The Seybold Report
ISSN 1533-9211
DOI 10.17605/OSF.IO/ZY8CB

THE IMPACT OF QUALITY GATES ON PRODUCT QUALITY IN A SELECTED AUTOMOTIVE ASSEMBLY ORGANISATION IN SOUTH AFRICA

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Abstract

Nowadays, quality control influences competitiveness of organisations, continually demanding managerial attention. With the arrival of total quality management, quality control has become an almost all-embracing control system. Thus, the philosophy of the quality gate as a quality control tool plays an important role in the assembly organisations of South Africa. Quality gate is used to improve the visibility of quality at strategic points in the production process, its main goal being to conform to the service quality as per customer's expectation. As a result, this study examines the influence of the quality gate on product quality in the 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 have adopted quality gate strategy for product quality improvement. The Ordinary Least Squares (OLS) model, using Statistical Package for Social Sciences (SPSS) was used to analyse data. The selected company operates in the eThekwini Municipality in KwaZulu-Natal province of South Africa. The study was achieved by collecting pre- and post-quarterly data for spoilage, production targets achieved and cost on quality. The results indicate that product quality has a relationship with both the spoilage rate and the cost on quality. Any decrease in the spoilage rate or the cost on quality increases product quality. This study uncovers the strengths and weaknesses of the quality gate on product quality in an automotive assembly organisation in South Africa.

Keywords: automotive assembly organisation, quality gate, quality control, product quality, spoilage rate, South Africa

INTRODUCTION

In the never-ending quest for improvement in the way processes are operated, quality control is management's top priority in the journey to excellence (Evans & Milligan, 2013). Whilst the engineers and inspectors have historically taken responsibility for quality assurance, other functional areas have also had major influences on product quality. Hence, quality gates play an important role in controlling quality through improving visibility of quality in the production process. Feigenbaum (1991) was the first quality scholar to identify the contribution that every functional area in a business makes to product quality. He called his idea "total quality control" (Feigenbaum, 1991). As he saw it, products go through an "industrial life cycle" where each functional area adds value to the product. The cycle begins when marketing evaluates the level of quality that consumers desire and for which they are willing to pay. Consumer preferences are then relayed to design engineers who translate these customer wishes into exact product specifications. The specifications are handed over to the purchasing department which selects, contracts with and monitors suppliers of materials and parts. Meanwhile, manufacturing

ISSN 1533-9211

DOI 10.17605/OSF.IO/ZY8CB

engineers determine the jigs, tools and processes they will need for production. When fabrication takes place, manufacturing supervisors and machine operators influence production quality through machine settings and the monitoring of production processes in various quality gates. Quality control personnel then inspect and test components and goods for conformance to specifications. Finally, shipping affects quality through the care it exerts in the packaging and transportation of finished goods. With so many diverse functional areas contributing to the quality of the final product, differences regarding what "quality" really means have emerged. This sentiment underpins the importance of service quality.

Service quality is one of the few topics in the marketing field that has been the subject of intensive academic research for over three decades (Evans & Milligan, 2013). This may be connected to economic prosperity, lifestyle changes and the number and complexity of goods needing services all of which have spurred growth in services economies. The importance of services in the European economy, as well as in the USA, is increasing, with nearly two-thirds of the European Union workforce in this sector (Dibb & Simkin, 2009). Lamb, Hair and McDaniel (2012) argued that the service industry would account for 98 per cent of total employment increase between 2008 and 2018, with nearly 80 per cent of employed people being in the service industry. Currently, research studies in the area of service quality span banking (Bahia & Nantel, 2000; Dhandabani, 2010), mobile telephones (Eshghi, Roy and Ganguli, 2008; Ilias and Panagiotis, 2010), transport (Eboli & Mazzulla, 2007; Nandan, 2010), hospitality (Dube, Enz, Renaghan & Siguaw, 1999; Fah & Kandasamy, 2011) and medical services (Babakus & Mangold, 1992; Chaniotakis & Lymperopoulos, 2009). Multi-sectoral research outcomes have equally been reported in literature (Cronin & Taylor, 1992; Sachdev & Verma, 2004). This context-specific growth in service quality research follows the concern that the automotive repair services sector has barely received significant research attention (Lebednik, 2012). Hence, this study evaluates the impact of quality gate on product quality in the selected automotive assembly organisation in South Africa. It is guided by the following research questions (RQs):

- RQ1: Is there a significant influence of quality gate on product quality in the automotive assembly organisation in South Africa?
- RQ2: Does quality gate influence the cost on quality in the automotive assembly organisation in South Africa?

