

The Application of Statistical Quality Control Methodologies within SMEs in Johor Bahru

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Abstract

Statistical quality control (SQC) methodology has been well recognized as a systematic approach for continuous quality improvement. Hence, SQC is adopted widely by both manufacturing and service industries as part of their operational strategy to improve quality performance. Holistically, SQC methodologies could be grouped into two categories, which are detection based methodology, such as Sampling Inspection, Statistical Process Control (SPC); and prevention methodology for instance Process Capability study, Design for Manufacturability (DFM). Findings from literature review suggested that the implementation of SQC methodology does improved organizational quality improvement. However, SQC methodology is generally viewed by prior researchers as single entity without exploring the attribution or type of SQC methodologies that are driving quality performance. Hence, this research close the literature gap by assessing the application level of each SQC methodology within Small and Medium Enterprises (SME) manufacturers in Johor Bahru (JB), and explore the relationship between implementation level of SQC methodologies and quality performance. The study is quantitative based via survey questionnaire and responded by 110 SME manufacturing companies within JB. The implementation level of SQC methodologies and their relationship with quality performance are examined separately via descriptive analysis and Pearson correlation test. Finding from the study revealed that SME manufacturers in JB tends to adopt detection based SQC methodologies (i.e. SPC and Sampling inspection) as their continuous quality improvement methodology. While prevention based methodologies (Process capability and DFM) are still not the common practices. In addition, result of this study also suggested that prevention based methodologies are more likely to improve organizational quality performance. The finding and the SQC framework developed in this study has descriptive value in terms of studying, classifying and defining the attributes of SQC and the relationships that govern continuous quality improvement in SME.

Index Terms: Sampling Inspection, Statistical Process Control, Process Capability, Quality Performance

1. Introduction

Intense global market competition compelled organizations to revisit their operation strategy regularly in order to sustain competitive advantage [1]. In the case of quality management, competitive advantage can be obtained by creating a continuous quality improvement culture within the organization, as well as to adopt a systematic quality improvement methodology across the entire organizational activities [2].

Continuous quality improvement (CQI) is being viewed as the continuous act of overseeing all organizational activities to ensure that the products or services are continuously meeting or exceeding

customer's expectation [3]. CQI process involves the identification of problems, implementing and monitoring corrective action via a series of quality improvement tools or methodologies. Hence, quality improvement methodology has become an increasingly important means of competition on the world market and has become a strategic weapon in the fight for market shares and to improve profitability, especially for Small and Medium Enterprises or SME [3].

Studies conducted by prior scholar revealed that the adoption of an appropriate quality improvement methodology helps SMEs to transfer from incubation stage to maturity stage effectively [4]. This enables SMEs to maintain as a customer oriented organizational, providing high quality products and services and quality improvement processes [4].

Statistical Quality Control (SQC) is one of essential methodology for continuous quality improvement. Study done by prior researcher [5] suggested that SQC could be divided into four approaches, which are Sampling Inspection, Statistical Process Control, Process Capability and Design for Manufacturability. However, the current literature of quality improvement tends to focus on assessing SQC methodology as single entity neither examine the attribution or approaches of SQC, nor explore the implementation level and impact of each SQC methodology toward quality performance. Hence, this research aim to close the SQC methodology gap by assessing the implementation level of each SQC methodology and the relationship with quality performance, with the focus on Small and Medium Enterprise (SME) manufacturing companies in Johor Bahru. Hence, two research objectives are developed for this study: RO 1: To assess the implementation level of Quality improvement methodologies in SME within Johor Bahru; RO 2: To explore the relationship between Quality improvement methodologies and quality performance.

2. Literature Review

A. Statistical Quality Control Methodology

Quality Improvement Methodologies (QIM) is the essential element of Quality Management System (QMS). In quality improvement methodology, Statistical Quality Control Hierarchy (SQCH) is the core concept that organizations need to comprehend prior to explore to the detail of each SQC methodology [5]. SQCH made up of four hierarchy levels; "Sampling Inspection" methodology at the lowest level of hierarchy, follow by "Statistical Process Control", "Process Capability" and ended with "Design for Manufacturing" (DFM) methodology at the top of hierarchy (refer Figure 1) [5].

