THE APPLICATION OF STATISTICAL QUALITY CONTROL METHODOLOGIES WITHIN *SME* IN JOHOR BAHRU

Tan Owee Kowang, Ong Choon Hee, Amalia Ferhat, Goh Chin Fei, Azman Hashim
Universiti Teknologi Malaysia, Johor Bahru, Johor, Malaysia.
oktan@utm.my

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 the literature review suggested that the implementation of SQC methodology does improve organizational quality improvement. However, SQC methodology is generally viewed by prior researchers as a single entity without exploring the attribution or type of SQC methodologies that are driving quality performance. Hence, this research closes 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 the implementation level of SQC methodologies and quality performance. The study is quantitatively based via a 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 tend 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, the 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 SMEs.*

Keywords—Statistical Quality Control; Sampling Inspection; Statistical Process Control; Process Capabilliyt; Six Sigma.

I. 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 adopting 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 expectations [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 SMEs [3].

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

Statistical Quality Control (SQC) is one of the essential methodologies for continuous quality improvement. A study done by a 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 on quality improvement tends to focus on assessing SQC methodology as a 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 aims 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 SMEs within Johor Bahru.

RO 2: To explore the relationship between Quality Improvement methodologies and quality performance.

II. LITERATURE REVIEW

A. Statistical Quality Control Methodology

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

Fig. 1. Statistical Quality Hierarchy.

Fig. 2.

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

The prevention approach lays on the principle of quality is determined by product and process design. Prevention methodology focuses on the analysis of process variation and product specification to ensure the process is the capability of producing the product with minimum defect [5]. The prevention approach aims to derive a product specification that insensitive to the influence of process variation, in consequence, provides 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 a 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 the producer's 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 the statistic. Whereas from a consumer's 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 the 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 sizes at various levels 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 the rectification of errors found [8]. Hence, the verifiers should have a higher level of understanding in order to do the inspection process. However, from a quality improvement perspective, quality cannot be inspected into a product [10]. Sampling inspection detects defective items without correct the deficiencies in the 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 exists in any manufacturing process regardless of how well the process is controlled and maintained [11]. In addition, another kind of variation might occasionally be present in the process and causes an unacceptable level of process performance. Such variation is referred to 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 a control chart. The control chart employs a 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 the defective still unknown and require 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, Cp or Cpk representing the ratio between design specification range versus process variation, whereby process variation is measured in terms of the process's standard deviation or sigma (σ) [12]. Cp or Cpk 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 a quality improvement perspective, Cp and Cpk 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 Cp, Cpk [13].

E. Design for Manufacturing

Design for Manufacturing is a quality improvement approach to ensure the product will continue to perform as the design intended despite process variation [4]. To achieve this, the variation of the process is measured and the product design specification is next developed bases on the Six Sigma concept. Conceptually, Six Sigma is a 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 Cp of more than 2.0 and Cpk of higher than 1.5 [14].

Design for manufacturing is increasingly viewed as an 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 conditions [5].

F. Quality Performance

The main objective for quality improvement effort is to boost organizational quality performance via continuous improvement on the quality of products and processes. A 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 enhances organizational quality performance.

In conjunction with the research framework, four hypotheses are developed, which are:

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

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

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

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

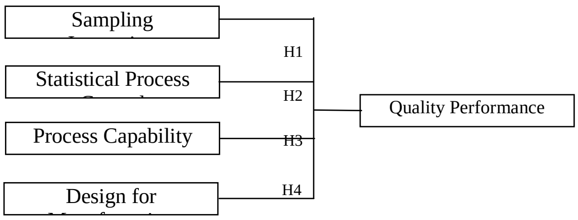

Fig. 2: Research Framework

III. RESEARCH METHODOLOGY

This research aims to examine the application of Statistical Quality Control methodologies as a quality improvement approach within SMEs in Johor Bahru. To achieve this, this research applies a 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 the southern part of Malaysia as the focus of the study. Subsequently, bases on the responses from the 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 to 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 the sampling table of Krejcie & Morgan [18],

B. Research Instrument

The study was quantitative-based, the questionnaire consists of 26 questions which are divided into three parts. The 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 the 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 parts 2 and 3 of the 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 the Pearson correlation test.

IV. ANALYSIS AND DISCUSSION

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

A. Normality and Reliability Test

Result of the 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 to data normality [18]. In addition, Cronbach Alpha reliability values for 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 the questionnaire, and summarized in Table 1.

TABLE I. IMPLEMENTATION OF SQCTABLE STYLES

Implementation Level of SQC Methodologies		
SQC Methodologies	***Implementation Level***	***Rank***
Sampling Inspection	3.509	2
Statistical Process Control	3.568	1
Process Capability	2.488	3
Design for Manufacturing	2.408	4

As refer to in Table 1, the implementation level for SPC and Sampling Inspection within SME manufacturing companies in JB are above average with implementation levels of 3.568 and 3.509 respectively. Whereas Process Capability and DFM are implemented at a 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 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 the defect. However, a 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 the 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 the 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 analyzed via Pearson correlation test. The purpose of the 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 the analysis is summarized in Table 2.

TABLE II. HYPOTHESES TEST RESULTS

Hypo	Table Column Head			
	SQC Methodology	***Coefficient of Correlation (r)***	***p-value***	***Result***
H1	Sampling Inspection	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 Manufacturin g	0.341	0.016	Supported

As refer to in 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 a confidence level of 95%, the relationship between Process Capability and Quality performance, as well as between DFM and Quality performance are significant, with a 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 the level of 0.05. Hence, based on the analysis result of the Person correlation test, two of the hypotheses for this study are supported, and the other two are failed to support (refer to Table 2.).

Finding from the study suggested that the adoption of detection-based SQC methodologies might not significantly enhance the organizational quality performance. Whereas organizational quality performance could be significantly improved 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.

V. 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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