Organisations must adopt a strategic overview of quality (Evans & Milligan, 2013). The approach must focus on developing a problem-prevention mentality, which requires commitment to quality by various groups and functional areas in the business.

The rest of the paper discusses the literature that was reviewed, the methodology used, study results as well as the discussion of results. It deliberates on the implications of results for policy and practice, study limitations, the conclusion, as well as future research required.

ISSN 1533-9211

DOI 10.17605/OSF.IO/ZY8CB

LITERATURE REVIEW

This section presents the influence of Quality on Business Performance as well as the effects of Quality Inspection in quality gates for variability reduction.

Influence of Quality on Business Performance

While many consultants and scholars have discussed quality management practices that are prerequisites for quality performance, few have tested their prescriptions empirically. Most of the quality philosophies and advice developed have been based on the individuals' consulting experiences (for example, Deming & Juran) or on the person's experience in one industry (for example, Crosby's 14 years at ITT Corporation as Vice-President of Quality) (Forker, 1996 in Evans & Milligan, 2013). At the beginning of the 1980s, Garvin (1983) conducted one of the first empirical studies, concentrating on manufacturers of room air conditioners. While the study covered only one industry, it captured virtually the entire population of US and Japanese producers of this product. The production and distribution of the room air conditioners were confined mostly to the borders of the manufacturers' home countries. However, there were neither Japanese subsidiaries (nor transplants) in the USA nor subsidiaries (or transplants) in Japan. This separation allowed for a controlled study of quality management practices and performance in each country. Garvin's (1983) findings were sobering. Differences in the failure rates between the highest-quality and lowest-quality producers across both countries ranged from 500 to 1,000 times less (Gavin, 1983). Garvin (1983) measured failure rates in two ways: "internal" failures (defects discovered before the product left the factory) and "external" failures (failures in the hands of consumers, measured by the number of service calls under first-year warranty coverage for the product). According to Forker (1996), the US companies paled in comparison to their opposite numbers in Japan: their average assembly-line defect rate was nearly 70 times higher and their average first-year service call rate almost 17 times worse than the rate for the Japanese companies. Even the poorest Japanese performer had a failure rate less than half the rate of the best US performer.

One of the academic studies conducted a couple of years ago relating to the relationship between quality management practices and quality performance was part of a quality management research instrument developed and tested in the transportation, electronics and machinery industries (Flynn, Schroeder & Sakakibara, 1994 in AIAG, 2013). Quality performance was measured on two dimensions – "internal quality performance" and "external quality performance". These measures differed somewhat from Garvin's "internal failures" and "external failures" (Garvin, 1983). Internal quality performance was an objective measure that asked survey respondents to report the percentage of items their firm produced that proceeded through final inspection without requiring rework (Flynn et al., 1994). External quality performance was a perceptual measure that asked survey respondents to assess the "quality programme's contribution to the plant's distinctive competence" (Flynn et al., 1994). Initial analyses using regression to evaluate the significance of the relationship between the eight quality management practices and the two quality performance measures found only one quality management practice to be directly related to internal quality performance (process management). Several quality management practices were related to external quality

DOI 10.17605/OSF.IO/ZY8CB

performance and external quality was found to be strongly correlated with a plant's competitive advantage.

