The Seybold REPORT

ISSN 1533-9211

DOI 10.17605/OSF.IO/MRPGE

STANDARDISATION OF QUALITY TESTING AND INSPECTION TOOLS FOR PRODUCT QUALITY IMPROVEMENT IN A SELECTED AUTOMOTIVE ASSEMBLY ORGANISATION IN SOUTH AFRICA

ROBERT WALTER DUMISANI ZONDO

Associate Professor, Durban University of Technology (DUT), Faculty of Management Sciences, Department of Entrepreneurial Studies and Management, Durban. E-Mail: dumsaniz@dut.ac.za, ORCID ID: http://orcid.org/0000-0003-0214-860X

Abstract

South Africa's quality system in the automotive sector has developed a number of methods, tools and solutions to improve quality processes. The statistically analysed data, obtained from quality tests and inspections, is one of them. Thus, the product quality testing and inspection tools play a significant role in the control of variation in the production process. A good quality system cannot function without adequate quality testing and inspection tools. It has been established that the automotive sector has an abundance of such tools in their production processes, and it is necessary that they are standardised for optimum quality results. Therefore, this study examines the effects of standardising quality testing and inspection tools for product quality improvement in a selected automotive assembly organisation in South Africa. The study was quantitative in design and examined production and related experiences of the automotive assembly organisation that has standardised its quality inspection tools for product quality improvement. The Ordinary Least Squares (OLS) model, using Statistical Package for Social Sciences (SPSS) was used to analyse data. The company operates in the eThekwini Municipality in KwaZulu-Natal. The study was achieved by collecting pre- and post-quarterly data for spoilage, cost of quality inspection and the external product failure as well as product quality. The results establish that the standardisation of quality testing and inspection tools does not improve product quality in the automotive assembly organisation in South Africa. However, the cost of quality testing and inspection has a relation to product quality resulting from the standardisation of quality testing and inspection tools. This study uncovers the strengths and weaknesses of standardising quality testing and inspection tools for product quality in an automotive assembly organisation in South Africa.

Keywords: automotive assembly organisation, cost of quality, product quality, quality testing and inspection tools, standardisation, South Africa.

INTRODUCTION

In the never-ending quest for improvement in the way processes are operated, numbers and information form the basis for understanding, decision making and actions (Oakland, 1997). Through data gathering using appropriate quality tools, the recording and presentation of information is of the utmost importance for product quality improvement (Lebednik, 2012). Such data gathering describes the significance of quality testing and inspection tools in the production process.

Historically, manual gauges have been used as the main tools in metrology, from go and no-go hard gauges (such as a simple pin with a given diameter to determine fit), to numerical manual callipers aimed at taking measurements from point-to-point (Marks, 2005). These hard gauges come in different sizes for different applications, including measuring small turbine blades, car

The Seybold REPORT
ISSN 1533-9211
DOI 10.17605/OSF.IO/MRPGE

doors and airplane doors. The process includes the use of reference geometry to position the part to be measured, and then using pass or fail hardware (pins, contact pins, etc.) to measure key characteristics. While easy to use, the hard gauges are not flexible enough to accommodate design changes and generally provide only qualitative (pass or fail) rather than quantitative information (that is, the numerical values) (Fu, 2006). As a consequence of the inflexibility of the testing tools, coordinate measurement machines (CMMs) have, over the past 30 years, been introduced (Marks, 2005). They are currently used to take measurements in the manufacturing industry. A CMM is a programmable 3-4 axis machine that, through the contact of a touch probe, follows a path to inspect a part at predefined points. As a requisite for accuracy, repeatability, automation and flexibility, CMMs are used to measure small as well as large parts (Lebednik, 2012). However, they are quite expensive and economically unsustainable (Marks, 2005). This has resulted in the sourcing of numerous types of quality testing and inspection tools for the improvement of quality (Wohlers, 2006). Hence, this study investigates the effects of standardising quality testing and inspection tools on product quality improvements in an automotive assembly organisation in South Africa.

Most industries use the automated quality testing and inspection tools (Putri & Yusof, 2009). These practices are part of the total quality management (TQM) approach to design, manufacture and assembly within the quality context. Quality means fitness for use, and the inspection systems are deployed to assure the pre-programmed level of "fitness for use" (Evans and Milligan, 2013). Inspection, as part of the feedback control loop of the overall TQM process, involves the continual satisfaction of customer requirements at the lowest cost by harnessing the efforts of everybody in the company (AIAG, 2013). Quality assurance means sustaining a system that prevents defects. This includes quality control and quality engineering (Evans & Milligan, 2013). Quality control also means establishing and maintaining specified quality standards of products. Hence, quality engineering is the establishment and execution of tests to measure product quality and adherence to acceptance criteria (Lebednik, 2012). As often defined, "quality is the overall level of product, process and service excellence" (PWC, 2013). Without similarly "excellent people, quality testing and inspection tools, as well as necessary software", one cannot provide the desired level of quality at the pre-programmed cost. However, there are many methods and solutions to improve any process, and stay within the established control limits. The quality testing and inspection tools represent the important quality improvement methods that lead to process improvement as the ultimate goal of TQM (Bagshaw & Newman, 2002; Chang & Jiang, 2002; Derganc, Likar & Pernus, 2003; Ranky, 2003). Thus, this study assesses the effects of standardising the numerous tools used by the automotive sector on product quality. It is guided by the following research questions (RQs):

- **RQ1:** Is there a significant effect of standardising the quality testing and inspection tools on product quality in an automotive assembly organisation in South Africa?
- **RQ2:** Do standardised quality testing and inspection tools influence the cost of quality in an automotive assembly organisation in South Africa?

