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NEW RESEARCH

Survey and case investigations on application of quality management tools and techniques in SMIs

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Abstract *Quality management (QM) cannot be assured unless some objective assessments are undertaken. A number of tools and techniques are available to conduct such analysis. Although some of them are product or service specific, however, a few basic tools and techniques are commonly used in manufacturing firms. This study focuses on the state of application of QM tools and techniques in small and medium industries (SMIs). The findings reveal that by-and-large, lack of methodical analysis is a major weakness of SMIs. Still some rule-of-thumb and subjective observations are dominating over objective evaluation in the process of quality control decisions. A few case studies which have been conducted, and one that has been briefly reported here, also support this conclusion. The methodology of the study has three folds: literature review, survey in SMIs and case studies.*

Introduction

Quality management (QM) is not really a new issue in manufacturing. Methodically, F. W. Taylor introduced simple inspection of finished goods in the late nineteenth century that was followed by several successive phases, with the change of the concept of "quality" during the last half-century, from compliance with specifications of a product to the entire cycle including product design, production, sales, distribution, use, and disposal (Crosby, 1980; Deming, 1982; Ishikawa, 1985; Feigenbaum, 1991; Payne *et al.*, 1996). A modified form of TQC was exported to the USA from Japan in the 1970s and appreciable training and implementation activities were undertaken in the private sector in the subsequent decades (Melan, 1998). Later it took the name of total quality management (TQM). Garvin (1988) identified them as major quality eras, and Bounds *et al.* (1994) listed the foremost quality advocates and practitioners of each era. By 1980, the meaning of the term "quality" took a new dimension, "whatever the customer perceived it to be". Therefore, the importance of systematic and objective analysis, and thus the need of QM tools, have been felt more and a range of new tools has been developed.

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One of the most important applications in manufacturing (or for industrial engineers) is statistical quality control (SQC). This is due to the nature of the engineering profession itself, which is largely concerned with the creation of products through product and process design, and operation of processes for the benefit of mankind (here we call it customers). To industrial engineers, the end products must conform to the engineering specifications, and so should be for components and materials from which parts are fabricated and end items are assembled. Quality control is inevitably associated with manufacturing and one of the main concerns of an industrial engineer is to ensure that the proper procedures are applied to monitor production and to correct any unusual mistakes to prevent the final product from being unsatisfactory.

To do so, the applications of one set or another of statistical, quantitative, and graphical tools and techniques could be noticed in every quality era. QM cannot be practiced effectively and objectively without using a set of tools and techniques. A large number of statistical tools and methods are applied in manufacturing and service firms. Statistical process control (SPC) includes a number of them. Shewhart introduced control charts (CCs) in the beginning of the 1930s (Shewhart, 1931), and currently it is one of the most widely discussed statistical techniques (Xie and Goh, 1999). The choice of any tool or method is not just automatic, rather situation specific. One thing should be said in clear terms: tools are not to solve the existing or would-be problems, but to use as means of identifying the problems or strengths in specific terms through systematic manners. Therefore, the users must understand the applicability of a particular tool before being applied. For detail, see the chapter "Tools and techniques: an overview" (Dale and Shaw, 1999). However, some tools and techniques are essential in any manufacturing firm – small, medium or large, if the management really wants to handle the business professionally.

This paper presents a concise study on the state of applications of those tools and techniques in SMIs. Although it is argued that QM, say TQM, tends to have a greater impact when implemented in larger firms than in smaller ones (GAO study, 1991; Garvin, 1988; Terziovski and Samson, 2000), however, SMI manufacturers also should be quality conscious for getting quality outputs, and so in their management practices. There is a little empirical research that explains the state of application of QM tools in SMIs. Most of such studies are so far held in large industries.

QM tools: literature review

Policy instruments in QM are not adequate if, for example, defect rates cannot be reduced or eliminated, the process and product reliability cannot be ensured, and the knowledge base cannot be continuously enhanced to improve the overall organizational performance. The obtaining of an ISO 9000 registration does not mean that the quality is continuously assured (Reimann and Hertz, 1994). A systematic and structured QM with the aid of relevant tools and techniques must be in action with regard to continuous improvement. SPC is the primary and one of the best techniques for controlling and improving product or service quality methodically, which is applicable for any type of organization. The basic SPC tools are Pareto diagrams, cause-and-effect diagrams (fishbone or Ishikawa diagrams), check sheets, graphs, histograms, CCs, and scatter diagrams (Besterfield *et al.*, 1999; Dale and Shaw, 1999). These are not all really statistical. Dale and Shaw (1999) termed them as seven quality control tools or QC7. Including the process flow chart or process mapping these are the seven basic and simple statistical tools (Rao *et al.*, 1996; Spring *et al.*, 1998). From the point of presentation of data on a process, tools can be classified as graphical tools and flow diagrams. In the former class there are histogram, stem-and-leaf diagrams, line charts, bar charts, pie charts, run or time series charts, CCs, and Pareto diagrams, and in the latter class there are flow diagrams, process flow charts, cause-and-effect diagrams, and tree diagrams. To facilitate data collection and summarization, tools like check sheets, location plots, and data tables are used. These basic quality control tools are powerful and acceptable for analyzing QM aspects. They deserve wide application and SMI's manufacturing firms as well should know and use them.

To the top management of an organization, the use of hard data is a matter of exception, what Taylor phrases "theory of exception". It mostly needs exceptional objective information and general subjective information. Some of the relevant management tools associated with QM are force-field analysis, nominal group technique, affinity diagram, interrelationship diagram, tree diagram, matrix diagram, prioritization matrices, process decision program chart (PDPC), and activity network diagram (PERT, CPM, arrow diagram, AoN) (Besterfield *et al.*, 1999), to generate and treat soft data. Dale and Shaw (1999) listed them under M7, namely, affinity diagrams, relation diagrams, systematic diagrams, matrix data analysis, PDPCs, and arrow diagrams. According to Rao *et al.* (1996), the advanced tools are brainstorming, affinity diagrams (or structured brainstorming), process potential index C_p, process performance index C_{pk}, Taguchi's loss function, and design of experiment (DoE). Antony *et al.* (1998) suggested a "successful" methodology to the use of advanced statistical quality improvement techniques. The fundamental techniques for presenting performance measures are time series graphs, CCs, capability indices, Taguchi's loss function, cost of poor quality, and quality award criteria (Besterfield *et al.*, 1999).

In processing a large volume of data associated with customer expectations and needs, numerous tools such as affinity diagrams, tree diagrams, why-why diagrams, interrelationship diagrams, and cause-and-effect diagrams are suited. The process capability indices, C_p and C_{pk}, are the essential pieces of information because they indicate the propensity of a manufacturing process of respecting the product specifications. The quality function deployment (QFD) is a powerful planning and product design technique in translating customer needs and manufacturing constraints into product attributes and specifications. It successfully covers the areas like product design, engineering and production requirements, and product evaluation. Besterfield *et al.* (1999) maintain that, if an organization can properly implement QFD, it can improve engineering knowledge, productivity and quality, and reduce manufacturing costs, product development time, and engineering changes.

A systematic approach can yield very significant benefits in the long run. Deming's plan-do-study/check-act (PDSA/PDCA) is an excellent technique in monitoring and problem solving for continuous quality improvement where any brilliant ideas of individuals can be accommodated. However, to apply this properly, a good number of other tools and techniques are inviting. In other words, it integrates a few essential tools and techniques. In fact, any tool or technique should not be taken in isolation for use without a strategic disposition. Figure 1 defines the systematic use of various tools in different operational stages.