Subsequent analyses used canonical correlation to establish a relationship between the set of TQM practices and the internal and external quality performance measures which were evaluated as a group (Forker, 1996). In a follow-on study of the same data set, Flynn, Schroeder and Sakakibara (1995) divided the 42 survey respondents into roughly equal groupings of high-, medium-, and low-quality performers, based on the internal quality performance measure (i.e. the plant's "percentage of products that pass final inspection without requiring rework"). Differences in the quality management practices used by these three groups were investigated using multiple discriminant analysis. Practices which most significantly differentiated high- from medium- and low-quality plants included (in order, from best to worst): employee involvement, process control, new-product quality practices, concurrent engineering, feedback, maintenance, supplier relationship, labour skill level and selection for teamwork potential (Forker, 1996). Practices that did a poor job of differentiation were customer interaction and design characteristics (Lebednik, 2012). The findings of this last study may be industry specific since other researchers (AIAG, 2013; Evans and Milligan, 2013; Lebednik, 2012) have found design characteristics and customer service to be important signals of "high" versus "low" quality.

The next section discusses the effects of quality inspection during the production process. This is due to the fact that this study assesses quality gates at strategic points of production for the improvement of visibility during both the inspection and production processes in the automotive sector.

The Effects of Quality Inspection in Quality Gates for Variability Reduction

The objective of a continuous quality improvement programme is to reduce the variation of key product performance characteristics about their target values (Oakland, 1997 in Krishnamoorthi & Krishnamoorthi, 2011). This requires effective quality gates for variability reduction. However, for those performance characteristics that cannot be measured in quality gates at strategic points for variability reduction 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 (Krishnamoorthi & Krishnamoorthi, 2011).

According to AIAG (2013), the core quality measurement tools aimed at reducing variation during the production process 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 the essential tools that are effective cornerstones helping in continuous improvements in any automobile company (Putri & Yusof, 2009). Thus, 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). The effectiveness of these tools in quality gates is crucial. In addition, the manufacturing and

ISSN 1533-9211

DOI 10.17605/OSF.IO/ZY8CB

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 in their quality gates (Komashie, Mousavi & Gore, 2007). This includes the Failure Mode Effect Analysis (FMEA). This technique was initially developed in the aerospace industry in the early 1960s as a method of risk and reliability analysis (Bahrami, Bazzaz & Sajjadic, 2012). It is an analytical and systematic quality planning tool for identifying possible failure in the product service, process design, and assembly stages of quality gates, 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 in their quality gates and each must be reviewed to detect possible failures (Bahrami et al., 2012). Failure probabilities, the severity of failure and the detection of failure before occurrence are the measures considered in FMEA (Bahrami et al., 2012).

The America Automobile Engineering Association combined syrchro engineering with FMEA in the early 1990s in order to improve quality (Evans & Milligan, 2013). Within the same period, Ford and two other automotive companies (that is, General Motors and Chrysler) came together and published a 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). Hence, this study examines the influence of quality gates on the spoilage rates in the automotive assembly organisation in South Africa.

Quality Costs Control: the Quest for Excellence in the Production Process

The control on the cost of quality is essential in quality gates' strategic areas of the manufacturing sector. Quality costing as a quality management technique has been around for some four decades, since the seminal paper of Feigenbaum (1991). It has traditionally been categorised as prevention, appraisal or failure-related (Krishnamoorthi & Krishnamoorthi, 2011). Prevention costs are associated with planning, training, and experimenting in order to prevent defects before they occur. However, the appraisal costs are associated with either receiving inspection, in-process inspection, or final inspection, whereas, the losses associated with the production of a nonconforming product are failure costs. This paper uncovers the impact of product quality on failure costs. The failures may be detected during the process through inspection or once the customer has purchased the product. The visibility in the production process through quality gates plays a role in reducing failure costs (Evans & Milligan, 2013). However, the prevention, appraisal, and failure-related costs are operatively related to conformance. In addition, the importance of the appraisal costs as they are related to product testing during the production process in the quality gates (Lebednik, 2012) is critical. 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 and release;

ISSN 1533-9211

DOI 10.17605/OSF.IO/ZY8CB

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 requires such assessment programmes (AIAG, 2013).

The only major appraisal activity identified outside the inspection area of the quality gate is in production control (AIAG, 2013). The material ordering and scheduling processes are dependent on the constant monitoring and updating of the orders placed. Considerable time and money is spent on ensuring that non-conforming components do not reach the customer and this is reflected in the low level of external failure costs resulting from the effective use of quality gates (Bahrami et al., 2012). Based on historical performance in the automotive sector, there is an argument for the improvement of product quality with the use of quality gates at strategic points (Evans & Milligan, 2013). They have the potential of improving the visibility in the production process, thus reducing quality costs.

