 2017). Six Sigma can be traced back to the work of Walter Shewhart, who created process control charts as a tool for managing process performance and identifying special causes affecting process performance (Pepper and Spedding, 2010; Carnerud, 2018). According to Albliwi, Antony, *et al*. (2014)'s comprehensive literature review, LSS is a new concept, with the first academic paper on the subject appearing in the 2000s. LSS employs several matrices to reduce defects to 3.4 defects per million opportunities (Al-Aomar, 2012; Antunes, Sousa and Nunes, 2013; Antony, Vinodh and Gijo, 2016, pp. 53–74). The sigma levels are inversely proportional to defects per million opportunities (DPMO), cost of quality (COQ), and directly proportional to quality levels (Table 1) (Antony, Vinodh and Gijo, 2016, p. 63).

Table 1. Quality levels and LSS levels (Morgan and Brenig-Jones, 2012; Antony, Vinodh and Gijo, 2016, p. 63)

Sigma	**DPMO**	**Quality level**	**COQ (% of sales)**	**Category**
1	690 000	30,85%	Over >40%	Non-competitive
2	309 000	69,00%		
3	67 000	93,30%	25–40%	Industry average
4	6 200	99,40%	15–25%	
5	230	99,98%	5–10%	
6	3.4	100,00%	0–5	World class

2.1 Define, Measure, Analyse, Improve and Control (DMAIC)

LSS employs the DMAIC framework to address complex issues in existing processes (Table 2.)(Antony, Vinodh and Gijo, 2016). DMAIC's five phases assist LSS practitioners in defining problems in detail, accurately estimating the magnitude of problems and root causes using specific tools and techniques (Timans *et al.*, 2012; Salman Taghizadegan, 2013). DMAIC is a simple framework to understand and apply, making it a good fit for the current study, and this paper report on the define and measure phase of the model.

Table 2. DMAIC Phases (Salman Taghizadegan, 2013, pp. 9–34; Antony, Vinodh and Gijo, 2016)

LSS Phase	**1. Define**	**2. Measure**	**3. Analyse**	**4. Improve**	**5. Control**
Objectives	• Identifying business requirements • Identifying critical to quality • Defining customer requirements	• Establish key process inputs/outputs • Identify the critical few with the greatest impact • Collect and analyze data • Estimate process capability	• Determine causal relationships. • Conduct multivariate analysis • Identify variance components • Evaluate correlation	• Create and evaluate solutions; • Reduce variation; • Standardize processes; and • Assess risk factors.	• Implement process control; • Create control charts for key variables; • Implement error-proofing procedures; and • Evaluate results regularly.
Tools and Techniques	• Interrelation diagram • Quality Function deployment • SIPOC process map • Project charter • Gant charts	• Data collection plan • Check/datasheet • Pareto chart • Gage R&R • Voice of process • Histogram/process capability	• Cause and effect • Multivariable chart • Scatter diagram • Statistical tools • Regression analysis	• Experimental method • Deployment flow chart • Tree diagram • Failure mode effect analysis	• Process control plan • Control chart • Poka-Yoke • Pareto chart (ongoing) • Process capability (ongoing)

3. Research Design

This is an exploratory study based on a case study of a logistics company in Durban, KwaZulu Natal, South Africa. The case study company uses a total of 259 vehicles to transport containers and automobiles for both export and domestic customers. The company's headquarters are in Durban, and it has service depots in Pretoria, Johannesburg, Kimberly, Kroonstad, Newcastle, Daveyton, Mpumalanga, and Pyramid South. The key performance indicators for the company were availability (total fleet size divided by the number of assets available for service) and a number of defects per vehicle in the maintenance and asset turnaround time from maintenance depots. The company employed a time-based maintenance strategy, and the depots were given an annual maintenance demand that included scheduled maintenance as well as a percentage of unplanned maintenance activities based on previous experience. The company has reported the challenge in meeting its business commitment which was further amplified by the Covid-19 regulations which force the companies to operate with the reduced staff levels. This paper report on the performance trends, the gap between the desired performance and current performance and defect rates. Figure 2 shows the focus areas for this research to identify the current business performance using lean six sigma tools.