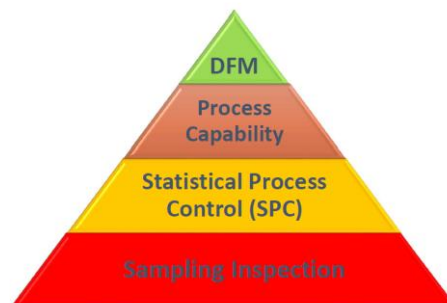


Fig. 1. Statistical Quality Hierarchy

Sampling Inspection and SPC are detection based SQC methodologies, while Process Capability and DFM are prevention based SQC methodologies [6]. Detection approach involves examining or inspecting parts or product versus specification to detect defect, follows by investigation on the cause of defect and developing countermeasure. Detection based methodology does not correct deficiencies in process or product and it is expensive [7].

Prevention approach lays on the principle of quality is determined by product and process design. Prevention methodology focuses on analysis of process variation and product specification to ensure process is capability of producing the product with minimum defect [5]. Prevention approach aims to derive a product specification that insensitive to the influence of process variation, in consequences, provide a powerful and efficient method for continuous quality management [7].

B. Sampling Inspection

The process of sampling inspection involves inspecting a relatively small number of items (or sample, n) from a batch of raw materials, semi finish products, or products (or lot, N), and subsequently comparing the inspection results (of the sample) with a predefined acceptance number (c) to either reject or accept the batch

[8].

From producer perspective, the acceptance number, c is derived from the producer's acceptable risk level that the sampling plan might fail to verify the batch's quality; or namely Type-I error in statistic. Whereas from consumers point of view, c could be derived from the quality level desired by the consumer, or namely Acceptance Quality Level (AQL). Hence, with a predefined acceptable Type-I error or AQL, c can be calculated using binomial distribution formula [9].

ANSI/ASQ Z1.4, ISO 2859 is the most widely used acceptance sampling standard in the industries. The standard tabulates the acceptance number (c) for different lot's size at various level of AQL. Hence, with the predefined batch size and AQL level, the acceptance number c can be identified from the standard table.

Sampling inspection involves rectification of errors found [8]. Hence, the verifiers should have a higher level of understanding in order to do the inspection process. However, for quality improvement perspective, quality cannot be inspected into product [10]. Sampling inspection detects a defective item without correct the deficiencies in process, product and services. Hence, sampling inspection is viewed at the lowest level of quality improvement methodology in the SQC hierarchy.

C. Statistical Process Control

An inherent or natural variation exist in any manufacturing process regardless of how well the process is controlled and maintained [11]. In addition, other kind of variation might occasionally be present in the process and causes unacceptable level of process performance. Such variation is referred as assignable causes of variation [11]. The objective of Statistical Process Control (SPC) is to provide a statistical signal when assignable causes of variation are present in the process. SPC provides such a system through the use of control chart. Control chart employs statistical method to develop a set of upper and lower control limits [12]. Control limits are the limits within which the process operates under normal conditions. Data points beyond the control limits or other unusual patterns indicate special causes of variability, hence action could be taken accordingly [12].

SPC detects process abnormality or assignable causes of variation rather than detecting defective items as what sampling inspection did. However, the cause of defective still unknown and required further investigation.

D. Process Capability

Process capability is an evaluation of the relationship between the natural variation of the process and the design specifications [4]. Process capability index, C_p or C_{pk} representing the ratio between design specification range versus process variation, whereby process variation is measured in term of the process's standard deviation or sigma (σ) [12]. C_p or C_{pk} of less than one reflects that the process's natural variation is bigger than the design specification, hence the process is not capable to produce an acceptable product. From quality improvement perspective, C_p and C_{pk} could be used as a measure to prioritizing the order of process improvements to be made, and determining whether or not a process is capable of meeting customer requirements. Hence, process capability goes beyond the traditional detection approach, whereby a proper matching of process and product could be made based on C_p , C_{pk} [13].

E. Design for Manufacturing

Design for Manufacturing is a quality improvement approach to ensure product will continue to perform as design intended despite process variation [4]. To achieve this, the variation of process is measured and the product design specification is next developed bases on Six Sigma concept. Conceptually, Six Sigma is statistical-based, data-driven approach and continuous improvement methodology for eliminating defects in a product. Statistically, a Six Sigma process is a process that achieved a quality performance of 3.4 defects per million; with C_p of more than 2.0 and C_{pk} of higher than 1.5 [14].

Design for manufacturing is increasingly viewed as important tool in quality improvement methodology in the competitive business environment [15] because it provides a powerful and efficient method for designing products that operate consistently and optimally over a variety of condition [5].