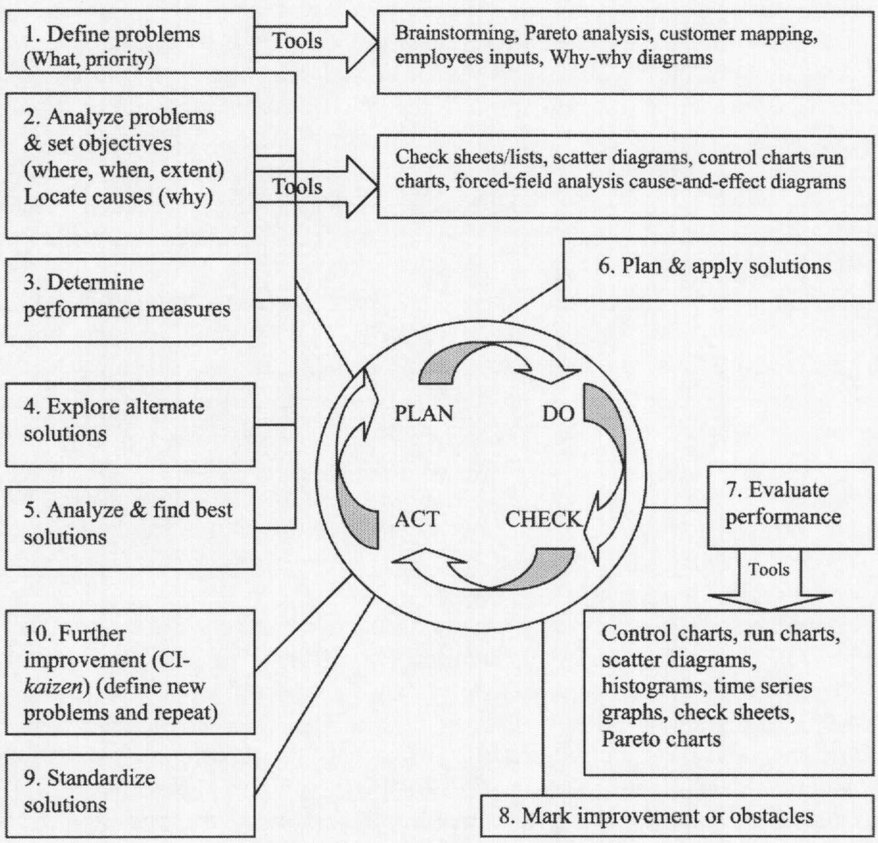

Figure 1.
Steps in application Deming's PDCA technique and associated tools

"Do-it-right-the-first-time (DRIFT)" is the fundamental slogan of QM/TQM. For that, quality is required to be introduced at the design level. The tools that have direct linkage with the introduction of new products are QFD, DoE, FMEA, and fault tree analysis (Spring *et al.*, 1998). Numerous other tools and methods such as computer aided (product/process) design (CAD), computer aided manufacturing (CAM), electronic data exchange (EDI), total productive maintenance (TPM), 5Ss housekeeping, finite element analysis (FEA), design for manufacture and assembly (DFMA), just-in-time (JIT), computer numerical control (CNC), and computer integrated manufacturing (CIM) are the modern ones.

The roles and benefits of those tools and techniques are explained in literature contributed by Antony *et al.* (1998), Besterfield *et al.* (1999), Dale and Shaw (1999), Motwani (2001), Powell (1995), Rao *et al.* (1996), Summers (2000) and Xie *et al.* (2001). The detail on role and benefits is beyond the scope of this article. However, a few points in this regard are given below.

The functions and activities of a manufacturing firm can be related to the following tools and techniques:

- *New product introduction* – brainstorming, DoE, QFD, cause-and-effect diagram.
- *In stage of production* – Pareto chart, process flow diagrams, control chart.
- *In assessing the process or product* – histogram, scatter diagram, pie chart, bar chart, etc.
- *In every stage of data collection* – check sheet or check list, capability indices, etc.

If applied correctly, they can provide repeatable and reliable results (Dale and Shaw, 1999). The basic tools make quality improvement and monitoring activities, and giving feedback to quality improvement team (QIT) much easier (Rao *et al.*, 1996). Essential to industry is to understand the distinction between a stable process and an unstable process. This is possible by developing CCs. The most powerful CCs are *r*- and *x*-bar charts (Duncan, 1974), which can be used jointly to present complex performance data in a simple form (Burney and Al-Darrab, 1998) to show the case management from special causes (Walsh, 2000) or training and development needs. Firms using more advanced tools can perform better than firms with less advanced tools (Powell, 1995).

By-and-large, QM or TQM is not limited to any type or size of the organization. However, due to lack of understanding and other pertinent constraints, SMIs are lagging behind their larger ones when it comes to introducing and adopting a new advanced technology or management concept, such as TQM (Moreno-Luzon, 1993). Spring *et al.* (1998) discussed the assessment methodology of the use of quality tools and techniques in new product design for any firms. They described a few useful tools and techniques.

To us, being the most vibrant partners in economic and technological development of a developing society, SMIs should be aware and understand the needs and benefits of applications of the modern methods. They should have the strength of the highly motivated management team with better managerial skills than large firms. From their case studies, Ghobadian and Gallear (1996) reported on SMEs that these firms could apply TQM with considerable success and they possess their inherent strength. We are thus motivated to explore the level of use of QM tools and techniques in small and medium manufacturing firms. Our basic questions in this study are as follows:

- Do SMIs apply the basic and advanced QM tools and techniques? Are the SMI manufacturers really about the QM practices?
- Are they aware about benefits of application of QM tools?
- In which area do they put more emphasis to assess their performance?
- Do they organize/manage adequate training for their employees?

For our study, we obtained data from Malaysian SMIs. Malaysia is a fast growing newly industrializing country (NIC). The manufacturing sector as a whole, and SMIs in particular, have a great contribution to the economy (NPC, 1993, 1994). The importance of its manufacturing sector or sub-sectors will increase continuously, and the firms have to strive hard in order to achieve the country's Vision 2020. In 1999, the external trade value of manufacturing goods exceeded 80 percent of its total. The share of the manufacturing sector in GDP continued to increase with a slight difference of 35.3 percent in 1999 (1993: 29.4 percent and 1997; 35.7 percent).

The lion's portion of the manufacturing firms fall under these two (SMI) categories. Most of the companies listed in the Federation of Malaysian Manufacturers (1999) Directory were exporting their outputs around the world. According to the *FMM Directory*, SMI employed 59.5 percent of 668,174 employees (small 27.4 percent and medium 32.1 percent). By annual sales value, SMI's share was 64 percent (small 44.4 percent and medium 19.6 percent). SMIs are supporting the large industries as well as exporting their products to different countries. Reportedly, there are several thousand SMI firms in Malaysia across different industrial groups. However, so far no such study has been conducted on these SMIs. Indeed, studies on QM/TQM implementation in SMIs are relatively scarce (Anderson and Sohal, 1999; Yusof and Aspinwall, 2000).

Methodology

After a few field visits and extensive literature survey, a research framework was developed to gather data as required for an empirical study. A short and easy-to-reply questionnaire was developed and mailed in two stages to a total of 663 SMI firms listed in the *Directory of Small and Medium Industries Development Corporation* (SMIDEC, 1999) and the *Directory of the FMM* (1999) between May and August 2000. To generalize the findings of the study, the

SMI firms were taken randomly (Balnaves and Cupit, 2001; Miah, 1993; Muda, 1998; Rea and Parker, 1997). Each mailing contained a forwarding letter stating the importance and objective of the study that was duly signed by a senior professor, a self-addressed prepaid return envelope, and the questionnaire itself. In some cases, short meanings of the items were placed to help the user to understand the respective items. A five-point Likert type scale was used for several items in different sections. This scale was found enough to rate all relevant alternatives along the continuum for the respondents to express their opinions.

As measures of pre-test and validity of its contents, a few factories were visited and some relevant managers were interviewed. Later, around 25 copies of the questionnaire were sent to the manufacturers for their comments. Accordingly, the preliminary questionnaire was edited before making it final. These are the established practices of survey data collection (Balnaves and Cupit, 2001; Co *et al.*, 1998; Miah, 1993; Rea and Parker, 1997).

A survey study cab be more fruitful if the questionnaire is sent to the managers directly involved in the implementation of a system. However, it is not very simple to find the very appropriate person from the given contact persons in a directory. Further, this type of questionnaire covers numerous factors that do not fall within a single domain or discipline. Rather, it essentially covers a number of multidisciplinary items, where one person might not appear the very right one *per se*. The organization concerned could help much by furnishing the questionnaire to the right personnel. In this regard, care was taken to find the suitable person to answer the various items. We posted mails to general manager, production manager, plant manager, quality control manager, or plant engineer, according to the suitability of the available/listed contact persons.

In order to get a good number of replies, as a follow-up measure, e-mails were posted to a good number of firms. Approximately 68 mails were returned undeliverable. Out of 595 delivered mails, 82 were furnished by respondents and of them 63 were found complete/useful. This valid response rate is around 11.15 percent, which is far below our expectation (over 100). However, this response rate appears to be okay as this trend is prevalent in other parts of the world, even in developed nations. For instance, in Australia, the response was 62 out of 670 delivered mails (Anderson and Sohal, 1999); in the UK 23 out of 600 or 5 out of 835 (Wright and Burns, 1998); in South Korea 89 out of 889 (Whybark, 1997); in Singapore 110 out of 1,000 (Co *et al.*, 1998); in the USA 164 out of 2,771 mailed posts (Spencer *et al.*, 1994). However, in the case of selected or stratified industry class having world-class reputation or Japanese-owned plants, the response rate could be high. For instance, in Hong Kong, a survey on ISO 9000 registered companies showed that out of 171 electronic manufacturing companies 72 replied completely (Chin *et al.*, 2000), in India, based on earlier interactions, 38 responses were accepted out of 95

(Nagabhushana and Shah, 1999); in Egypt, in public-holding companies, 93 replies were accepted out of 320 companies (Salehuddin and Francis, 1998); and in the USA's Japanese-owned traditional plants having world-class reputation, 45 replies were accepted out of 75 companies targeted (Flynn *et al.*, 1997).