The automotive assembly organisations in South Africa use a number of quality testing and inspection tools on their quest for quality. These include (amongst others) the Product Part

ISSN 1533-9211

DOI 10.17605/OSF.IO/MRPGE

Approval Process, Statistical Process Control (SPC), Advanced Product Quality Planning, Measurement System Analysis, Failure Mode Effect Analysis (FMEA) and numerous Quality Engineering Tools (Lebednik, 2012). Such tools are either used by Quality Inspectors whilst others the non-inspectors. A number of such tools are used to evaluate (amongst others) the materials and spares, supplier monitoring, on-site performance tests, testing of material as well as internal tests (Krishnamoorthi & Krishnamoorthi, 2011). Hence, this study draws attention to the need to standardise quality testing and inspection tools for product quality improvement in the automotive sectors of South Africa.

The rest of the paper discusses the literature that was reviewed in this study, the methodology employed, study results, as well as the discussion of results. In addition, it deliberates on the implications of results for policy and practice, study limitations, conclusion, as well as future research required.

LITERATURE REVIEW

This section presents the overview of quality testing tools, as well as the effects of quality inspection and testing tools for spoilage and variability reduction. The influence of quality testing and inspection on quality costs concludes the theoretical framework of the study.

Overview of quality testing tools

When Leonardo da Vinci designed his advanced machines, there was no concept of manufacturing tolerances or quality inspection measurements (Bahrami, Bazzaz & Sajjadic, 2012). In the nineteenth century the approach was no different from that of Leonardo's time: "cut and try, file and fit." At the turn of last century, the concept of "Plus and Minus" tolerances was developed and around 1920, the "Taylor Principle" that defined the functional requirement for assembly was introduced (Krishnamoorthi & Krishnamoorthi, 2011). During World War II, development commenced on geometrical dimensioning and tolerancing (GD&T) and soon thereafter, in 1957, evolved to prominence in the present day (Lebednik, 2012).

Nonetheless, the automotive sector has remained the fast growing and competitive industry in the world (Holweg, Davies, Podpolny & James, 2009; PWC, 2013). In order to sustain its growth, it needs to gain competitive advantage and become customer-focused using the quality testing tools in the best possible way to gain sustainable competitive advantage. The quality testing tools that are used during and after production lead to the creation of error-free products by saving costs and meeting customers' expectations (Juran & Godfrey, 1998). The proper implementation of quality tools help in building brand loyalty of the product along with helping in the retention of sales (Putri & Yusof, 2009). This, in turn, helps in creating a positive impact on the sales and profits of the organisation and improving the overall image of the company.

The effects of quality testing and inspection tools for spoilage and variability reduction

The objective of a continuous quality improvement programme is to reduce the variation of key products performance characteristics about their target values (Oakload, 1997 in Evans and Milligan, 2013). The widespread practice of setting specifications in terms of simple upper

The Seybold Report
ISSN 1533-9211
DOI 10.17605/OSF.IO/MRPGE

and lower limits conveys the wrong idea that the customer is satisfied with all values inside the specification band, but suddenly not satisfied when a value slips outside one of the limits. Oakland (1997) adds that the practice of stating specifications as tolerance intervals only can lead manufacturers to produce and dispatch goods whose parameters are just inside the specification band. Owing to the interdependence of many parameters of component parts and assemblies, this is likely to lead to quality problems. The target value should be stated and specified as the ideal, with known variability about the mean. This requires the effective use of standardised quality testing and inspection tools (Lebednik, 2012). However, for those performance characteristics that cannot be measured on a continuous scale, the next best thing is an ordered categorical scale such as excellent, very good, good, fair, unsatisfactory, very poor, rather than the binary classification of 'good' or 'bad' that provides meagre information with which the variation reduction process can operate (Lebednik, 2012).

According to AIAG (2013) the core quality measurement tools in the automotive industry include the Production Part Approval Process (PPAP), Statistical Process Control (SPC), Advanced Product Quality Planning (APQP), and Measurement Systems Analysis (MSA). Quality Engineering (QE) tools are essential tools that are effective cornerstones helping in continuous improvements in any automobile company (Putri & Yusof, 2009). Thus, the quality engineering has been defined as a set of engineering operations and managerial activities used by companies to ensure that quality characterised products are produced at the nominal levels (Montgomery, 2005). However, the manufacturing and service sectors of the automotive industry use various and numerous statistical tools, as well as methods for improvement of quality and quantification of its products (Komashie, Mousavi & Gore, 2007). This includes the Failure Mode Effect Analysis (FMEA). Specifically, this technique was initially developed in the aerospace industry in the early 1960s as a method of risk and reliability analysis (Bahrami et al., 2012). It is an analytical and systematic quality planning tool for identifying possible failure in the product service, process design, and assembly stages, thereby diagnosing the fault or cause (Evans & Milligan, 2013). In general, FMEA is a technique applied in the automotive manufacturing industry to produce several components and improve system performance by identifying potential failures through preliminary analysis (Scipioni, Saccarola, Centazzo & Francesca, 2002). During the application of this technique, several components are examined and each must be reviewed to detect possible failures (Bahrami et al., 2012). Failure probabilities, severity of failure, and the detection of failure before occurring are the measures considered in FMEA (Bahrami et al., 2012).