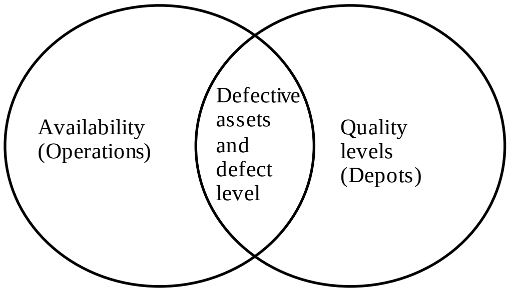


Figure 2. Study Focus Areas

4. Lean Six Sigma Implementation

This paper is part of the ongoing research in the implementation of LSS based on the DMAIC model in the South African logistic company. The paper report on the define and measure phase of the DMAIC model.

4.1 Define Phase

The primary goal of this phase was to justify the project by developing a business case (Table 2), as well as to develop teams, expectations, critical to quality, and management support (Salman Taghizadegan, 2013; Antony, Vinodh and Gijo, 2016).

Table 2. Business Case

Business Case	**Statement of Opportunities**
The logistics firm is having difficulty meeting its business commitments to its stakeholders. Due to the vehicles' availability for operations, the company has reported volume losses of 5 million tons per quarter during the 2020/2021 fiscal year. Fleet availability, which is currently below acceptable levels, is one of the performance indicators used to assess the company's ability to respond to business demand.	1. Reduce the number of the defective vehicle below 10%, 2. Maintain the availability target of 90 to 100 percent, 3. Reduce defect per unit to zero across all maintenance depot.
	Defect definition
	The total number of defective vehicles reduces the number of vehicles available for operations.
Goal statement	**Project Scope**
Determine the performance gap and the factors influencing fleet performance that is causing poor availability.	Project start time: 2021/02/1
	Project end time: 2022/03/31
Expected benefit or Saving	**In scope**
1. Decrease the number of vehicles that are out of service. 2. Identify the magnitude of the hidden factory and the current defect rate. 3. Identify the performance gap.	1. Fleet availability 2. Quality levels of the depots
	Out of Scope
	1. Quality-related costs associated with the depot's quality levels 2. Other businesses that assist the logistics firm

Given the company's difficulties in meeting its business commitments, one of the driving forces behind this research was to identify the gap between the required performance levels and current performance. To meet customer demand, the company has committed with its stakeholders to meet daily availability targets of 90 to 100% of its fleet. The company's performance goal is to keep defective vehicles to less than 10% of the total fleet and to reduce the defect per vehicle after maintenance to zero (depot performance).

The defined phase also included the development of the project plan, the identification of stakeholders and stakeholder analysis, roles and responsibilities, and the development of a high-level risk plan. Table 3 depicts the suppliers, inputs, processes, outputs, and customers (SIPOC) model, which was developed to gain a more in-depth understanding of the processes. The SIPOC model was created through a series of four brainstorming sessions (2021-02-25; 2021-03-04, 2021-03-17, and 2021-03-23) with 15 engineers and managers from the case study company, and Microsoft teams was a platform for meetings.

Table 3. SIPOC

Suppliers	**Inputs**	**Processes**	**Outputs**	**Customers**
Sales and marketing	Business demand	Budgeting	Detail financial budget for each maintenance type and the assets required to meet the business demand for the year	Fleet managers
Equipment manufacturers and Research and development	Engineering maintenance plan	Scoping	Scope of work for each maintenance type, bill of materials, and suppliers	Depot managers
Depot managers	Demands (weekly)	Procurements (Material and services)	List of approved suppliers and delivery plans	Procurement offices
Fleet managers and Depot managers	Maintenance schedules and asset conditions	Maintenance activities	The total number of asset maintained, defects, and defectives assets	Quality, Technical support, and fleet manager
Technical Support	Vehicle preparations checklist	Quality Assurance	The condition of the asset before hand over to operations	Quality, Fleet, and operations manager