Data analysis and discussions

The objective of QM and the product characteristics determine the use of tools or techniques. Some tools or techniques appear simple over others in their development and interpretation. Nevertheless, a tool is a tool; it is the failure of an analyst if inappropriate messages are picked out from the use of it. The purpose of each of them is distinct and problem specific. So, no one tool should be irrationally preferred over others and none should be taken in isolation to serve the whole purpose. Again, there is no alternative for learned analysts to draw the right kind of conclusions from the application of a tool.

Certainly, not all tools or techniques are required in one firm. However, some of the tools and techniques are commonly (even frequently) used, for example, cause-and-effect diagram, Pareto chart, quality CCs or histogram for quality performance monitoring and improvement, and some others can be used less frequently (say, QFD, benchmarking). Some of the techniques are used, for example, FMEA, QFD, and design for manufacturability (DfM), in the design and development processes. Different CCs and process capability indices are used in controlling manufacturing processes. Non-production related functions or subjective decision areas, say clerical work and administrative activities, are not covered by those groups of tools. But TQM is a result of both subjective and objective support systems. With all these in mind, the respondents were requested to show on a five-point scale how often a specific QM concept/tool was used in their organizations (1=has never been used, 2 = tried once or is considering, 3 = occasionally used, 4 = regularly used, 5 = part of the organizational policy or standard operating procedure (SOP)).

By using SPSS software, a few statistical tests, namely, chi-square goodness-of-fit test, one-sample Kolmogorov-Smirnov test, Friedman analysis of variance (ANOVA) test, Kendall's *W* test, and Cochran test have been conducted to analyze the survey data. For all the tests, significance interval of 95 percent was used and the outcomes were developed based on 10,000 sample tables (simulations). The outcomes of those tests are presented in the following tables with short discussions.

The median of data is the more appropriate measure of central tendency for ordinal data than mean. In case of a Likert scale, which generally associates numerical values with ordinal data (here 1-5), this permits a researcher to calculate an arithmetic mean that rather provides more and proper information within a category than the median (Rea and Parker, 1997, p.154). Here, the mean values cannot be used to compare the levels of different categories. The same is the role of standard deviation values. However, ordinality affords a researcher the ability to rank the data, not the ability to manipulate the data arithmetically. Therefore, both mean and mean rank as measures of central tendency, and standard deviation and chi-square values as measures of dispersion are presented here.

Company profile

The definition of small-and-medium industries (SMIs/SMEs) varies from country to country (Gustafsson *et al.*, 2001). In Malaysia, an industrial unit which has employed a maximum of 150 full time workers and whose annual turnover does not exceed RM25 million (USD 6.56 million, RM3.8 = 1USD) is termed a small or a medium industry. A firm falls into the small industry category if it employs 50 full time workers and makes a turnover below RM10 million. Any industry beyond these limits, but falling within the former definition, is termed as medium industry.

In our questionnaire, we requested for data/information on quite a few things in several sections. In the following paragraphs we give those data/information and their implications (inferences).

According to *FMM Director* (1999, p. A11), the largest industry sub-sector in Malaysia is electrical and electronics (22.6 percent), followed by food, beverage and tobacco (16 percent), chemical (14.3 percent), fabrication of metal (12 percent), plastics (9.3 percent), and the rest is other industry sub-sectors. We did not send the questionnaire to food, beverage and tobacco industries. Our respondent profile is shown in Table I.

Over one-half (54 percent) of the responding industries fall within the category of medium industry. In other words, the medium sized firms were more responding than small category firms. They might have better skilled manpower to furnish this type of questionnaire. The extent of direct labor force was seen 77 percent and the indirect manpower was the rest, 23 percent. The size of the overhead staff was almost one fourth of the total staff.

In Malaysia, manufacturing industries are mainly privately owned. This is reflected from the response of the most respondents (Table I). However, this is a very simplified conclusion based on this survey, as "family" owners might not come with a number of replies. Most of the sample industries (76 percent) were producing industrial products. As we have surveyed upon manufacturing industries, this is quite obvious. In other words, SMIs are mainly the suppliers to large manufacturers. Therefore, in assuring quality outputs from a large manufacturing system, this assurance must be done at the suppliers' (SMIs) points. Other surveyed industries were producing products for end users (customer products) or both industrial and customer products as we asked for.

Manufacturing processes

Respondents were also seen according to their manufacturing/production processes into several prescribed categories. Since many SMIs do not design the products for themselves (Gustafsson *et al.*, 2001), most of them go for some

	No. of respondents	Percentage
Industry sub-sectors		
Electrical and electronics	23	37
Plastics	11	17
Metal fabrication	9	14
Chemical	6	10
Basic metal	4	6
Machinery, paper and packaging, wood based products, footware, automotive (each of two)	10	16
Years in business		
<5	10	16
5-10	17	27
11-20	22	35
>20	14	22
Number of direct labors		
<10	7	11
11-20	9	14
21-50	13	21
51-100	20	32
101-150	14	22
Ownership category		
Private	52	82
Family	8	13
Public	3	5
Turnover class		
Within 5 million (Ringgit Malaysia)	17	27
5-10 million	14	22
10-25 million	31	49
Over 25 million	1	2

Table I.
Industry classification, age in business, and employment pattern

fabrication and then do subassemblies for larger companies. Naturally, some companies are providing repair or other services in addition to their manufacturing activities. A few companies did mention it. Their replies can be seen in Table II.

On another query, respondents replied that their production type was mostly (43 percent) batch production (medium variety and medium volume). The

Type of the process	No. of respondents	Percentage
Fabrication and assembly	36	57
Assembly only	10	16
Continuous/intermittent (chemical)	7	11
Fabrication only	6	10
Repair/service	4	6

Table II.
Production processes

second highest producers' group had been producing under job-shop production (high variety and low volume) (36 percent). However, sometimes a combination of job-shop, batch type or flow-shop (low variety and high volume) production type was in action. This happens because companies producing industrial products for large manufacturers are receiving orders in batches. The companies producing under job-shop or batch production or a blend of these two are exposed to make-to-order (MTO) and/or assemble-to-order (ATO) manufacturing environments. The MTO environment is mainly characterized by the larger share of customer (large manufacturers or end users) opinions in product design. In ATO environment, manufacturers have the scope to produce some common modules based on the standard design prepared by their own designers. One pure type of manufacturing environment is engineering-to-order (ETO), which is characterized by customer dictation. In this case, the customer can supply the product design. The recent name of this type of environment is mass production, where the customer enjoys the scope to send the design of his/her products through the Internet as well and expect the product on his/her doorstep. Producers who have the scope to produce under make-to-stock (MTS) environment, for instance, chemical industries, can produce based on their own design. Here, the interaction between the customer and producer is minimal among the different manufacturing environments mentioned and the production system need not be quality sensitive either, for example, MTO environment. This signifies that QM criteria vary from one production or manufacturing type to another.

QM

Implementation of TQM or organized QM has a great bearing on the application of tools and techniques. Regarding practices relating to quality assurance, the overwhelming majority (74 percent) of the respondents replied that they had already implemented "some" in-house quality standards. Around 15 percent SMIs have planned for and the rest (11 percent) have not yet planned for implementation of in-house quality standard practices. Third party quality standards were implemented by 27 percent of the reported companies and 46 percent planned to do so. The remaining 27 percent SMIs had yet to plan for that remaining. About 48 percent of the companies were practicing benchmarking (partial), 17 percent planned for and the rest 35 percent not yet planned to do so. It seems that many SMIs (39 percent) were not well aware of the Malaysian body of quality standards. Only 26 percent of SMIs followed that standard and the remaining companies planned to relate their practices with their local standards.

However, TQM practices were undertaken, reportedly by 29 percent of the SMIs. Yusof and Aspinwall (2000) reported that many small businesses (in Britain) were still lagging behind in introducing new management techniques in general and TQM in particular. Taking QM applied in certain areas only, the TQM practitioners in Malaysia were about 61 percent. This figure makes an apparent contradiction between quality assurance practices mentioned earlier (74 percent). Nevertheless, quality assurance activities are undertaken to ensure the quality of customer products or services, but TQM is concerned with all activities related to product/services and in all other areas. So, the said contradiction does not hold. Dale and Duncalf (1984) reported that small business was less likely to have a coherent quality assurance policy and a quality department than large companies, which was again supported by Terziovski and Samson (2000). In many cases, small companies are forced to implement a quality system (Gustafsson *et al.*, 2001).