Consequently, this study investigates whether quality gates have the ability to improve product quality in the automotive sector in South Africa. It explores the suitability of a quality gate as an appropriate tool for product quality improvement.

Hypothesis

The study is based on the following assumption:

H1: The implementation of a quality gate leads to product quality improvement in the automotive assembly organisation.

H1o: The implementation of a quality gate does not lead to product quality improvement in the automotive assembly organisation.

The following are sub-hypotheses:

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

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

H3: An increase in the rate for achievement of production targets increases product quality in the automotive assembly organisation.

H3o: An increase in the rate for achievement of production targets decreases product quality in the automotive assembly organisation

The Seybold Report
ISSN 1533-9211
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H4: An increase in the cost on quality increases product quality in the automotive assembly organisation.

H4o: An increase in the cost of quality 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 labour productivity as a dependent variable to absenteeism rate and employee participation in quality circles, as well as post employee engagement dummy. 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). For this study, the pre- and post-quality gate data that were collected over time from an 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 a large automotive assembly organisation situated within the eThekwini Municipality in the province of KwaZulu-Natal in South Africa was used. The company that has implemented three quality gates in strategic zones of their production processes agreed to participate in the study. Six years prior to the implementation of quality gates, it experienced a significant increase in the quality costs resulting from rework. The quarter-to-quarter spoilage rates increased from 13 to 19.7 per cent. This affected the quality of products. Coupled with the cost of quality increase was the inability of employees to achieve production targets per day. The quarter-to-quarter production decline ranged from 7 to 11 per cent. The company had 1197 employees. It operates a three-shift system.

Data Collection

The collection of data from the company that participated in the study was carried out in two phases, that is, the collection of pre- and post-quality gate results by a Quality Control Team Leader from the operational records. The data for spoilage rates, the achievement of production targets and the cost on quality were kept on the System, Applications and Products (SAP) version 6.0 data management programme. The collection of such data over time provided a

ISSN 1533-9211

DOI 10.17605/OSF.IO/ZY8CB

greater capacity for capturing the complexity of quality gate changes than 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-quality gate results were quarterly data reflecting the company's performance over the four-year period prior to quality gate implementation. This includes data from the first quarter of 2011 to the final quarter of 2014. The post-quality gate data reflect the company's performance for four years after quality gates were implemented. This includes data from the first quarter of 2015 to the final quarter of 2018.

Measurement and Data Analysis

The company's quarterly time series data on spoilage, production targets achieved and the costs on quality were used. The measurements were based on a total of 96 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 is 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 provided the statistical method that enabled the researcher to examine the relationship between the variables effectively.

The OLS model used was as follows: *Product Quality* = B_o + B_1 *Spoilage rate* + B_2 *Production targets achieved rate* + B_3 *Cost on quality*

Where B_o *is the constant*

B=coefficient of the independent variables

The above model identifies product quality as a function of spoilage rate, the production targets achieved and the cost on quality. Data was analysed using the statistical package for social sciences (SPSS) version 25. It enabled the quality gate 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 2011 to the last quarter of 2018 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, production targets achieved as well as the cost on quality.

ISSN 1533-9211
DOI 10.17605/OSF.IO/ZY8CB

Table 1: normality tests for spoilage rate, production targets achieved as well as the cost of quality

	Kolmogorov-Smirnov[a]				Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
Spoilage rate	0	0.216	16	0.045	0.875	16	0.033
	1	0.299	16	0.000	0.875	16	0.032
Production targets achieved	0	0.180	16	0.178	0.893	16	0.062
	1	0.187	16	0.139	0.857	16	0.018
Cost on quality	0	0.149	16	0.200*	0.905	16	0.096
	1	0.203	16	0.078	0.821	16	0.005

*. This is a lower bound of the true significance

a. Lilliefors Significance Correction

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-quality gate means comparison, as well as product quality.