In addition, the American Automobile Engineering Association combined, synchronously, the engineering with FMEA in the early 1990s in order to improve automobile quality (Evans & Milligan, 2013). Within the same period, Ford and two other automotive companies (that is, General Motors and Chrysler) came together and published an FMEA handbook to address supplier issues (Deng, Chiu & Tsai, 2007). They indicate that FMEA reduces customer complaints, performance related deficiencies and defects during production (Evans & Milligan, 2013). Considering the growing number of quality testing and inspection tools in the automotive industry, this study examines the effect of standardising such tools for spoilage reduction in the automotive organisation in South Africa.

The Seybold Report
ISSN 1533-9211
DOI 10.17605/OSF.IO/MRPGE

The influence of quality testing and inspection on quality costs

Quality costs have traditionally been categorised as prevention, appraisal or failure-related (Krishnamoorthi & Krishnamoorthi, 2011) with the prevention costs associated with planning, training and experimenting in order to prevent defects before they occur (AIAG, 2013). However, the appraisal costs are associated with either receiving inspection, in-process inspection, or final inspection. The losses associated with the production of a nonconforming product are failure costs (Krishnamoorthi & Krishnamoorthi, 2011). Such failures may be detected during the process through inspection or once the customer has purchased the product. Prevention, appraisal, and failure-related costs are operatively related to conformance. This paper focuses on the appraisal costs since they are related to product testing. The appraisal costs are associated with the direct costs of measuring quality and include laboratory acceptance testing; inspection and tests by inspectors; inspection and tests by non-inspectors; set-up for inspection and test; inspection and test materials; product quality audits; review of test and inspection data; on-site performance tests; internal test; evaluation of materials and spares; supplier monitoring; ISO 9000 qualification activities; and Baldrige Award assessments (Evans & Milligan, 2013). These costs have undergone a fundamental change as US companies have accepted Japanese management practices (Lebednik, 2012). For instance, such costs were traditionally easily accessible to assess as appraisal was performed by a centralised quality control function. The in-process inspection has made it more difficult to measure appraisal costs accurately (Krishnamoorthi & Krishnamoorthi, 2011). However, the appraisal and auditing costs have been affected by assessment activities associated with ISO 9000 and the Malcolm Baldrige Award undertaken by companies that require such assessment programmes (AIAG, 2013). This necessitates the requirement to standardise quality measurement tests for product quality improvement.

According to PWC (2013), the inspection and test category is broken down into four sub-categories. These include the first-off inspection, inter-operation checks, and final inspection. The final inspection relates to customers' specified contractual requirements with final inspection required on 100 per cent of the components. The costs relating to this category are, in the main, the salary bill for each of the three areas. For example, productive time is lost awaiting inspection decisions and this also occurs when direct workers are moved temporarily into the inspection area, taking away capacity from the production system, contributing to a possible under-recovery of overhead costs (Evans & Milligan, 2013).

The only major appraisal activity identified outside the inspection area is that of production control. The material ordering and scheduling processes are dependent on the constant monitoring and updating of the orders placed. Considerable time and money is spent to ensure that non-conforming components do not reach the customer and this is reflected in the low level of external failure costs (Bahrami et al., 2012). Based on historical performance in the automotive sector, there is an argument for a reduced and standardised amount of quality testing and inspection tools at various inspection stages, with a subsequent reduction in costs (AIAG, 2013). As a result, this study investigates whether the standardisation of quality testing and inspection tools has the ability to improve product quality in the automotive sector. It

The Seybold Report
ISSN 1533-9211
DOI 10.17605/OSF.IO/MRPGE

explores the suitability of standardising quality testing and inspection tools as an appropriate practice for product quality improvement.

Hypothesis

The study is based on the following assumption:

H1: The standardisation of quality testing and inspection tools leads to product quality improvement in the automotive assembly organisation.

H1o: The standardisation of quality testing and inspection tools does not lead to product quality improvement in the automotive assembly organisation.

The following are sub-hypotheses:

H2: An increase in spoilage rate increases product quality in the automotive assembly organisation.

H2o: An increase in spoilage rate decreases product quality in the automotive assembly organisation.

H3: An increase in the cost of quality testing and inspection increases product quality in the automotive assembly organisation.

H3o: An increase in the cost of quality testing and inspection decreases product quality in the automotive assembly organisation

H4: An increase in the rate for external product failure increases product quality in the automotive assembly organisation.