Adoption of TQM is not a matter of "quick-fix", and SMIs cannot afford to do so either – large ones too. Researchers also advised small companies not to implement TQM at once (Asher, 1992; Barrier, 1992; Henricks, 1992). Certain fundamental changes, including the structural adjustment and value-vision, are necessary for the implementation of TQM, which is a function of resource availability. In Asian culture and a multi-racial society where rigorous QM/TQM practices sounds very new, it may not be very easy to offer those kinds of changes. Understanding of TQM and its benefits and requirements are the other pertinent questions. However, in Malaysia, among the TQM practitioners, 33 percent said that they had integrated its concepts in almost all areas of the organizations and the other 67 percent applied it in certain areas, so far.

As 29 percent SMIs implemented TQM in their organizations, they are supposed to involve all parties in designing TQM plans. About 33 percent of respondents said that they involved employers, top management, employees, customers and suppliers. This is again in line with the study report of Dale and Duncalf (1984). Some 50 percent of organizations were practicing QM using cross-functional quality teams. The rest (17 percent) of the TQM practitioners were practicing this through TQM team technique training.

Training

Training or education is the cornerstone for individual and collective development. For adoption of QM/TQM or use of tools and techniques, continuing education and training is one of the most vital issues – for SMIs as well. SMIs possess some potential advantages in imparting training to their managers and workers in their workplace, such as each SMI has a small size of manpower, and they are working closely with each other. The scope of team formation and participation is easier than large companies. So, it is much easier for them to train and educate their employees, mainly locally, and the amount of time required to cascade training to lower levels is much shorter than that of large companies (Yusof and Aspinwall, 2000). However, as SMIs have a shortage of needed learned manpower (Nwankwo, 2000), and run under very constrained funding (Gustafsson *et al.*, 2001), there are some limitations that deserve mentioning. The major limitations are as follows:

- lack of knowledge and thus lack of clear vision of what training is really required;
- lack of resources or facilities in carrying out an effective training program or maintaining a training wing in the organization;
- difficult to afford absence of employees from workplace for training as there is poor scope for substitution;
- lack of space within organization and shortage of funds to be allocated for adequate training.

Around 58 percent of the respondents replied that they are imparting one or another type of QM training to their employees in different terms. The break-up of training programs is given in Table III.

Various types of training are listed and respondents were requested to place their experience on the basis of importance they attach. They ranked them (1 for most important, … 5 not at all important), and the findings are shown in Table IV.

From the Friedman ANOVA test, $\chi^2(3) = 110.21$. The Kendall's coefficient of concordance is 0.583, where both the lower and upper bounds are nil. A Cochran-Q test revealed that some type of training was more often than others, $Q(3) = 82.61, p < 0.01$.

ISO certification

It is appreciable to notice that about two-fifths (39 percent) of SMIs reportedly could obtain one or other ISO 9000 certification on their quality

Training frequency	n	(%)
Once in a year	32	55
1-3 times per year	16	28
More than 3 times per year	10	17
In-house	36	61
Ouside organization	3	6
Both	19	33

Table III. Training frequency in all firms

Areas	Mean rank (Australia)	Mean (STD)	χ^2 value	*K-S Z*-value
Literacy training (very basic)	3.71 (3.50)	4.03 (0.98)	54.40 (3)	3.03
Regular training	2.63 (2.60)	2.87 (1.23)	19.46 (4)	1.63
Induction training	2.03 (2.34)	2.29 (1.31)	28.03 (4)	1.90
On the job training	1.63 (1.57)	1.68 (1.03)	21.89 (3)	2.24

Table IV. Types of training and their ranks in all firms practices. Firms having any ISO 9000 (or QS 9000) standards do not reflect the actual quality practices. Rather, it is used to advertise to customers that those firms could provide documentation to support whatever claims they make about quality (Krajewski and Ritzman, 1999). Securing an ISO 9000 registration as an evidence of an organization's product quality assurance system is certainly appreciable, but it should not be taken as an end in itself. Many firms, reported by Goh and Ridgway (1994), from their survey findings, viewed certification to be the end point in their quality drive. Still the firm may lack QM, if it does not adhere to continuous improvement, which is vital for sustained quality assurance. A number of instances could be cited where many SMIs obtained one kind or another ISO certification, not from their own urge/motivation, but out of pressure given by their customers (large companies) (Chittenden *et al.*, 1996; McTeer and Dale, 1994; Mo and Chan, 1997; Rayner and Porter, 1991). However, once QM practices are introduced in a capital-intensive manufacturing firm, they can be sustained and improved for a longer period than a service firm. The role of ISO certification in TQM is, however, catalytic.

The basic SPC tools

The list of the basic SPC tools or techniques has been mentioned earlier. These tools are quite useful in any organization, be it large or SMIs. We have assumed that those tools and techniques are broadly used in SMIs (H_o). However, let us have a look to what extent they were being applied in those industries. SMI management provided the basic data on a five-point scale (Table V).

A Friedman ANOVA test generates $\chi^2(9) = 188.43$. The Kendall's coefficient of concordance is 0.332. A Cochran-*Q* test revealed that certain tools are used more often than others, $Q(9) = 168.57$, $p < 0.01$. From the above-derived information, it is apparent that these SPC tools are not much in use in SMIs. The check sheet, mostly tally sheet, which is the simplest tool for data collection, ranks first. The application of this tool is not enough unless the CCs (*r*-chart, *x*-bar chart, *p*-chart, etc.) are developed. The process flow charts

Table V.
Use of basic SPC tools in all firms

SPC tools	Mean rank	Mean (STD)	χ^2 value	*K-S Z* value	Validity of H_o
Check sheet	7.68	3.26 (1.15)	6.29 (4)	1.33	Yes
Process flow diagram	7.64	3.03 (1.49)	2.46 (4)	1.71	Yes
Histogram	6.12	2.32 (1.41)	31.52 (4)	2.26	No
Cause-and-effect diagram	5.87	2.22 (1.42)	31.21 (4)	2.24	No
Pareto analysis	5.30	1.83 (1.16)	62.32 (4)	2.77	No
P-chart	4.94	1.62 (0.97)	85.18 (4)	3.08	No
X-bar chart	4.69	1.62 (1.10)	90.57 (4)	3.02	No
R-chart	4.71	1.57 (1.03)	64.43 (3)	3.12	No
Scatter diagram	4.27	1.41 (0.82)	88.94 (3)	3.62	No
C-chart	3.77	1.21 (0.60)	74.67 (2)	3.78	No

and cause-and-effect diagrams are not really statistical tools. However, these are important to synchronize process elements and identify the redundant activities or causes behind something wrong.

However, examinations of the SMIs implement TQM in their organizations reveal that the basic SPC tools and techniques are significantly understood and applied there (Table VI). Table VI illustrates the central tendencies and dispersion of their practices compared to all industries together.

A Cochran-Q test reveals that certain tools and techniques are used more often than others, but better in use than all industries together, $Q(9) = 76.79$, $p < 0.01$. Again, the use of check sheet ranks first, followed by the process flow charts and cause-and-effect diagrams.

Management decision techniques

Use of the management tools and techniques facilitates the objective decision making. All of these tools might not be suitable for small industries, but medium industry can use them as part of their decision support system (DSS). We received the raw data on a five-point scale from SMI firms (Table VII).

From Friedman ANOVA test, $\chi^2(5) = 11.54$. The Kendall's coefficient of concordance is 0.037. A Cochran-Q test revealed that those techniques were of similar, but low level use, $Q(5) = 3.66$, $p < 0.01$. It is obvious that these

SPC tools	Mean rank	Mean (STD)	Median	χ^2 value
Check sheet	9.06	4.89 (0.32)	5.00	10.89 (1)
Process flow diagram	7.33	4.00 (1.28)	4.00	6.00 (3)
Cause-and-effect diagram	7.03	3.89 (1.23)	4.00	8.11 (4)
Histogram	6.06	3.33 (1.61)	4.00	3.11 (4)
Pareto analysis	5.44	2.72 (1.27)	2.50	2.56 (4)
X-bar chart	4.61	2.44 (1.34)	2.00	3.67 (4)
R-chart	4.53	2.17 (1.42)	2.00	6.00 (3)
P-chart	4.36	2.17 (1.25)	2.00	6.44 (4)
Scatter diagram	3.83	1.94 (1.11)	1.50	6.44 (3)
C-chart	2.75	1.39 (0.98)	1.00	16.33 (2)

Table VI. Use of basic SPC tools in TQM firms

Management tools	Mean rank	Mean (STD)	χ^2 value	*K-S Z* value
Deming PDCA	3.80	1.68 (1.16)	87.40 (4)	3.02
FMEA	3.70	1.78 (1.26)	81.68 (4)	3.03
Matrix diagram	3.54	1.52 (0.84)	66.21 (3)	3.30
Arrow diagrams	3.41	1.51 (0.98)	82.84 (3)	3.52
Tree diagram	3.32	1.32 (0.69)	64.67 (2)	3.86
Affinity diagrams	3.23	1.35 (0.90)	118.14 (3)	3.91

Table VII. Status of application of management techniques in all firms

TQM/QM tools are seldom used in SMIs. This reflects that their decision support system is still weak and highly subjective. They might be facing the shortage of the right kind of manpower to exercise objective decision making. This supports the generally said message that the country has a few industrial engineers.