Pre- and Post-Quality Gate Means Comparison

Table 2 compare the means (in percentages) for spoilage, production targets achieved and cost on quality.

Table 2: pre- and post-quality gate percentage means comparison

No.	Variable	Pre-quality gate period (%)	Post-quality gate period (%)	% mean difference (post – pre)
1.	Spoilage rate	56.75	10.69	+46.06
2.	Production targets achieved	72.19	96.63	-24.44
3.	Costs on quality	71.88	12.19	+59.69

Source: Author's own work.

Results in Table 2 indicate that the percentage mean data for pre-quality gate on the spoilage rate, production targets achieved and the costs on quality are 56.75%, 72.19% and 71.88%; respectively. In addition, the percentage mean data for post-quality gate on the spoilage rate, production targets achieved and the costs on quality are 10.69%, 96.63% and 12.19%; respectively. Table 2 shows mixed results of mean values on the three variables (that is, the spoilage rate, production targets achieved and the cost on quality) from pre-quality gate mean data to post-quality gate mean data. However, they show a decrease in mean values on the spoilage rate and the cost on quality when post-quality gate is compared with the pre-quality gate periods. This indicates the effect of quality gates in the organisation that participated in the study. Consequently, the next section assesses product quality results as a consequence of quality gate implementation.

The Seybold Report
ISSN 1533-9211
DOI 10.17605/OSF.IO/ZY8CB

Product Quality Results

Table 3 presents the results for product quality as a dependent variable to the spoilage rate, production targets achieved and the costs on quality.

Table 3: product quality results on the spoilage rate, production targets achieved and the costs on quality

Regression	Coefficient	t-statistic	Probability
constant (B_o)	0.922	3.813	0.001
Spoilage rate	-0.010	-2.372	0.025
Production targets achieved	0.003	1.145	0.262
Cost on quality	-0.007	-2.023	0.058
R-squared	0.972	F-statistics	324.075
Adjusted R^2	0.969	Sum of squares	7.776
Standard error of regression	0.089	Durbin-Watson stat.	1.089

Source: author's own work

Note: Regression data: 2011–2018 for 96 observations. The following OLS estimation is based on the equation: Product quality = B_o + B_1 Spoilage rate + B_2 Production targets achieved rate + B_3 Cost on quality.

Product Quality as a Dependent Variable to Spoilage Rate

The results in Table 3 show that the spoilage rate has a relationship and is statistically significant with the product quality as shown by its t-value of -2.372 and the p-value of 0.025. The t-value is above the critical value of 2.021 at the 5% level of significance (Curwin & Slater, 2002) and the p-value is below the 0.05 level. The negative sign indicates that any decrease in the spoilage rate results in an increase in product quality. It has the adjusted R^2 of 0.969, which implies that quality gate accounts for approximately 97% of the variance in product quality. Furthermore, the serial correlation is also low at 1.089 compared to the standard value of 1.73 at the 5% level of significance (Curwin & Slater, 2002).

Product Quality as a Dependent Variable to the Production Targets Achieved

Results as illustrated in Table 3 show that the achievement of production targets has no relationship with product quality in the automotive assembly organisation. This is determined by its t-value of 1.145 as well as the p-value of 0.262. The t-value is below the critical value of 2.021 at the 5% level of significance and the p-value is above the 0.05 level. The null hypothesis of no relationships between these two variables is acceptable.

Product Quality as a Dependent Variable to the Cost on Quality

Results show that the cost on quality has a relationship and is statistically significant with the product quality as shown by its t-value of -2.023. The t-value is above the critical value of 2.021 at the 5% level of significance. The negative sign indicates that any decrease in the cost on quality results in an increase in product quality.