H4o: An increase in the rate for external product failure decreases product quality in the automotive assembly organisation

METHODOLOGY

The method for this research will be discussed under the following headings, namely: research design and approach, company that participated in the study, data collection, as well as the measurement and data analysis.

Research design and approach

This study was quantitative in nature. It examines the relationship of product quality as a dependent variable to spoilage rate, the cost of quality testing and inspection, as well as the external product failure rate. Bryman and Bell (2007) explain that the quantitative approach involves the use of statistical procedures to analyse the data collected. Consequently, after the measurements of the relevant variables, the scores were transformed using statistical methods. In addition, the study adopted a panel data analysis. According to Curwin and Slater (2002), panel data analysis is the statistical analysis of data sets consisting of multiple observations on each sampling unit. It contains more degrees of freedom and less multicollinearity than cross-sectional data, thus improving the efficiency of econometric estimates (Bryman & Bell, 2007).

The Seybold Report
ISSN 1533-9211
DOI 10.17605/OSF.IO/MRPGE

For this study, the pre- and post-standardisation of quality testing and inspection tools data that were collected over time from the automotive assembly organisation were analysed using the regression model. The study was also conclusive in design. Conclusive studies are meant to provide information that is useful in decision-making (Yin, 2008).

Company that participated in the study

A convenience sample from one large automotive assembly organisation situated within the eThekwini Municipality in the province of KwaZulu-Natal in SA was used. The company, which has standardised its testing and inspection of quality tools, agreed to participate in the study. In the period prior to the standardisation of quality test and inspection tools, the company had more than 17 quality testing and inspection tools in its production processes. This had a minimal effect on the reduction of spoilage and customer complaints. Over the past six years, customer complaints have increased from 7 to 13.5 per cent due to product failure. Hence, the standardisation of quality testing and inspection tools was aimed at reducing the cost of quality testing and inspection process in the assembly plant, as well as the external product failure rate. The ultimate goal was the improvement of product quality.

Data collection

The collection of data from a single company that participated in the study was carried out in two phases, that is, the collection of pre- and post-standardisation of the quality testing and inspection tools by a quality control team leader from the operational records of the assembly plant. The data for spoilage, cost of quality testing and inspection, as well as the external product failure rate were kept on the System, Applications and Products (SAP) version 6.0 data management programme. The collection of such data over time provided a greater capacity for capturing the complexity of standardisation of quality tools' changes than that of using the one group post-test design that involves the collection of only the post-data after the changes have been implemented, resulting in threats to internal validity (Bryman & Bell, 2007). The validation of data from the SAP programme was done by the researcher. This was achieved by comparing data from SAP with the documented data kept on files for accuracy. The pre-standardisation of quality tools results were quarterly data reflecting the company's performance over the three-year period prior to standardisation of quality inspection tools implementation. This includes data from the first quarter of 2014 to the final quarter of 2016. The post-standardisation of quality inspection tools data reflect the company's performance for two years after standardisation of quality tools was implemented. This includes data from the first quarter of 2017 to the second quarter of 2019.

Measurement and data analysis

The company's quarterly time series data on spoilage, cost of quality inspection and the external failure rate were used. The measurements were based on a total of 132 observations. According to Westland (2010), there is no rule regarding the minimum number of observations for a balanced data panel. However, 50 observations are acceptable but more than 100 are recommended (Bryman & Bell, 2007). The regression model used was of the Ordinary Least Square (OLS) variety. The choice was influenced by data constraints. However, the model

The Seybold REPORT

ISSN 1533-9211

DOI 10.17605/OSF.IO/MRPGE

provided the statistical method that enabled the researcher to examine the relationship between the variables effectively.

A dummy variable which assumed the value of 0 and 1 to represent the pre- and post-standardisation of quality testing and inspection tools, respectively, was introduced into the OLS model. The aim was to isolate the pre- and post-product quality effects. Consequently, if the standardisation of quality testing and inspection tools proved to be a useful strategy in raising product quality levels, this would result in a statistically significant coefficient on the dummy variable.

The OLS model used was as follows: *Product quality* = B_o + B_1 *Spoilage rate* + B_2 *Cost of quality testing and inspection* + B_3 *External product failure rate* + B_4 *Pre/Post-Dummy.*

Where B_o is the constant

B=coefficient of the independent variables

The above model identifies product quality as a function of spoilage, cost of quality testing and inspection, customer satisfaction and the standardisation of quality testing and inspection strategy. Data was analysed using the statistical package for social sciences (SPSS) version 25. It enabled the quality testing and inspection tools data that was obtained, quarterly, over the multiple period time from the same company, to be appropriately analysed. Hence, the results provided unbiased estimations (Yin, 2008). Furthermore, the OLS was based on the fixed effects model. The fixed effects is a statistical model in which the model parameters are fixed (that is, non-random quantities) (Curwin & Slater, 2002). Consequently, the variables were collected, quarterly, from the first quarter of 2014 to the last quarter of 2019 from the same company.

For this study to achieve its objectives, the normality test was conducted using Kolmogorov-Smirnov and Shapiro-Wilk for the overall score of the constructs. Table 1 presents results for normality tests for spoilage rate, the cost of quality testing and inspection, as well as the external product failure rate.