4.2 Measure Phase

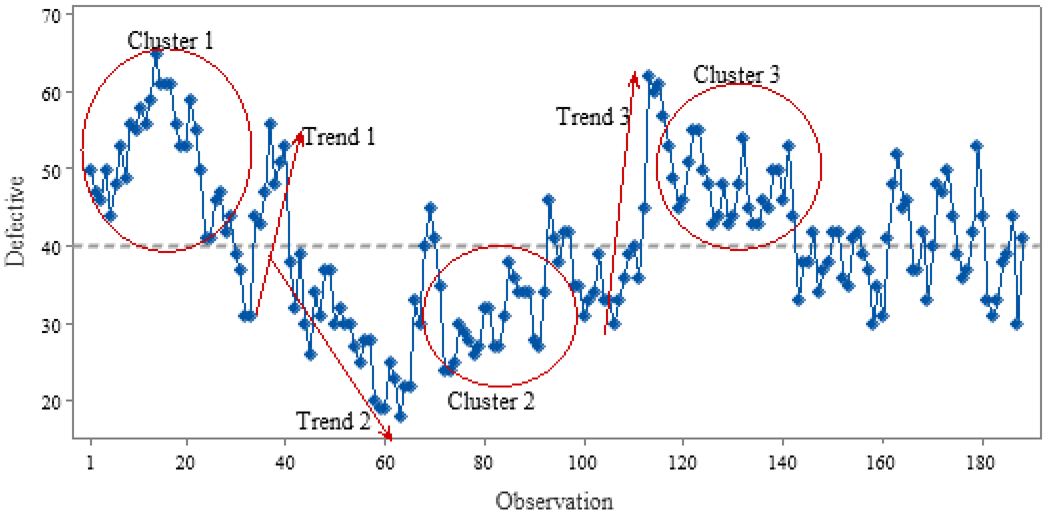
The measure phase's goal was to collect data that would provide current performance levels, as well as to collaborate with process owners identified during stakeholder identification to develop a data collection plan. The SIPOC was used as an input in the process of creating the data collection plan, which included the process for collecting data, determine the type of data (discrete or continuous) required to answer the research questions, sample size, who collect data, how data was to be collected, and when data were to be collected. At this point, the data gathered was limited to fleet availability, the number of defective assets, the number of vehicles released from the depot without requiring any rework, and the number of defects per unit. The measure phase also included the reliability and validity checks of the data. Typically, practitioners use gauge repeatability and reproducibility (GR&R) or measurement analysis as a method to ensure data reliability and validity (Morgan and Brenig-Jones, 2012; Salman Taghizadegan, 2013; Antony, Vinodh and Gijo, 2016). GR&R studies were not possible in this study due to Covid-19 restrictions. As a method of validating the results, the research used triangulation of secondary data from processes and questionnaires from engineering staff and managers in the case study company. The subsequence section presents both the secondary and primary study results.

5. Results and Discussion

Figure 3 depicts the run chart of the defective units from 14 August 2020 to 01 April 2021. Throughout the observation period, the company experienced a fluctuating number of defective assets (Figure 3). The results show that the fluctuation was caused by special causes associated with failing processes (p-value clustering = 0.000) (Gauri, 2010). The clustering indicated by the cycle in Figure 3 is a sign of failing processes. The other special cause identified from the results is related to changes in the processes (p-value for trend = 0.000), which is also demonstrated by arrows. The results also show that the company had an average of 40 defective vehicles per day, with the number of defective vehicles ranging from 18 to 65 vehicles.

5.1 Process Capability

Binomial process capability analysis was used in this study to evaluate business performance based on the number of defective vehicles (Figure 4). The P-chart depicts the statistical process control of the number of defective vehicles, while the histogram depicts the difference between the expected and actual performance. The P-chart revealed two issues with business performance: 16 observations were found to be more than three standard deviations from the centerline. The second problem is the number of observations in a row that are on the same side of the centerline. Nine observations on the same side of the centerline indicate the existence of a special cause, and 84 observations were found to be on the same side of the mean in this study.