The Seybold Report
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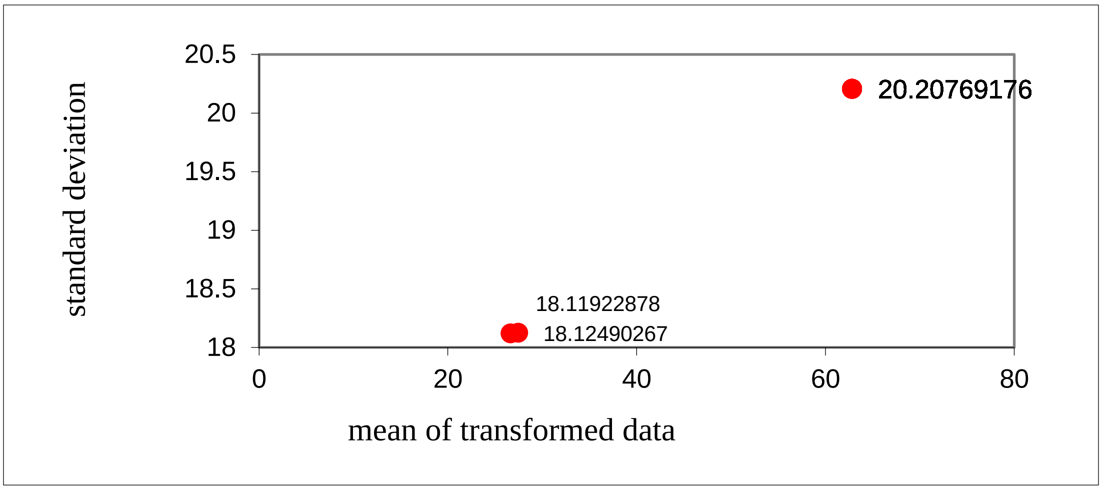
SUMMARY OF RESULTS: Statistical tests and box plots

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



In addition, Table 4 presents detailed results of Bartlett's test for homogeneity of variances for spoilage, production targets achieved circles as well as the costs on quality.

Table 4: Bartlett's test for Homogeneity of Variances

Variables	means of transformed data	standard deviations of transformed data	P-Value
Spoilage	26.625	18.119	0.781
Production targets achieved	62.8125	20.208	
Costs on quality	27.4375	18.125	

The p-value in the Bartlett's tests (at p>0.05) shows that the homogeneity of variance is violated. The p-value at 0.781 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.

The Seybold Report
ISSN 1533-9211
DOI 10.17605/OSF.IO/ZY8CB

Table 5: Levene's test of equality

F	T	Sig.
1.996	28.557	0.168

Source: Author's own work.

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

Porkess (2005) defines Levene's test 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. As a result, the findings in Table 5 show that the obtained similarities between the variances in the samples for pre- and post-data at p-value 0.168 did not occur. They are above the statistical significant level of 0.05. The results are confirmed by box plots in Figure 2.

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

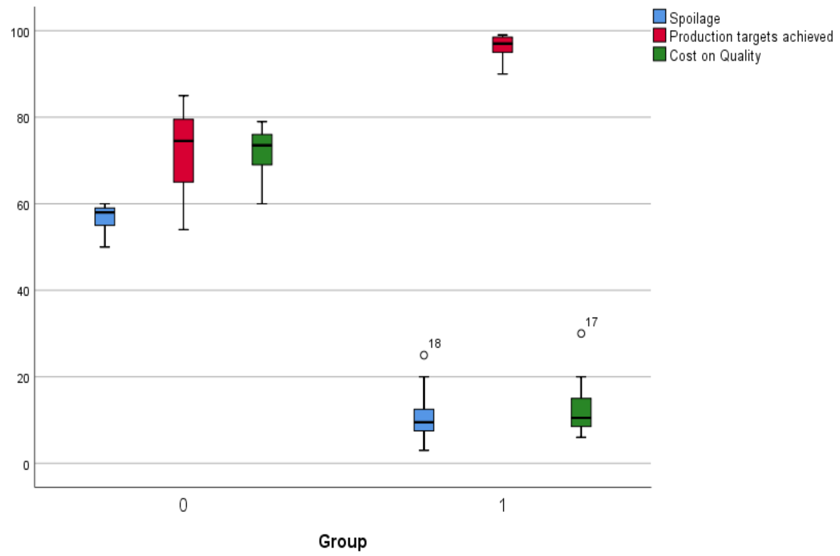


Figure 2 shows that the mode of change from pre- to post-quality gate period are homogeneous. However, the box plots indicates that the variances for spoilage, production targets achieved and the costs on quality are not equal. This was confirmed by Bartlett's test results in Table 5.