Table 1: normality tests for spoilage rate, the cost of quality testing and inspection as well as the external product failure rate

	Kolmogorov-Smirnov[a]				Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
Spoilage rate	0	0.132	12	0.200*	0.957	12	0.743
	1	0.118	10	0.200*	0.955	10	0.732
Cost of quality testing and inspection	0	0.230	12	0.080	0.829	12	0.021
	1	0.128	10	0.200*	0.949	10	0.659
External product failure rate	0	0.374	12	0.000	0.640	12	0.000
	1	0.300	10	0.011	0.815	10	0.022

*. This is a lower bound of the true significance

a. Lilliefors Significance Correction

ISSN 1533-9211

DOI 10.17605/OSF.IO/MRPGE

Statistical tests in Table 1 showed that the data were normally distributed ($p>0.05$). Hence, the study was analysed using parametric test, that is, the t-tests.

STUDY RESULTS

This section analyses the results for pre- and post-standardisation of quality testing and inspection tools means comparison, as well as product quality.

Pre- and post-standardisation of quality inspection tools means comparison

Table 2 compare the means (in percentages) for the spoilage rate, cost of quality testing and inspection as well as the external product failure rate.

Table 2: pre- and post-standardisation of quality inspection tools percentage means comparison

No.	Variable	Pre-standardisation of testing and inspection tools period (%)	Post- standardisation of testing and inspection tools period (%)	% mean difference (post – pre)
1.	Spoilage rate	35.25	26.90	-5.35
2.	Cost of quality testing and inspection	87.75	23.20	-64.55
3.	External product failure rate	2.58	1.00	-1.58

Source: Author's own work.

Results in Table 2 indicate that the percentage mean data for pre-standardisation of quality testing and inspection tools on the spoilage rate, cost of quality testing and inspection, as well as the external product failure rate are 35.25%, 87.75% and 2.58%; respectively. In addition, the percentage mean data for post-standardisation of quality testing and inspection tools on the spoilage rate, cost of quality testing and inspection, as well as the external product failure rate are 26.90%, 23.20% and 1.00%; respectively. The results shows a decrease in mean values on all the three variables (that is, the spoilage rate, cost of quality testing and inspection, as well as the external product failure rate) when post-standardisation of quality testing and inspection tools is compared with the pre-standardisation of quality testing and inspection tools periods. This indicates the effect of standardisation of quality testing and inspection tools on product quality.

Product quality results

Table 3 presents the results for product quality as a dependent variable to the spoilage rate, the cost of quality testing and inspection, the external product failure rate as well as post-standardisation of quality testing and inspection tools dummy.

The Seybold REPORT
ISSN 1533-9211
DOI 10.17605/OSF.IO/MRPGE

Table 3: product quality as a dependent variable to the spoilage rate, the cost of quality testing and inspection, as well as post-standardisation of quality testing and inspection tools dummy

Regression	Coefficient	t-statistic	Probability
constant (B_o)	0.799	1.827	0.085
Spoilage rate	-0.005	-0.934	0.363
Cost of quality testing and inspection	-0.014	-12.820	0.000
External product failure rate	0.007	0.319	0.753
Post dummy	0.007	1.746	0.099
R-squared	0.990	F-statistics	415.188
Adjusted R^2	0.987	Sum of squares	5.399
Standard error of regression	0.057	Durbin-Watson stat.	1.835

Source: author's own work

Note: Regression data: 2014–2019 for 132 observations. The following OLS estimation is based on the equation: Product quality = B_o + B_1 Spoilage rate + B_2 Cost of quality testing and inspection + B_3 External product failure rate + B_4 Pre/Post-Dummy.

Product quality as a dependent variable to spoilage rate

The results show that the spoilage rate has no relationship with the product quality in the automotive assembly organisation. This is determined by its t-value of -0.934 as well as the p-value of 0.363. The t-value is below the critical value of 1.960 at the 5% level of significance (Curwin & Slater, 2002) and the p-value is above the 0.05 level. Thus, the null hypothesis that there is no relationships between these two variables is acceptable.

Product quality as a dependent variable to the cost of quality testing and inspection

Results as illustrated in Table 3 show that the cost of quality testing and inspection has a relationship and is statistically significant with product quality as shown by its t-value of -2.820 and the p-value of 0.000. The t-value is above the critical value of 1.960 at the 5% level of significance (Curwin & Slater, 2002) and the p-value is below the 0.05 level. The negative relationship indicates that any decrease in the cost of quality testing and inspection would result in an increase in product quality. It has the adjusted R^2 of 0.987, which implies that the cost of quality testing and inspection accounts for approximately 99% of the variance in product quality.

Product quality as a dependent variable to external product failure

Results show that the external product failure has no relationship with the product quality in the automotive assembly organisation. This is determined by its t-value of 0.319 as well as the p-value of 0.753. The t-value is below the critical value of 1.960 at the 5% level of significance (Curwin & Slater, 2002) and the p-value is above the 0.05 level. Thus, the null hypothesis that there is no relationships between these two variables is acceptable.