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Number of runs about median:        29   Number of runs up or down:          96
Expected number of runs:           95,0  Expected number of runs:          125,0
Longest run about median:           31   Longest run up or down:              6
Approx P-Value for Clustering:   0,000   Approx P-Value for Trends:       0,000
Approx P-Value for Mixtures:     1,000   Approx P-Value for Oscillation:  1,000
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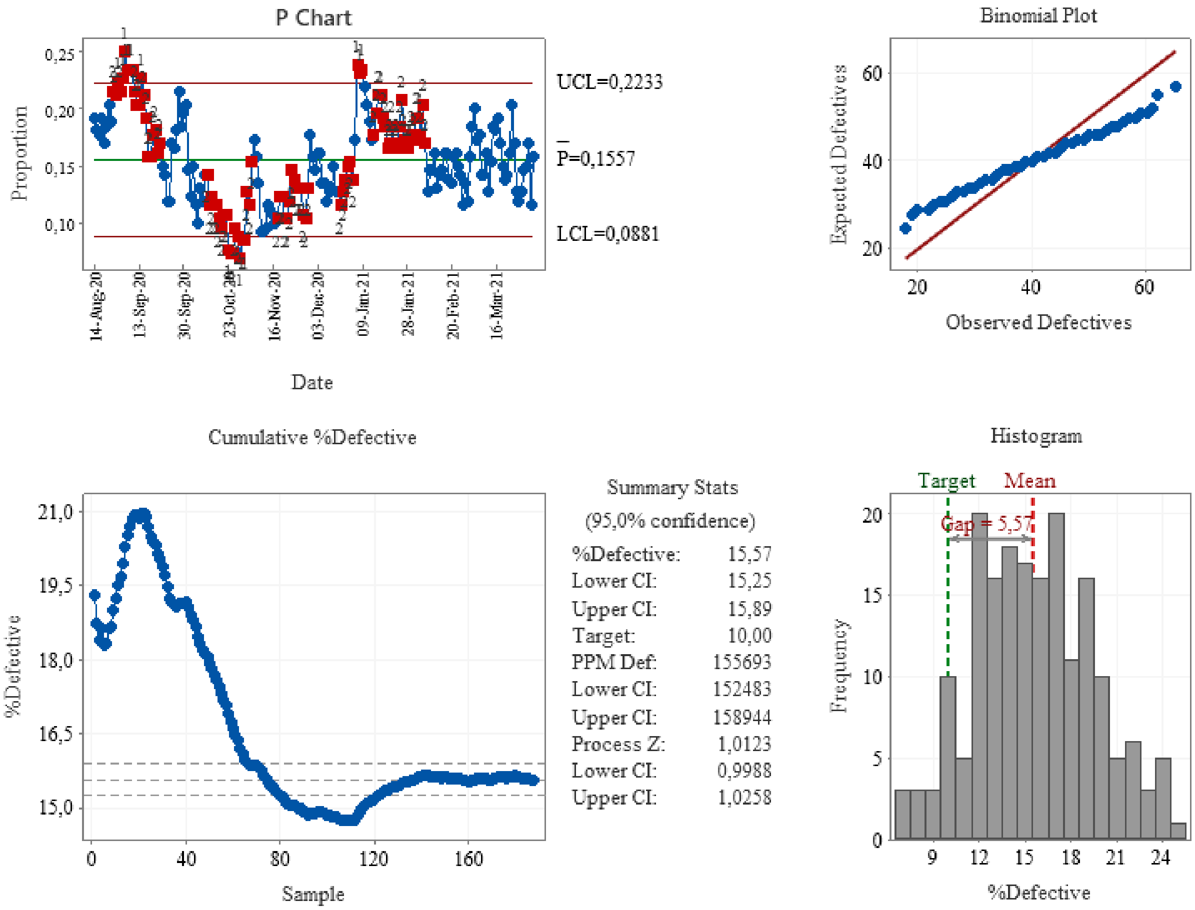
Figure 3. Defective Trends

The P-chart also shows that the number of defective vehicles has a lower control limit of (LCL) 8.8% and upper control limit (UCL) of 22.33%, with an average of 15.57 % (16%) (Figure 4). Based on the average number of defective vehicles, we concluded that the company had an average availability of 84 % and that the observed defective vehicles were not within statistical process control 100 (53.2 %) subgroups were out of control. The findings indicate that the number of defective vehicles was caused by factors other than normal business processes. The average number of defective vehicles (15.57%) was higher than the maximum threshold of 10%, indicating a 5.57% (6%) performance gap with the DPMO=155651. Based on the DPMO number and interpolation, the company was found to be operating at a 2.45 sigma level with a quality level of 82.51%, and we also concluded that the company's cost of quality was greater than 40% of sales (Table 1).