DISCUSSION

This study investigates the impact of quality gate on the improvement of product quality in an automotive assembly organisation in South Africa. It examined the production and related experience of the automotive assembly organisation that had adopted quality gate strategies within its operations. Quarterly time series data on spoilage, production targets achieved and the cost on quality were used to analyse data. The results indicate that product quality has a relationship to both the spoilage rate and the cost on quality. Any decrease in the spoilage rate

The Seybold Report
ISSN 1533-9211
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or the cost on quality increases product quality. However, the achievement of production target has no relation to product quality in this automotive assembly organisation in South Africa.

According to Lebednik (2012), the visibility in the production process through quality gate plays a role in reducing failure costs. However, the prevention, appraisal, and failure-related costs are operatively related to quality conformance. Hence, the importance of the appraisal costs (as a cost factor) that is related to product testing during the production process in the quality gate area plays a significant role (Krishnamoorthi & Krishnamoorthi, 2011).

IMPLICATIONS OF RESULTS FOR POLICY AND PRACTICE

Organisations in South Africa should revise their performance system and develop quality control strategies and practices that help to achieve new quality goals and support organisational change (Smith, 2007). This must be based on an understanding of the economic factors affecting quality gates and the significance of improving product quality in the manufacturing process. The reduction of variation of key product performance through continuous quality improvement programmes plays a significant role in product quality improvement (Putri & Yusof, 2009). This requires an effective use of quality gate for variability reduction (Krishnamoorthi & Krishnamoorthi, 2011). Besides the achievement of study objectives, the following conclusions can be made on the quality gate philosophy:

1) They are the levers gearing the organisations towards success through product quality.
2) They have the capability to improve the visibility of quality at strategic points in the production process (AIAG, 2013).
3) In order to maximise performance, a comprehensive performance policy must be developed, which aligns the quality gates system to product quality (Farouk, 2014).

STUDY LIMITATIONS

The study was limited to an automotive assembly organisation within the eThekwini Municipality. The investigation was conducted in a single company that has adopted quality gate strategy. As there are eight registered assembly companies in South Africa (SAinfo, 2018), the results cannot be extrapolated to other companies within the sector. Secondly, it did not examine the process followed during the quality gate execution including (amongst 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 quality gate strategy. Lastly, the econometrics model used was of the OLS variety, solely due to data constraints. Future studies ought to use the more advanced Johansen VAR methodology, which relies on large datasets.

The Seybold Report

ISSN 1533-9211

DOI 10.17605/OSF.IO/ZY8CB

CONCLUSION

Quality gates have the ability to improve the visibility of quality at strategic points in the production process. They represent significant decision points within the production process (Dhandabani, 2010). They are often used in certain domains (such as car assembly strategic points) or in serial production of industrial goods (Evans & Milligan, 2013). Properly implemented and managed, the system results in an improved product quality. Hence, the relationship between the cost on quality and product quality exists after the quality gate has been implemented. However, there was no direct relation between the achievements in production targets and product quality in the selected automotive assembly organisation. The system is not a solution to inherent production problems. It is an approach that takes advantage of a focused organisational strategy to improve product quality and, ultimately, customer satisfaction (Lebednik, 2012).

FUTURE RESEARCH REQUIRED

During the course of this study, issues relating to the long-term survival of quality gate strategy after implementation were not covered. This includes the applicability of quality gates 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 use and when not to use a quality gate system;
- The applicability of a quality gate approach to other industrial sectors;
- The process followed during the implementation of a quality gate system; and
- A more comprehensive investigation should be carried out using a randomised sample of the registered automotive manufacturers that use a quality gate strategy to see if the results can be generalised.

The study investigated the impact of quality gate on product quality in the automotive assembly organisation in South Africa. The pre- and post-quality gate quarterly data from company records were collected. It established that product quality has a relationship with both the spoilage rate and the cost on quality. Any decrease in the spoilage rate or the cost on quality increases product quality.

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