ISSN 1533-9211

DOI 10.17605/OSF.IO/MRPGE

Product quality as a dependent variable to the standardisation of quality testing and inspection tools

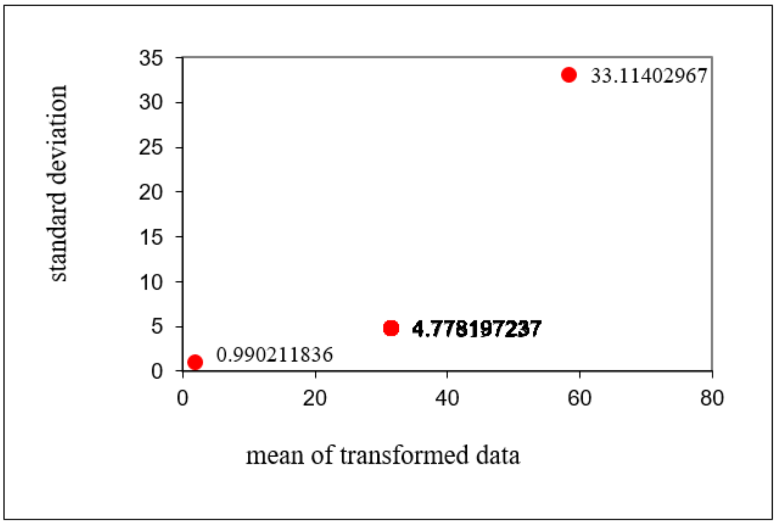
Results as illustrated in Table 3 show that the standardisation of quality testing and inspection tools has no relationship with the product quality in the automotive assembly organisation. This is determined by its t-value of 1.746 as well as the p-value of 0.099. The t-value is below the critical value of 1.960 at the 5% level of significance (Curwin & Slater, 2002) and the p-value is above the 0.05 level. Thus, the null hypothesis that there is no relationships between these two variables is acceptable.

SUMMARY OF RESULTS

Statistical tests and box plots for determining whether the normality and homogeneity of variances have been met

This section analyses data using factorial designs. It incorporates box plots to determine whether the factorial ANOVA assumptions of normality and homogeneity of variances have been met. Porkess (2005) explains that the populations represented should be normally distributed (that is, the normality), making the mean an appropriate measure of central tendency. However, the homogeneity of variance indicates that the population from which the data are sampled should have the same variance. The Bartlett's test was used to verify whether the variances were equal for all the samples (Curwin & Slater, 2002). The following Figure 1 presents a summary of the results from the Bartlett's test for homogeneity of variances.

Figure 1: Bartlett's test for homogeneity of variances



Source: Author's own work

In addition, Table 4 presents detailed results of Bartlett's test for homogeneity of variances for internal product defect rate, cost of quality testing and inspection as well as external product failure rate.

ISSN 1533-9211

DOI 10.17605/OSF.IO/MRPGE

Table 4: Bartlett's test for homogeneity of variances

Variables	means of transformed data	standard deviations of transformed data	P-Value
Spoilage rate	31.454545	4.778	0.799
Cost of quality testing and inspection	58.409091	33.114	
External product failure rate	1.863636	0.99	

Source: Author's own work.

The p-value in the Bartlett's test (at p>0.05) shows that the homogeneity of variance is violated. The p-value at 0.799 is above the significant level of 0.05. Therefore, the variances are not equal, given the amount of variability in the variances that can naturally occur in the data. This is confirmed by Levene's test of equality shown in Table 5.

Table 5: Levene's test of equality

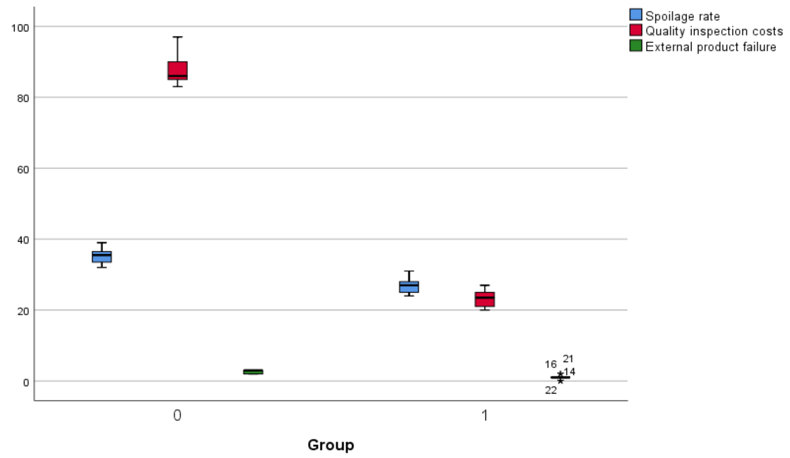
F	T	Sig.
0.003	8.759	0.957

Source: Author's own work.

Note: Fisher-Snedecor (F); t-statistics for equality of means (T); significant (sig)

Porkess (2005) defines Levene's tests of equality as an inferential statistic used to assess the equality of variance on different samples. In Levene's test of equality, the statistical procedure assumes that variances of the populations from which different samples are drawn are equal. However, the results in Table 5 show that the obtained similarities between the variances in the samples between the pre- and post-dataset at p-value 0.957 did not occur. They are above the statistical significant value of 0.05. The associated plots in Figure 2 confirm the results.