5.2 Depots Performance

This section shows the number of defects per unit from 2020-January-01 to 2021-April-01, as determined from depot quality control documents. In Figure 5, 29 observations (1; 2; 6; 7; 8; 9; 10; 11; 12; 26; 27; 28; 29; 30; 31; 32; 38;52;53;54;55;56; 57; 58; 59; 60; 61; 62; 63) were more than three standard deviations from the mean (Test 1). Test 2 (nine points in a row on the same side of the centerline) failed at the following points: 9;10; 11; 12; 34; 35; 58; 59;60;61;62; 63. The observations that failed tests 1 and 2 were excluded from the final calculation. The final test results show that the defect per unit has a lower control limit (LCL) of zero, an upper control limit (UCL) of 4.93, and an average of 1.39 defects per unit. The result shows that the average number of defects per unit was greater than zero defects per unit as expected by the case study company.



Summary Stats
(95,0% confidence)

%Defective:	15,57
Lower CI:	15,25
Upper CI:	15,89
Target:	10,00
PPM Def:	155693
Lower CI:	152483
Upper CI:	158944
Process Z:	1,0123
Lower CI:	0,9988
Upper CI:	1,0258

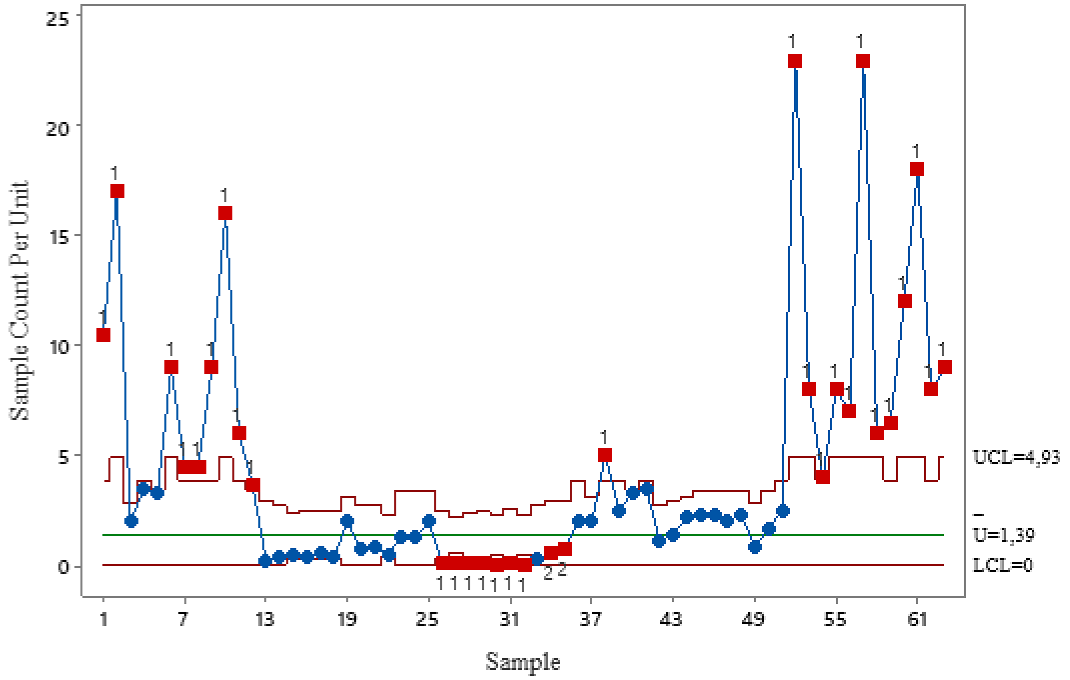
Figure 4. Binomial Process Capability

5.3 Questionnaire Results

The questionnaire was given to a total of 85 engineering employees at the case study company. The global email address of the case study company was used as a sample frame, and the questionnaire received 47 responses. The questionnaire was divided into four sections: the first section covered demographic information, the second section covered the use of standard operating procedures, the third section covered the management of uncontrollable factors, and the last section covered controllable factors.