F. Quality Performance

The main objective for quality improvement effort is to boost organizational quality performance via continuous improvement on quality of products and process. Study done by prior researchers tends to agree that organizational quality performance is a complex phenomenon that required more than a single criterion to characterize it. Finding from literature review also reveals that there are three common measures for organizational quality performance, which are financial performance (such as profit, sales and return of

investment), non-financial performance (customer satisfaction, supplier relationship, employee morale) and Operation performance (number of defective product, waste level, throughput time) [16][17].

G. Research Framework

Figure 2 shows the research framework of this study. The framework is developed bases on the concept that the implementation of the four SQC methodologies, which are sampling inspection, SPC, process capability and DFM enhance organizational quality performance. In conjunction with the research framework, four hypotheses are developed, which are:

H1: There is significant and positive relationship between Sampling Inspection and Quality Performance

H2: There is significant and positive relationship between Statistical Process Control and Quality Performance

H3: There is significant and positive relationship between Process Capability and Quality Performance

H4: There is significant positive relationship between Design for Manufacturing and Quality Performance

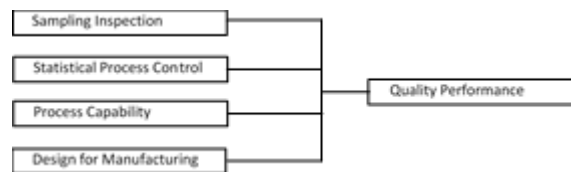


Fig. 2. Research Framework

3. Research methodology

This research aims to examine the application of Statistical Quality Control methodologies as quality improvement approach within SME in Johor Bahru. To achieve this, this research applies quantitative survey to assess the implementation level of the four SQC methodologies (i.e., Sampling Inspection; Statistical Process Control; Process Capability and Design for Manufacturing) as well as the level of quality performance. The research selected SME manufacturing companies within southern part of Malaysia as the focus of study. Subsequently, bases on the responses from survey questionnaire, the implementation level of each SQC methodology is derived via descriptive analysis, and the relationship between SQC methodologies and quality performance analyzed via Pearson correlation test.

A. Population and Sampling

The study focused on SME manufacturing companies within Johor Bahru. Other SME companies were excluded from the study as SQC methodologies might not applicable on non-manufacturing-based SME companies. Based on the list of SME companies published by SMEcorp, there are 1,925 SME manufacturing companies within Johor Bahru. Hence, the sampling frame for this study is 300 which is derived from sampling table of Krejcie & Morgan [18].

B. Research Instrument

The study was quantitative based, the questionnaire consist of 26 questions which are divided into three parts. First part is to collect the respondents' demographic information, while the second part of the questionnaire is to assess the implementation level of the four SQC methodologies, and the third part of questionnaire assesses the company's quality performance level. The assessment was done via 5-points scales from "1" representing "No implementation" to "5" indicating "Fully implemented".

C. Analysis Tool

The normality and reliability of data collected from part 2 and 3 of questionnaire are assessed via Skewness & Kurtosis value and Cronbach Alpha test respectively. Skewness & Kurtosis range of +/- 2 represents data is normally distributed.

Meantime, Cronbach Alpha reliability value of greater than 0.60 is suggested to be adequate for testing the reliability of factors [18]. Subsequently, the implementation level of each SQC methodology is derived via descriptive analysis, and the relationship between SQC methodologies and quality performance is analyzed via Pearson correlation test.

4. Analysis and discussion

A total of 400 questionnaires were distributed with 115 responded. However, 5 unusable questionnaires were screened out due to missing value. As the result, 110 usable questionnaires were collected, with the respond rate of 28%.

A. Normality and Reliability Test

Result of normality test for all measurement items shown that the value of Skewness and Kurtosis are within -2 and +2, hence there is no issue in regard with data normality [18]. In addition, Cronbach Alpha reliability values for the all measurement items are ranged from 0.7982 to 0.8627. This implies that the data is statistically significant to proceed for further analysis.

B. Implementation Level of SQC Methodologies

To address research objective 1 of this study (i.e. To assess the implementation level of Quality Improvement methodology in SME within Johor Bahru), the average implementation level of SQC methodologies (Sampling Inspection; SPC, Process Capability and DFM) that perceived by SME manufacturing companies is calculated based on the data collected from part 2 of questionnaire, and summarized in Table 1.