Figure 2: Box plots determining the normality and homogeneity of variance



Source: Author's own work

ISSN 1533-9211

DOI 10.17605/OSF.IO/MRPGE

Figure 2 shows that the mode of change from pre- to post-standardisation of quality testing and inspection tools period are homogeneous. However, the box plots indicates that the variances for spoilage, cost of quality testing and inspection, as well as the external product failure rates are not equal. This was confirmed by both Bartlett's and Levene's tests results

DISCUSSION

This study investigates the effectiveness of standardising quality testing and inspection tools for the improvement of product quality in the automotive assembly organisation in South Africa. It examined the production and related experience of the automotive assembly organisation that had standardised quality testing tools within its production processes.

Quarterly time series data on spoilage rate, cost of quality testing and inspection, as well as the external product failure were used to analyse data. The results indicate that the cost of quality testing and inspection has a relationship to product quality. However, the spoilage rate, as well as the external product failure have no relation to product quality in the automotive assembly organisation in South Africa. Bahrami et al. (2012) indicate that organisations spend considerable time and money to ensure that non-conforming components do not reach the customer and this is reflected in the low level of external failure costs. Based on the historical performance in the automotive sector, there is an argument for a standardised amount of quality testing and inspection tools at various inspection stages, with a subsequent reduction in costs (AIAG, 2013).

IMPLICATIONS OF RESULTS FOR POLICY AND PRACTICE

Organisations in South Africa should revise their quality management systems and review their quality testing and inspection strategies, policies and practices that help to achieve new business goals and support organisational and quality culture change (Lebednik, 2012). This must be based on an understanding of the economic factors affecting quality testing and inspection tools, as well as the significance of quality to the customer. Besides the achievement of study objectives, the following conclusions can be made on the standardisation of quality testing and inspection tools:

1) It is a strategy gearing the organisations towards success through product quality.
2) It reduces the amount of quality testing and inspection tools at various inspection stages, with a subsequent reduction in costs (Evans & Milligan, 2013).
3) In order to maximise product quality, a comprehensive total quality policy must be developed, which aligns standardisation of quality testing and inspection tools to product quality (AIAG, 2013).

STUDY LIMITATIONS

This study was limited to an automotive assembly organisation within the eThekwini Municipality. The investigation was conducted in a single organisation that has adopted a standardised quality testing and inspection strategy. As there are eight registered assembly organisations in South Africa (SAinfo, 2020), the results cannot be extrapolated to other organisations within the sector. Secondly, it did not examine the process followed during the standardisation of quality testing and inspection tools including (among others) the individuals that participated in the implementation process. It only used quarterly time series data to determine the pre- and post-product quality effects resulting from the standardisation of quality testing and inspection of tools strategy. Lastly, the econometrics model used was of the OLS variety, solely due to data constraints. Future studies ought to use a more advanced Johansen VAR methodology which relies on large datasets.

CONCLUSION

The reduction of variation of key products performance characteristics about their target values is possible through the standardisation of quality testing and inspection tools. Properly implemented and managed, the standardisation of quality testing and inspection tools results in cost reduction and product quality improvement. Hence, the relationship between the cost of quality testing and inspection, as well as product quality exists after the standardisation of quality testing and inspection tools is implemented. However, there was no direct relation between the external product failure and product quality in the selected automotive assembly organisation. The methodology is not a solution to inherent product failure problems. It is an approach that takes advantage of a focused organisational strategy to quality cost reduction, decision making and continuous quality improvement. The standardisation of quality testing and inspection tools helps in building brand loyalty of the product along with the retention of sales (Putri & Yusof, 2009).

FUTURE RESEARCH REQUIRED

During the course of this study, issues relating to the long-term sustainability resulting from the standardisation of quality testing and inspection tools after implementation were not covered. This includes the standardisation of quality testing and inspection tools to a wider sector of the economic activity, including the public sector. The nature of this research did not allow these areas to be covered in depth. It is recommended that future research should examine the following issues in greater depth:

- When to standardise quality testing and inspection tools;
- The standardisation of quality testing and inspection of tools to other industrial sectors;
- The process followed during the implementation of the standardisation activity; and
- A more comprehensive investigation should be carried out using a randomised sample of the registered automotive manufacturers that have standardised their quality testing and inspection tools to see if the results can be generalised.

The study investigated the effects of standardisation of quality testing and inspection tools for product quality improvement in a selected automotive assembly organisation in South Africa.

The Seybold REPORT

ISSN 1533-9211

DOI 10.17605/OSF.IO/MRPGE

The pre- and post-standardisation of quality testing and inspection tools quarterly data from company records were collected. It established that the standardisation of quality testing and inspection tools does not improve product quality in the automotive assembly organisation in South Africa. However, the cost of quality testing and inspection has a relation to product quality. This emanates from the standardisation of quality testing and inspection tools.