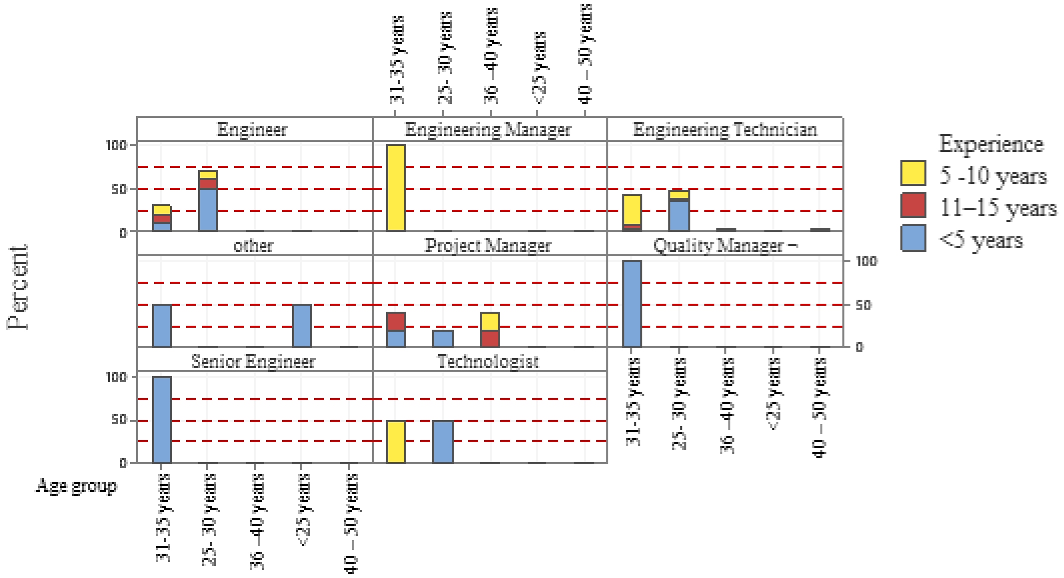
5.4 Demographic Information

Respondents were asked to provide their experience, position, and age group in this section. The majority (50%) of respondents were engineering technicians between the ages of 25 and 30 (48%); the other larger group (35%) of engineering technicians was between the ages of 31 and 35 years old. Engineers made up 22% of all respondents, with the majority (70%) being between the ages of 25 and 30 years old and having less than 5 years of experience (50 percent). The project managers with experience ranging from less than 5 years to 15 years made up the other larger group (11 percent) of total respondents. This study benefited from the different engineering employee groups with different experience levels.



Tests are performed with unequal sample sizes.

Figure 5. Statistical Process Control defect per unit



Panel variable: Position
Percent is calculated within all data.

Figure 6. Demographic Information

5.5 Numerical Results

The respondents were asked to rate the statement in Table 4 on a scale of 1 (strongly disagree) to 5 (strongly agree), and the validity and reliability were assessed using factor analysis and Cronbach's Alpha. Six items were used to assess the use of standard operating procedures (SOP), and all of them had high factor loadings greater than 0.6 and a

Cronbach's Alpha of 0.92. Uncontrollable and controllable factors were assessed using five items each, with factor loadings greater than 0.6 and Cronbach's Alpha of 0.89 and 0.85, respectively. The findings show that the scale was both valid and reliable (Awang, 2014; Essmui *et al.*, 2014). The findings revealed that the company placed a high priority on controllable factors (M=3.49) and the use of SOP (M=3.43); the management of uncontrollable factors (M=3.29) was identified as an area that needs improvement.