In case of management tools too, firms with TQM are in a better positions than others as seen in Table VIII.

Friedman ANOVA test generates $\chi^2(5) = 14.30$ at $p < 0.01$. A Cochran-Q test revealed that those techniques were of similar but low level use, $Q(5) = 5.58$, $p < 0.01$. The above information reveals that TQM/QM practices are yet to be fully adopted in those organizations either, although in some cases they are somewhat more systematic than others. This reflects that their DSS is still weak and highly subjective. They also might be facing the shortage of right kind of people to collect and analyze factual data.

Advanced techniques

How some advanced techniques, such as benchmarking, QFD, and concurrent engineering, or SPC as a whole and TQM as a whole are viewed in SMI firms, had been checked through a five-point scale. Some sort of inspection is done before delivering their products to customers. From our field visit, we really doubt if the other tools and techniques are widely in use. After processing the basic data, the following information has been developed (Table IX).

From the Friedman ANOVA test, $\chi^2(8) = 102.91$. The Kendall's coefficient of concordance is 0.204 and p-value is nil. A Cochran-Q test revealed that certain management practices are a bit more frequent than others, $Q(9) = 81.15$, $p < 0.000$. If we look into the mean, standard deviation, and χ^2 values, it is evident that those are narrowly applied in these firms. Under those circumstances, hinted in the case of SPC and management tools, one can hardly expect a good level application of advanced tools or techniques. That is truly portrayed in Table IX. Although, for instance, SPC ranks a bit higher in position compared to TQM, it is still in a nascent state, let alone the company wide TQM practices with the strong participation of each and everyone.

Do SMIs apply inspection-sampling technique? Despite its less significance in a TQM environment, however, in some industries where large volumes of some items are produced, inspection sampling could be a useful technique.

Table VIII.
Status of application of management techniques in TQM firms

Management tools	Mean rank	Mean (STD)	Median	χ^2 value
FMEA	4.56	2.78 (1.67)	2.50	4.22 (4)
Tree diagram	3.69	1.61 (0.85)	1.00	6.33 (2)
Matrix diagram	3.36	1.67 (0.91)	1.00	10.89 (3)
Arrow diagrams	3.33	1.61 (1.04)	1.00	17.11 (3)
Deming PDCA	3.06	1.39 (0.92)	1.00	20.33 (2)
Affinity diagrams	3.00	1.56 (1.29)	1.00	16.00 (2)

Application of inspection sampling through development of operating characteristic (OC) curves certainly deserves some human skills. These firms assumed lack of that type of manpower and thus use of inspection sampling technique has found to be in a little range.

Application areas

To have a close look (and do some cross checking) we have examined the areas where these tools/concepts were applied. For this, we indicated the following ten areas (there was one open-ended question, "others, please specify"). We asked them to rank the following (Table X) on a five-point scale according to their relative importance (1 for least important … 5 for most important).

$\chi^2(9) = 121.10$. Kendall's coefficient of concordance is 0.214. A Cochran-Q test revealed that certain areas receive more attention than others, $Q(9) = 61.61, p < 0.01$.

For TQM firms, analysis is presented in Table XI.

$\chi^2(9) = 57.78$. A Cochran-Q test revealed that certain areas receive more attention than others, $Q(9) = 35.46, p < 0.00$.

Advanced techniques	Mean rank	Mean (STD)	χ^2 value	*K-S Z* value
Inspection sampling	6.84	2.98 (1.70)	8.18 (4)	2.06
Benchmarking	5.41	2.11 (1.59)	52.16 (4)	2.61
SPC	5.13	2.02 (1.43)	65.97 (4)	2.89
Capability measures	5.11	1.94 (1.34)	71.21 (4)	2.99
TQM practice	5.00	1.73 (1.19)	95.49 (4)	3.27
House of quality	4.79	1.76 (1.41)	118.98 (4)	3.58
Concurrent engineering	4.52	1.56 (1.04)	91.60 (3)	3.69
QFD	4.13	1.38 (0.94)	154.70 (4)	3.83
Taguchi methods	4.06	1.25 (0.67)	35.06 (1)	4.13

Table IX. State of application of advanced tools in all firms

Areas	Mean rank	Mean (STD)	χ^2 value	*K-S Z* value
In assembly operations	6.72	3.30 (1.50)	7.56 (4)	1.50
Fabricating parts	6.69	3.32 (1.57)	18.02 (4)	2.15
Raw material acceptance	6.68	3.22 (1.48)	6.13 (4)	1.78
Delivery service	6.44	3.10 (1.49)	7.08 (4)	1.62
Inventory management	6.20	2.94 (1.37)	4.70 (4)	1.54
Product design	5.23	2.56 (1.41)	6.92 (4)	1.53
Packing and packaging	4.99	2.41 (1.27)	19.46 (4)	1.42
After sale service	4.84	2.38 (1.58)	28.67 (4)	2.01
Conducting meeting	3.88	2.06 (1.06)	16.18 (3)	2.15
Maintaining office stationery	3.33	1.78 (0.87)	9.24 (2)	2.56

Table X. Areas of application in all firms

Table XI.
Areas of application in TQM firms

Areas	Mean rank	Mean	STD	Median	χ^2 value
Raw material acceptance	7.64	4.50	0.51	4.5	00.00 (1)
Product design	7.00	4.33	0.69	4.0	4.00 (2)
Inventory management	6.97	4.39	0.61	4.0	6.33 (2)
Fabricating parts	6.39	4.06	0.87	4.0	6.44 (3)
Delivery service	6.19	3.94	1.35	4.5	6.44 (3)
After sale service	5.56	3.61	1.54	4.0	8.11 (4)
Packing and packaging	4.97	3.44	1.29	3.0	2.44 (3)
In assembly operations	4.50	3.11	1.64	3.5	2.56 (4)
Conducting meeting	3.50	3.00	0.97	3.0	6.00 (3)
Maintaining office stationery	2.28	2.33	0.77	2.5	3.00 (2)

Organizational standing from the point of equipment, process and frame of mind

To produce quality goods or services, reliable facilities (equipment) and processes, clear-cut and up-to-date documentation, etc., that is, a smooth procedure and appropriate process are the prerequisites. We have tested those issues by asking several questions (Table XII). Like others, we asked them to rank those items on a five-point scale (1 for not at all … 5 for most suitable/often).

Table XII.
Compatibility assessment in all firms

Elements	Mean rank	Mean (STD)	χ^2 value	*K-S Z* value
Is your workforce flexible?	9.56	3.64 (1.18)	17.87 (4)	1.66
Is documentation clear and up-to-date?	9.25	3.60 (1.12)	22.48 (4)	1.57
Do you accept the need for continual change?	8.94	3.41 (1.12)	17.56 (4)	1.78
Is the facility (completely) reliable?	8.37	3.38 (1.04)	32.00 (4)	2.08
Do you emphasize importance of developing your product and processing reengineering?	8.34	3.35 (1.43)	5.18 (4)	1.71
Do you always achieve the shortest possible throughput time?	7.62	3.19 (1.05)	26.29 (4)	1.76
Are you committed to total quality and CI?	7.61	3.10 (1.50)	6.29 (4)	1.25
Are you committed to training?	7.50	3.18 (1.23)	7.71 (4)	1.54
Is the reduction of manufacturing costs appreciable?	7.25	3.22 (1.22)	9.14 (4)	1.39
Can you count manufacturing lead times measured in terms of days/hours?	7.06	3.02 (1.26)	12.64 (4)	1.55
Could you remove all sorts of waste/misuse?	6.49	2.87 (1.16)	23.43 (4)	1.86
Is inventory turnover satisfactory?	6.63	2.78 (1.29)	7.40 (4)	1.36
Is the shop floor a source of ideas?	5.92	2.65 (1.30)	17.40 (4)	1.61
Did you change a plan several times?	4.45	2.30 (1.16)	41.52 (4)	2.24

$\chi^2(13) = 109.52$. Kendall's coefficient of concordance is 0.134. A Cochran-Q test revealed that certain practices/items are used more frequently than others, $Q(13) = 123.28$, $p < 0.01$. This derived information reveals that SMIs are required to be stronger in improving human qualities and ensure their participation, creation of a conducive work culture, facility reliability, etc. for improvement of performance in different areas, viz. inventory turnover, and waste minimization.