References

1) AIAG, Automotive Industry Action Group (2013). Quality. [Online]. Available at: http://www.aiag.org/staticcontent/committees/workgroup.cfm?FC=QU&grp=QUALITY&group=QUTC#.UX_PmLXvvss or http://www.aiag.org/staticcontent/files/Quality-Quality-Management-Systems.pdf

2) Bagshaw, R.W. & Newman, S.T., (2002). Manufacturing data analysis of machine tool errors within a contemporary small manufacturing enterprise. International Journal of Machine Tools and Manufacture, 42 (9), 1065-1080.

3) Bahrami, M., Bazzaz, D.H. & Sajjadic, S.M., (2012). Innovation and Improvements in Project Implementation and Management; Using FMEA Technique. Procedia Social and Behavioural Sciences, 11 (41), 418–425.

4) Bryman, A. & Bell, E., (2007). Business Research Methods. Oxford Press: USA.

5) Chang, D.S. & Jiang, S.T., (2002). Assessing quality performance based on the on-line sensor measurements using neural networks. Computers and Industrial Engineering, 42 (2), 417-424.

6) Curwin, J. & Slater, R., (2002). Quantitative Methods for Business Decisions. British Library Cataloguing Data: London.

7) Deng, W.J., Chiu, C.C, & Tsai, C.H., (2007). The Failure Mode and Effects Analysis Implementation for Laser Marking Process Improvement: A Case Study. Asian Journal on Quality, 8(1), 137 – 153.

8) Derganc, J., Likar, B. & Pernus, F., (2003). A machine vision system for measuring the eccentricity of bearings, Computers in Industry, 50 (1), 103-111.

9) Evans, D. & Milligan, R., (2013). Quality tools. [Evans D & Milligan R lectures 2013: Quality Techniques and Analysis].

10) Fu, P., (2006). DSSP the shape of things to come, Time Compression Magazine, January 2006.

11) Holweg, M., Davies P., Podpolny P. & James R.P., (2009). The Competitive Status of the UK Automotive Industry. [Online]. Available at: http://www-innovation.jbs.cam.ac.uk/publications/downloads/holweg_competitive.pdf (Accessed 25 August 2022).

12) Juran, J. & Godfrey, B.A., (1998). Juran's Quality Handbook, New York: McGraw Hill.

13) Komashie, A., Mousavi, A. & Gore, J., (2007). Quality Management in Healthcare and Industry: A Comparative Review and Emerging Themes. Journal of Management History, 3(4), 359-370.

14) Krishnamoorthi, V.R. & Krishnamoorthi, K.S., (2011). A First Course in Quality Engineering Integrating Statistical and Management Methods of Quality. US: CRC Taylor & Francis Inc.

15) Lebednik, C., (2012). Tools and Techniques for Quality Control in the Automobile Industry. Available at: http://www.ehow.com/list_7559133_tools-quality-control-automobile-industry.html (Accessed 21 October 2021).

16) Marks, P., (2005). Capturing a competitive edge through digital shape sampling and processing (DSSP). SME Blue Book Series, October 2005.

ISSN 1533-9211

DOI 10.17605/OSF.IO/MRPGE

17) Montgomery, D.C., (2005). Introduction to Statistical Quality Control. 5th edition, United States of America: John Wiley and Sons, Inc.

18) Oakland, J.S., (1997). Total Quality Management. England: Butterworth

19) Putri, N.T. & Yusof, S.M., (2009). Critical Success Factors for Implementing Quality Engineering Tools and Techniques in Malaysian's and Indonesian's Automotive Industries: An Exploratory Study. International Multi-Conference of Engineers and Computer Scientists (IMECS), Vol. II, March 2009.

20) Porkess, R., (2005). Collins internet-linked dictionary of statistics. HarperCollins, Glasgow.

21) PWC (2013). Industry Issues. Available at: http://www.pwc.co.uk/automotive/issues/index.jhtml (Accessed 22 April 2022).

22) Ranky, P.G., (2003). An Introduction to Total Quality Management and the International Quality Standards. An interactive multimedia eBook publication with 3D objects, text and videos in a browser readable format on CD-ROM/intranet by http://www.cimwareukandusa.com, CIMware USA, Inc. and CIMware Ltd, UK, ISBN 1-872631-06-1, 2002-2003, p. 185.

23) Scipioni, A., Saccarola, G., Centazzo, A. & Francesca, A., (2002). FMEA methodology design, implementation and integration with HACCP system in a food company, Food Control, 13(8), 495–501.

24) SAinfo, (2020). South Africa's automotive industry (Accessed 14 March 2022, from http://www.southafrica.info/doing_business/economy/key_sectors/ motorindustryboost.html

25) Westland, J.C., (2010). Lower bounds on sample size in structural equation modelling. Electron. Comm. Res. Appl, 9(6), 476-487.

26) Wohlers, T., (2006). The Whohlers Report 2006: Rapid Prototyping and Manufacturing State of the Industry. Annual Worldwide Progress Report, Wohlers Associates, Fort Collins, CO, 5(2), 205-215.

27) Yin, R.K., (2008). Handbook of Applied Research: California. Sage. Thousand Oaks.