Table 4. Descriptive Statistics

Variable	**SOP (F1)**	**Uncontrollable factors (F2)**	**Controllable factor (F3)**	**Communality**
Q1. We have measurement systems standard operating procedures (SOP)	0,85			0,74
Q2. The SOPs are up to date or in line with the current standards	0,84			0,80
Q3. The SOPs are being followed	0,83			0,82
Q4. The SOPs are understood	0,82			0,73
Q5. There is an operator certification performed	0,77			0,73
Q6. There are regular audits for measurement systems	0,72			0,74
Q7. We know what are the noise factors in the measurement systems		0,88		0,81
Q8. We have the procedure to manage the noise factors		0,82		0,79
Q9. Operators are in a position to compensate for noise factors		0,79		0,68
Q10. Measurement systems are robust enough for noise factors		0,70		0,68
Q11. It is practical to control for noise factors		0,69		0,67
Q12. There is a process to monitor controllable factors			0,63	0,49
Q13. There is a policy guiding the frequency of verification of controllable factors			0,82	0,77
Q14. Controllable factors are recorded regularly			0,67	0,45
Q15. Optimum target values for controllable factors are known			0,82	0,70
Q16. The variation around the target is known			0,87	0,81
Variance	4,22	3,69	3,50	11,40
% Variance	26%	23%	22%	71%
Cronbach's Alpha	0,92	0,89	0,85	
Mean (M)	3,43	3,29	3,49	

5.6 Proposed Improvements

According to empirical data, the organization was unable to meet the targeted business performance with a performance gap of 6%, an average defective asset of 16% higher than the threshold of 10%, a quality level of 82.51 percent, and an overall sigma level of 2.45. The company was not competitive in its current state, and the results show that the majority of the observed variables were influenced by factors outside the normal business processes. For example, the number of defective assets was discovered to be outside of the statistical control process, similar to the number of defects per unit, indicating a special cause in the business processes. Based on the findings, we concluded that the case study company's business performance was influenced by a complex network of interconnected factors, making LSS an ideal methodology for business process improvement. Future research should create a conceptual model of the factors influencing business performance based on the literature and the personal experiences of local experts, and then test the model with empirical data. The senior management team should also advocate for LSS implementation, provide LSS training to all employees, and invest in change management. All enhancements should strive to reduce the number of defective assets and defects per unit from 1.39 to zero.

5.7 Validation

This research validated the theory that LSS tools and techniques can be used in a variety of industries (Antunes, Sousa and Nunes, 2013; Peimbert-García *et al.*, 2019). In addition to the research's theoretical contribution, this study used multiple data collection methods, statistical analysis tools, and triangulation to improve the study's rigor. The researchers collaborated with local experts in developing the SIPOC model, developing the data collection plan, and obtaining operational records. This collaboration allowed the research team to better understand the business processes while also ensuring that the data was a true reflection of the business performance. To improve the study's objectivity, the research team used a questionnaire that focused on the use of standard operating procedures, the management of uncontrollable factors, and the management of controllable factors over and above the secondary data. Factor analysis and Cronbach's Alpha allowed us to validate the validity and reliability of the questionnaire. The included items were highly correlated with their respective factor and the Cronbach's Alphas were greater than the threshold of 0.7.

The study confirms that the organization was unable to meet its business commitment. The secondary data analysis demonstrated both the number of defective assets and the number of defect per unit were out of statistical process control which shows that the business performance was affected by special causes or factors outside the normal business processes. The secondary data findings were confirmed by primary data, demonstrating that the company was unable to effectively manage uncontrollable factors. We confirm that the research had both reliability and validity based on the audit trail used to collect data, the process of ensuring the reliability of the questionnaire, and the similarities between different data sources.

6. Conclusion

According to the findings, the company was unable to meet its availability target of 90 percent to 100 percent during the period of observations, with an average availability of 84 percent, which was 6 percent less than the threshold level. The number of defective vehicles ranged from 18 to 65 vehicles with and median of 40 vehicles per day. The company committed to keeping the number of defective vehicles under 10% of the total fleet size, and the results show that the company had an average of 16% defective vehicles, which was higher than 10%. Overall, the company was operating at a 2.45 sigma level with a quality level of 82.51 %, which meant 17.49% of the time was spent on defect repairs (Morgan and Brenig-Jones, 2012; Antony, Vinodh and Gijo, 2016). According to quality control documents, the depots had an average of 1.39 defects per unit, which was higher than the organization's target of zero defects. The analysis shows that special causes had an impact on company performance, which was confirmed by questionnaire results, which indicated that the company needed to improve its approach to managing uncontrollable factors. The results show that the factors influencing business performance are complex, making LSS an excellent quality improvement strategy for improving business performance. Future research should create a conceptual model of the factors influencing business performance based on the literature and the personal experiences of local experts, and then test the model with empirical data.

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