Table XIII presents the analyses for TQM firms.

$\chi^2(13) = 49.15$. A Cochran-Q test revealed that certain practices/items are used more frequently than others, $Q(13) = 58.78$, $p < 0.00$. This derived information reveal that TQM firms still required to be stronger in improving human qualities and ensure their participation, creation of a conducive work culture, facility reliability, etc. for the improvement of performance in different areas, viz. inventory turnover, and waste minimization.

Performance measures

The ultimate use of any system or technique is evidenced by performance measures. There could be a lot of measures in areas of product and process design, production, customer's relation, supplier's relation, human resources, marketing and finance, R&D and management. All of them cannot be quantified. We have noted down some of the prominent tangible entities here (1 for very low, . . . 5 for very high). The general findings from all data are listed in Table XIV.

Elements	Mean rank	Mean	STD	χ^2 value
Do you emphasize importance of developing your product and processing reengineering?	10.19	4.72	0.46	3.56 (1)
Is documentation clear and up-to-date?	9.28	4.56	0.71	9.33 (2)
Do you accept the need for continual change?	8.94	4.44.	0.71	5.33 (2)
Is the facility (completely) reliable?	8.69	4.39	0.78	4.33 (2)
Are you committed to total quality and CI?	8.56	4.00	1.46	10.00 (3)
Is your workforce flexible?	8.36	4.33	0.84	4.00 (2)
Are you committed to training?	8.00	4.28	0.75	2.33 (2)
Do you always achieve the shortest possible throughput time?	7.44	4.17	0.71	3.00 (2)
Is the reduction of manufacturing costs appreciable?	7.03	3.94	1.11	4.66 (3)
Can you count manufacturing lead times measured in terms of days/hours?	6.86	3.94	1.62	9.11 (3)
Could you remove all sorts of waste/misuse?	6.49	3.78	0.88	2.33 (2)
Is the shop floor a source of ideas?	5.36	3.17	1.54	4.67 (3)
Did you change a plan several times?	5.06	3.11	1.45	3.67 (4)
Is inventory turnover satisfactory?	5.06	2.83	1.51	5.89 (4)

Table XIII. Compatibility assessment in TQM firms

From Friedman ANOVA test, the value of chi-square is $\chi^2(5) = 53$. A Cochran-Q test revealed that some factors are more often than others, $Q(5) = 24.93$, $p < 0.00$.

When the same measures in firms with TQM were evaluated, Table XV has been generated.

From Friedman ANOVA test, the value of chi-square is $\chi^2(5) = 23.48$. A Cochran-Q test revealed that some factors are more often than others, $Q(5) = 11.82$, $p < 0.03$.

From these pieces of information, it is obvious that firms with TQM and better use of tools and techniques could earn greater performance than average firms.

The case presentation

A few companies were visited during this study. However, a detailed case study was conducted in a company to:

- know about their understanding and awareness of the benefit of QM tools;
- determine the state of application of the basic SPC tools and management techniques; and
- experiment on the effect of applications of a few tools in the existing situation.

About the company

The company is a leading producer of standardized and other customized guide pins, mostly under the MTO manufacturing environment. However, in some cases, small batches of complex products were made under ETO environment, where these had been produced on customers' design. Most of the existing customers of the company included the electronic and computer peripherals

Table XIV. Performance level of all firms

Performance measure	Mean rank	Mean (STD)	χ^2 value
Overall competitiveness	4.29	3.98 (1.09)	40.10(4)
Sales	4.29	4.00 (0.92)	14.91(3)
Market share	3.39	3.44 (1.28)	12.32(4)
Cash flow	3.28	3.48 (1.20)	12.48(4)
Exports	2.95	2.94 (1.44)	8.35(4)

Table XV. Performance level of TQM firms

Performance measure	Mean rank	Mean (STD)	χ^2 value
Sales	4.64	4.72 (0.46)	3.56 (1)
Overall competitiveness	4.31	4.67 (0.49)	2.00 (1)
Cash flow	3.25	4.00 (1.08)	4.22 (3)
Exports	3.05	3.61 (1.38)	3.67 (4)
Market share	2.83	3.83 (1.04)	4.22 (3)

industries. Product specifications were often changing, meaning that a high variety of products was manufactured. For this type of firm, new product introduction (NPI) is a key feature. These guide pins were used to align and guide the placement of printed circuit board (PCB) onto the test jigs. The correct alignment of PCBs was very important because it would greatly affect the function of the test jigs and also the outcome. Therefore, the conformance to specifications "right-at-the-first-time" needs adequate attention. The test jigs were produced by other companies and then delivered to still other production companies that produce completed devices like VCR, VCD player, and CD player. The respective companies tested those test jigs as measuring devices if they really function well. Therefore, if the guide pins produced did not meet the specification limits set by next higher producers, the alignment of the PCBs would run, causing the test jig to fail. This in turn would cost the business of the whole chain. Nearly 80 people man the company and it was a relatively young firm founded in 1995. The company is living up to the highest expectations of its founding members. Therefore, the company has to focus on the following:

- if it pays due attention to quality design, or lack any clarity to and from the customer, or considers design as "black art" (Spring *et al.*, 1998) – only reliable products are to be produced;
- continuous quality improvement; and
- achieving the highest levels of performance by integrating response time, lower cost, reduced product introduction time, and productivity to company objective.

The case investigation was chosen to get an in-depth analysis and look in person into a real life situation. The field observations mainly concentrated on a few parts selected for investigation purposes. The study was based on the following framework (Figure 2) and the study was conducted according to the order of the contents depicted in Figure 3. It was examined how the customer

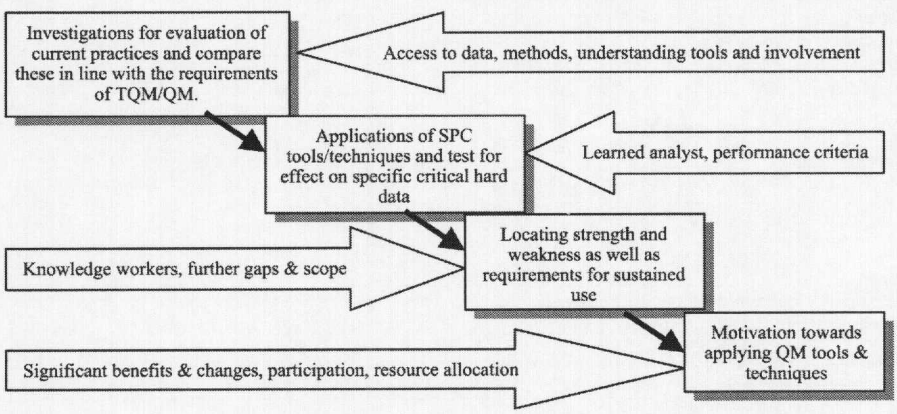

Figure 2. SPC application methodology

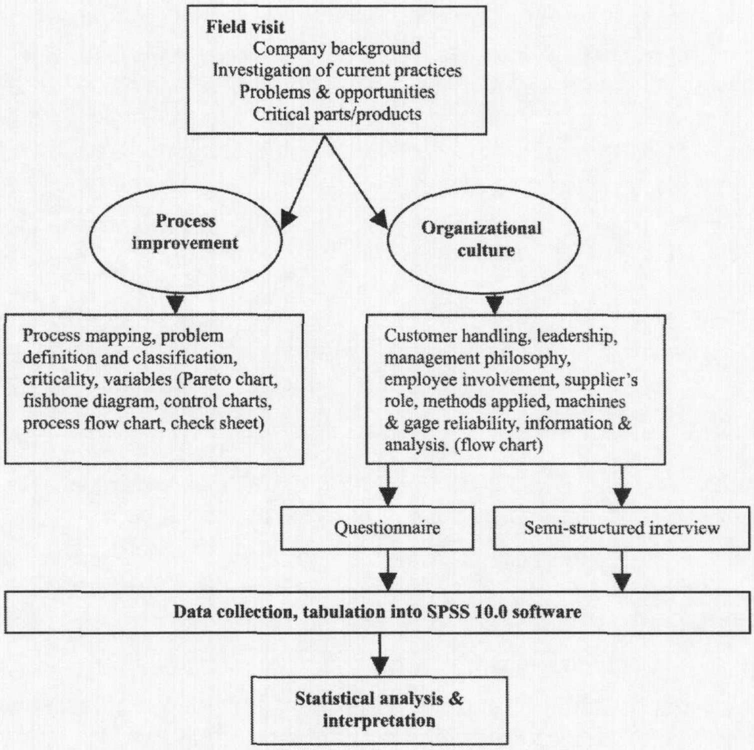

Figure 3.
Flow chart on research methodology

orders were addressed and incorporated into the product design and a methodical flow diagram has been developed. The significant causes behind any defects in producing customer products were located by developing the cause-and-effect diagrams, Pareto diagrams, CCs, and process flow diagrams. The analysis was also done to check process capabilities. The reliability and repeatability of measuring equipment were calculated. These were all based on observed and measured numerical data.