TABLE I. IMPLEMENTATION OF SQC TABLE STYLES

Implementation Level of SQC Methodologies		
<i>SQC Methodologies</i>	<i>Implementation Level</i>	<i>Rank</i>
Sampling Insepection	3.509	2
Statistical Process Control	3.568	1
Process Capability	2.488	3
Design for Manufacturing	2.408	4

As refer to Table 1, the implementation level for SPC and Sampling Inspection within SME manufacturing companies in JB are above average with implementation level of 3.568 and 3.509 respectively. Whereas Process Capability and DFM are implemented at below average level of 2.488 and 2.408 respectively. The result suggested that within the context of SME manufacturing companies in JB, SQC methodologies that adopted by the companies are still confined within the traditional detection-based methodology. Traditional detection quality improvement methodologies dependent on inspecting parts or product versus specification to detect defect. However, study done by prior researchers [10], [14], [15] revealed that Inspection does not improve the quality, nor guarantee quality. Inspection is too late, and “quality cannot be inspected into product” [19].

Finding from the study also revealed that most of the SME manufacturing companies in Johor Bahru are yet to explore the prevention based SQC methodologies. Prevention SQC methodology views “Quality is built into product” and Quality is determined by product and process design (i.e. DFM, Process Capability). Hence, in order to improve quality performance and reduce quality cost, SME manufacturing companies in Johor Bahru should explore how prevention based SQC methodologies could be applied in their manufacturing environments.

C. Relationship between SQC Methodologies and Quality Performance.

To address the research objective 2 of this study (i.e. to explore the relationship between Quality Improvement methodology and quality performance), as well as to test the four research hypotheses, data collected from part 2 (SQC methodologies implementation level) and part 3 (Quality performance level) of questionnaires is further analysed via Pearson correlation test. The purpose of Pearson correlation test is to assess the relationship between the implementation level of the four SQC methodologies and quality performance level within SME manufacturing companies in Johor Bahru. The result of analysis is summarized in Table 2.

As refer to Table 2, the significant value (i.e. p-value) for two of the SQC methodologies, Process Capability and Design for Manufacturing are less than 0.05. This suggested that at confidence level of 95%, the

relationship between Process Capability and Quality performance, as well as between DFM and Quality performance are significant, with person correlation coefficient of 0.312 and 0.341 respectively (i.e. moderately correlated). Whereas, the relationship between the other two SQC methodologies, Sampling inspection and Statistical Process Control (SPC) with quality performance are not significant at level of 0.05. Hence, based on the analysis result of Person correlation test, two of the hypotheses for this study are supported, and the other two are failed to support (refer to Table 2.).

TABLE II. HYPOTHESES TEST RESULT

Hypo	Table Column Head			
	<i>SQC Methodology</i>	<i>Coefficient of Correlation (r)</i>	<i>p-value</i>	<i>Result</i>
H1	Sampling Insepection	0.128	0.722	Not supported
H2	Statistical Process Control	0.227	0.108	Not supported
H3	Process Capability	0.312	0.017	Supported
H4	Design for Manufacturing	0.341	0.016	Supported

Finding from the study suggested that adoption of detection based SQC methodologies might not significantly enhance the organizational quality performance. Whereas organizational quality performance could be significantly improve via the implementation of prevention based SQC methodologies.

Hence, within the context of SME manufacturing companies in Johor Bahru, in order to enhance competitive advantage via quality performance, SME manufacturing companies should align their companies' continuous quality improvement strategy to be in line with the concept of SQC prevention methodologies such as Process Capability and DFM. Whereby quality should be design into the product via the analysis of process capability and the application of design for manufacturing.

5. Conclusion

Continuous quality improvement (CQI) is a quality management philosophy that involves an ongoing process of evaluating organizational quality performance and identify ways to improve. Finding from this study suggests that within the context of SME manufacturing companies in Johor Bahru, the adoption of prevention based Statistical Quality Control (SQC) methodologies (Process Capability study and Design for Manufacturing) are relatively low, but prevention based SQC methodologies is significantly correlated with quality performance. Hence, the practical implication of this study is SME manufacturing companies in Johor Bahru shall revisit the SQC methodologies used in their organization, and realign the CQI strategy to make it in line with prevention philosophy. In addition, finding from this study has descriptive value in terms of selecting and implementing SQC methodologies and the relationships that govern SQC methodologies and organizational quality performance, which is significant to the literature and study of CQI as well as Quality Management.

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