This study attempted to locate the strengths and weaknesses of the firm in deploying the SPC methodology. The ongoing QM practices including documentation were investigated and the cultural problems faced by the organization had been observed. For this, a number of structured, semi-structured interviews and a few questionnaire surveys had been conducted. Based on those findings, the above framework had been applied to use SPC and other tools and techniques.

Current practices

The company had been maintaining an increasing relationship with its customers. Before producing the whole lot ordered by a customer, they used to produce a prototype and reach a joint agreement with the customer. The necessary changes and modifications were made before sending the prototype for production of the whole lot, but they did not apply the QFD concept. In the inspection stage, both attribute and variable nonconformities on the prototype were checked based on counts of defect rates, not by developing CCs or applying sampling techniques. The main focus had been given on the part measurements, and if found to be out of tolerance limits, the process parameters including machining methods, measuring gage, worker skills were checked before proceeding to mass production. The quality personnel carried out in-process inspections at an interval of 15 minutes. The critical dimensions of the parts were measured using digital calipers. Attribute defects like scratches and obvious out-of-shape were also inspected. The frequency of inspection was relatively high during the machine start-up time until a stable production was observed. They used to do some inspection upon the incoming raw materials. About 10 percent of the final products had been inspected prior to delivery. In short, the company seems to have QM practices.

Before this study, the company did not apply any methodical SPC or other QM tools to locate the gravity and sources of problems. For instance, no cause-and-effect, Pareto diagram, CCs, and paper records have been developed. They used to apply post-action technique when the rejection rates were seen noticeably high.

Trial applications of a few tools

The conformance to specifications of guide pins has been experienced to be very sensitive. However, there was a constant threat before the company because the design of the parts/products was done at the customer's company. Product designers were mainly concerned about their product's performance and functionality and rarely took the process design and/or manufacturing constraints into consideration Therefore, if the drawings were just tossed over the wall of the manufacturing department, the company would have to modify the design to manufacture products on its shop floor or adapt the manufacturing conditions to accommodate the design specifications. This might result in poor quality products. This might also bring more errors, create gray areas and consume longer time for correction. What could be done to avoid or minimize this problem? The application of QFD technique or its house of quality appears to be useful for the company.

Upon receipt of the drawing from the customer, the project manager of the manufacturer would review the drawings before releasing it for production (Figures 4 and 5), and might consider the following questions:

- Are the requirements of the contract clearly defined? If not, sit down with the customer.
- Are there any unusual quality requirements? Check if it falls in any standard.

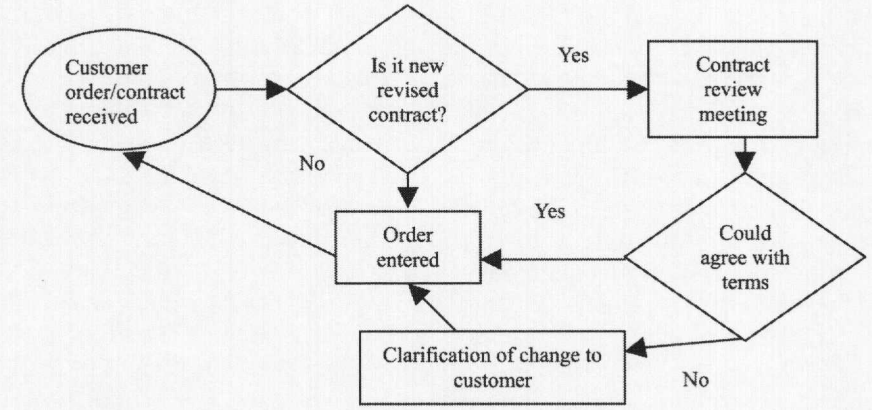

Figure 4.
Contract review flow diagram

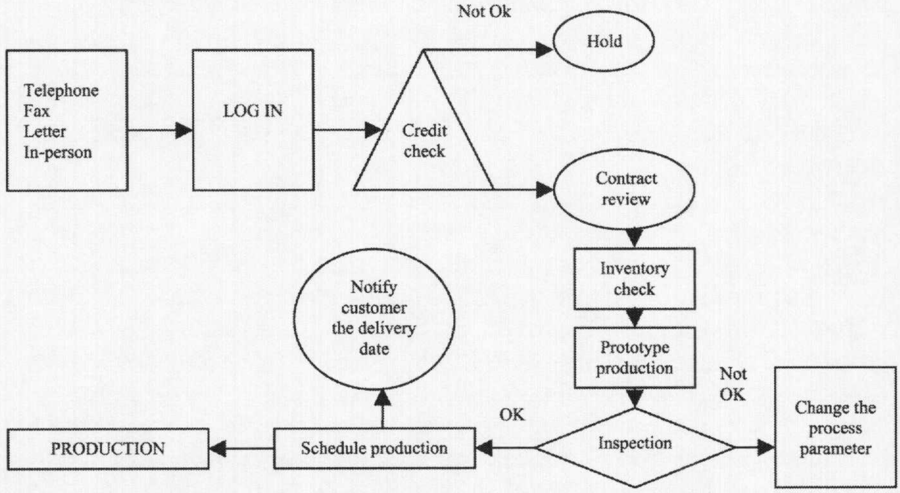

Figure 5.
Flow diagram for order entry and production scheduling

- Does the organization have the capability to meet the requirements? Check material, equipment, technology, qualified employees and the ability to deliver on time.

After a thorough examination of the entire production process through the application of some basic tools, for example, check sheet, flow chart, Pareto diagram, and CC, the company was convinced of the advantages of using those tools. For the sake of space constraint, all of them have not been presented here. A few basic tools were used and recommended. The development of a contract review flow diagram (macro level) has been recommended to make the design manufacturable (Figures 4 and 5) and a production detailed process flow chart (micro level) is presented in Figure 6.

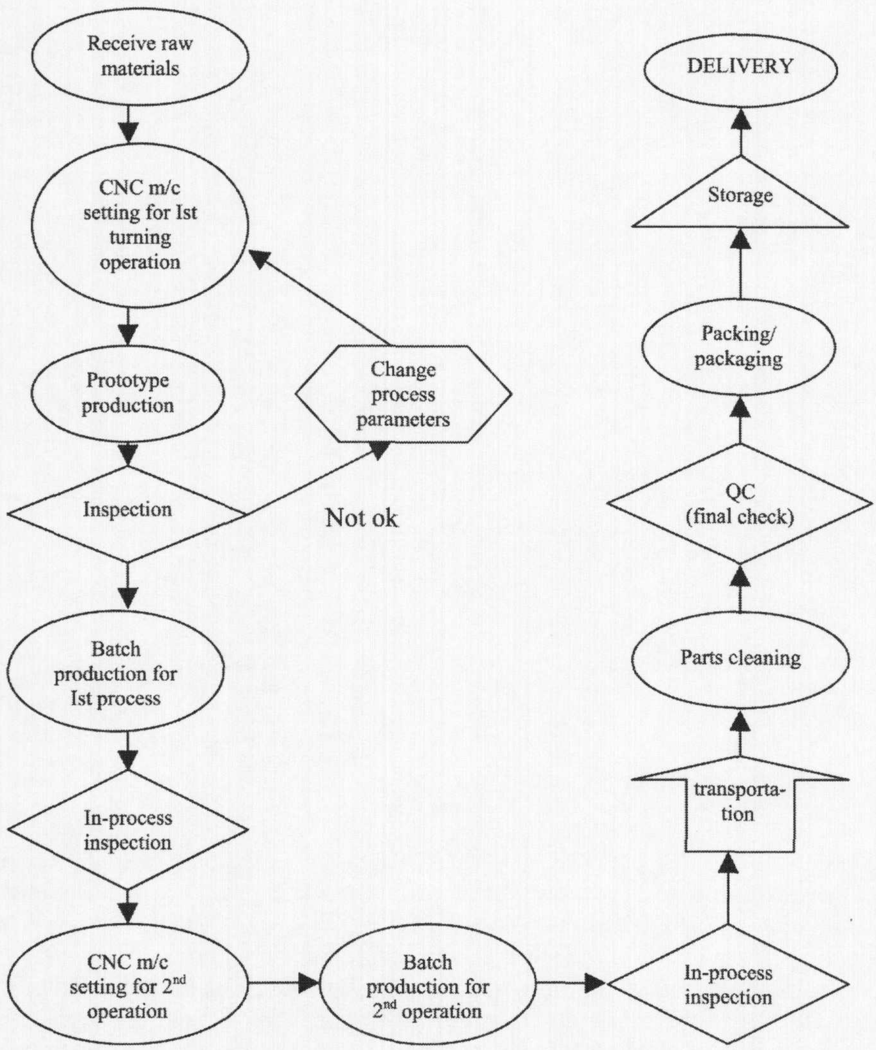

Figure 6.
The process flow chart for the production of guide pins

The Pareto chart could be used to depict the degree of various problems. Dr Josheph Juran has seen the problems as vital few and useful many (Besterfield *et al.* 1999). Several charts have been recommended to visualize the gravity of different types of critical problems. Two charts are exemplified here: one on types of defects and the other on rejection of different types of pins (Figure 7). The dimension out had appeared to be the most frequent problem where process capability should be investigated. In case of rejection rate, one type of guide pins had the highest rejection rate relative to others. This was again for the cause of dimension out. Therefore, Pareto charts are locating the problems and help to discover the cause of those problems.

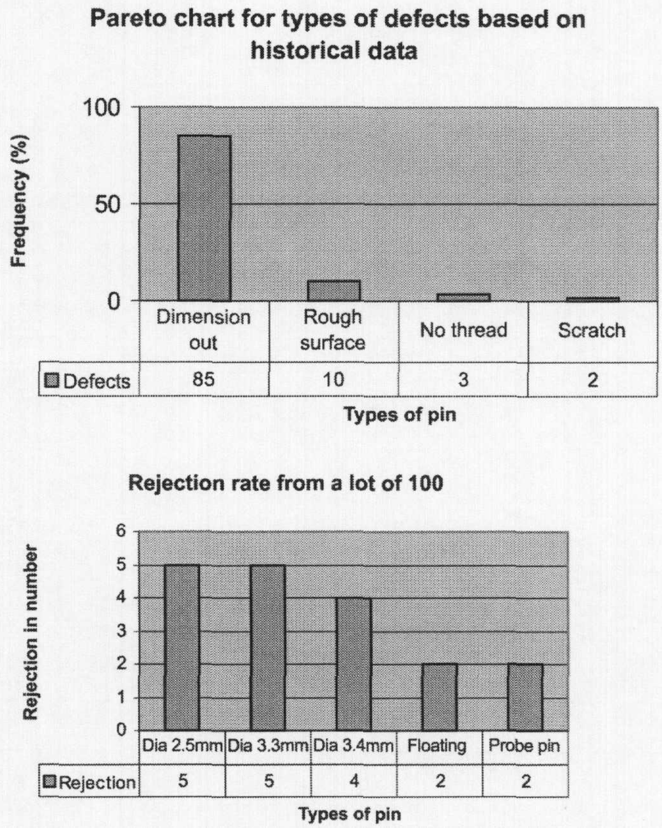

Figure 7.
Pareto charts for problem analysis

A good number of CCs, mostly *r*- and *x*-bar charts, were produced to check if the dimensions of different variables go beyond the process control limits. Among some of the critical processes and dimensions, the turning process to produce guide pins with sensitive perpendicular angle was taken under consideration. Certainly, the perpendicular angle could not be maintained at exactly 90°, since the angle depends on the cutting tool inclination angle and the parameter angle. Besides, vibration of the tool could also cause a rough surface finish, noticeably if the length of the material to cut exceeds three times the diameter of the rod. Those were displayed before the operators and explained how those could be used to locate the problems towards improvement.

A large volume of data was collected to make the distribution normal; the process capability charts were then developed if the processes were capable enough to produce products within the specifications limit. This was found most desirable as $6\sigma < (USL - LSL)$. A good number of C_p and C_{pk} values have been calculated. The values of C_p varied from 0.81 to 3.65 and that of C_{pk} from 0.73 to 3.14. The standard value of C_p considered was 1.33 (Summers, 2000). By observing the process capability charts or values, it could be concluded that some processes were good enough or exceeding expectations of meeting the customer specification and in some other cases they fell behind. The processes which were capable enough to produce products comfortably within the specifications could allow more room for process shifts while staying within specifications and increase customer interaction abilities. In cases where the value of C_p or C_{pk} fall short of 1.00 either, it was revealed that the process could not conform to the specifications, although the R and X-bar charts showed good sign. The varied values of C_p and C_{pk} indicated the inability of the process to be centered. When the causes were examined, it was clear that the equipment itself was too old and responsible and the causes were natural. The machine was producing parts with low accuracy. This could be explained by kurtosis value of 11.42 which was much larger than three. This was an indication of the necessity of change in technology. Earlier, it was suggested to monitor the process closely and do 100 percent inspection, which was really expensive. In short, the process capability indices identify the strength and weakness of a process and suggest the need for process innovation.

Through these few examples of statistical tools, it is evident that, these tools generate important information that could help eradicate the relevant problems and improve, not only the product quality alone, but also the quality of management practices. The management of the organization was impressed and then convinced to apply the SPC tools in their operations. The generation of these tools, especially in periodic manner, is not a troublesome job. Operators easily understand them. Without having some of these tools, it is really difficult to convince people towards better contribution and production of improved products.

The case presentation is not exhaustive

Quite a few other areas of QM were investigated through a questionnaire, semi-structured and structured interviews, and intensive field observations. The areas covered are management policy, methods, leadership, customer focus, employee involvement, supplier involvement, machine and measuring equipment, and information and analysis. The whole study report is beyond the scope of this paper.

Discussion and conclusion

Discussions on different issues were placed earlier along with the presentation of data. It is now obvious that QM cannot be ensured without the application of the appropriate tools or following some statistical methods. Firms with greater implementation of QM tools can secure better performance than those with less implementation. These are required in any firm irrespective of its size (SMI or large). Firms with TQM can accrue higher performance than firms without it.

However, both survey and case studies reveal that SMIs are still far behind in applications of various statistical and managerial methods or tools. They do not make full and efficient use of the tools and techniques available to them. The attitudinal problem is the main hindrance for this "sitting behind" status. The lack of industrial engineers or right kind of manpower coupled with lack of modern measuring methods and equipment and data processing devices are the other main reasons responsible for this. SMI management should understand that for their sustained growth and increased contribution to the stakeholders, objective decision making has no alternative. The so-called satisfactory product demand in the market is not enough if the defective rates, rate of rework or scrap, extent of non-value adding activities, introduction of new and varied products, etc. cannot be adequately manifested and brought to their possible and probable levels. Otherwise, the current happy market demand must mean a short-term growth and it will die quickly. Firms implementing TQM have greater use of modern tools and techniques. Therefore, TQM should be taken as "part of our life in this organization".

QM, importantly, TQM is not a matter of quick fix. SMIs are giving importance to the short-term achievements. They are doing business under a more constrained environment than large industries. However, SPC tools are very basic and can be applied for both short and long term goals in many small industries and all medium ones. This will ensure more benefits for them both in the short run and long run. In summary, the following few points should be emphasized.

- Quality practices should be accepted as part of life in SMIs for self benefit.
- Advantages of application of the basic tools should be realized.
- Starting from personnel in design to implementation and evaluation, well-drawn training and development should be provided for them to understand the importance of the application of basic and advanced tools, and be able to apply them.

The overall results of the case study have appeared rewarding, especially when considering the effect of using SPC methodology to evaluate both the manufacturing process and organizational culture in the firm. The full implementation of a technical system such as SPC was difficult due to the lack of resources and upper management support, and lack of statistical knowledge. The design and manufacturing managers and engineers require education and training to understand the importance and approach of deployment of SPC methods. Therefore, the case study focused on analyzing the current technical and management systems, and at the same time, identifies gaps for improvements. The case study was also directed to assist the managers with limited skills in statistics and manufacturing for tackling process quality problems more efficiently and effectively.

The use of various SPC tools to evaluate the process performance led the upper management to believe that SPC (statistical) techniques had merit in the company. Production personnel and quality control management recognized SPC as part of the philosophy of TQM that empowered employees to improve their processes. They saw that SPC was a way to improve their performance rather than just a CC hanging on the wall of manager's office.

Some of the advantages of the case study experienced by the organization are summarized as follows:

- Improved communication between engineers, managers and floor workers in using SPC for solving manufacturing quality problems.
- Assisting industrial engineers/managers with limited statistical knowledge by providing strategic analysis and interpretations for greater understanding of the results.
- Assisting operators in distinguishing special causes of variation from common causes of variation and thereby achieving consistency in greater product performance.
- A better understanding of the process by those who are either directly or indirectly involved in the process. SPC can be used to integrate the processes into problem solving structure within improvement teams.

However, the quality of a product does not only depend on the quality of the process, but also on the quality of management system. If management does not provide adequate resources and participation for improvement actions, continuous improvement of product/process quality would not be successful.

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