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# *Relationships between Total Quality Management Critical Techniques in Automotive Industry*

*Amir Azizi*
*Faculty of Manufacturing Engineering, Universiti Malaysia*
Pahang, 26600 Pekan,
Pahang Darul Makmur,Malaysia
amirazizi@ump.edu.my

***Abstract*—The concept of Total Quality Management (TQM) was introduced in Japan and United States. Most of researchers have focused on soft TQM (principles and concepts) while some of them have concentrated on hard TQM (tools and techniques). More attention to TQM techniques has recently been applied in the manufacturing sector especially in automotive industry. This study proposes nine critical techniques as hard TQM for automotive industry. The purpose of this study was to identify the relationships between nine critical techniques of TQM. The relationships have been identified using opinions evaluation of 30 quality experts at 10 automotive factories in Malaysia through questionnaires and statistical analyses. Among the TQM critical techniques, SPC with FMEA, QFD with APQP, and QFD with FMEA have highest relationship degree. This study strongly recommends implementing the soft TQM along with the hard TQM using the results of this paper based on the importance and relationship level of nine critical techniques in order to have a more effective and efficient quality system.**

***Keyword*—Total Quality Management; QFD; SPC; FMEA; Automotive Industry***

## I. INTRODUCTION

TQM is a philosophy that involves everyone in an organization and in a continual effort to improve quality and achieve customer satisfaction [1]. Reference [2] defined the TQM process as a total corporate focus on meeting and exceeding customers' expectations and significantly reducing costs resulting from poor quality by adopting a new management system and corporate culture. In other word, TQM is a customer-oriented approach, which uses statistical tools and techniques, the Plan-Do-Check-Act (PDCA) scheme to continuously improve the procedures. The implementation of TQM usually consists of philosophy from Deming's 14 points, Juran's 10 steps, and Crosby's 14 steps as soft TQM and the current tools and techniques as hard TQM [3]. The elements of TQM may be grouped into two dimensions: the management system (leadership, planning, human resources) and the technical system (TQM tools and techniques) [4]; or into the soft and hard parts [5]. The hard part of TQM, in fact, has a profound impact on organizational performance. For instance, the implementation of hard TQM resulted to increase product quality and to reduce the process cost at companies such as DuPont, Ford, Motorola, Xerox and General Motors. Other examples include the impact of six sigma in Motorola, Quality Function Deployment (QFD) in Toyota, seven simple tools in Honda, Statistical Process Control (SPC) in Motorola, and Taguchi methods in Mazda and Ford [6, 7].

The experience has shown that some firms fail when they implement TQM [8] because the implementation of TQM cannot be successful without the use of suitable quality management methods and techniques [9]. Reference [10] also concluded that TQM cannot be ensured without the application of the appropriate tools. Using the wrong ad redundant technique it causes to waste time, cost, and to be unsatisfied. Most researches focused on soft TQM [11]. Few studies have investigated on analyzing the relationships between the implementation of different elements of TQM and their performance [3, 12]. For example, Reference [13] examined the effect of organizational environment on TQM performance.

Although TQM techniques have been recognized useful but practically there are many difficulties in compelling people to implement it effectively. There are lots of studies upon TQM tools and techniques but only individually or separately on one or two techniques [14].

Quality Management cannot be effectively practiced without using a set of tools and techniques. Some tools and techniques are essential and critical to be implemented for a specific industry. Hence, the type of industry should be considered and analyzed too.

Whereas it is not economical for any industry to apply all TQM techniques and there is no effective study on relationship between the TQM techniques, this study focuses on the critical TQM techniques and identifies the relationship of these techniques. This study proposes the implementation of nine TQM techniques that have highest relationship/interaction using a survey and statistical analysis in automotive industries. Implementation of the TQM techniques considering their interaction and interrelationship can make quality management system a more value. It attains a higher quality, revenue and customer satisfaction.

## II. LITERATURE REVIEW

References [15] highlighted that the usage and selection of quality management tools and techniques are vital to support and develop the quality improvement process. Implementation of TQM needs to apply the critical TQM tools and technique [16].

Reference [17] revealed that the most important issues for a successful TQM implementation are:

1. Managerial understanding and commitment to the techniques and tools
2. Training that should be undertaken just in time and given in such a way to the employees that can practice in a step-by-step manner
3. Using a planned approach for the application of tools and techniques.

Reference [15] presented some of difficulties for usage of TQM tools as shown in Table I. For example, the encountered difficulties with the SPC are related to understanding, terminology, and resources.

TABLE I. ENCOUNTERED DIFFICULTIES OF USE OF TOOLS AND TECHNIQUES

| Tools \ Difficulty | *Time* | *Understanding* | *Terminology* | *Resources* | *Flexibility* | *Accuracy* |
|---|---|---|---|---|---|---|
| Cause and effect | | ✓ | | | ✓ | |
| Pareto | | | | | | |
| SPC | | ✓ | ✓ | ✓ | | |
| Quality costing | | ✓ | | | | ✓ |
| Departmental purpose analysis | | | | | ✓ | |
| Flow chart | | ✓ | | ✓ | | |
| FMEA | ✓ | | | ✓ | | |
| QFD | ✓ | | | ✓ | | |
| Check sheet | | | | | | |
| Histogram | | | ✓ | | | |
| Scatter | | | ✓ | | | |
| Graphs | | | ✓ | | ✓ | |

ISO 9000 is the foundation of TQM implementation. QS-9000 is an essential quality management system for suppliers of production parts, materials and services to the automotive industry. ISO/TS 16949 is the automotive ISO technical specification that applies the ISO 9001 standard to an automotive supplier. In addition to all the ISO 9001:2000 requirements, it also needs to meet additional automotive supplier tools such as Production Part Approval Process (PPAP) and Measurement Systems Analysis (MSA) [18].

### *A. Tools and Techniques for Quality Improvement*

Reference [19] proposed SPC to identify the factors that caused the convexity defect during the firing process. The convexity defect contributed 50% of the total number planarity defects or 27000m$^2$ of tiles per year. Design of experiment was also implemented by constructing the 23 factorial designs. The result presented that the convexity defect was reduced from 530m$^2$ per week to 315m$^2$.

Reference [20] applied SPC to study shocker seals defect in an automotive industry. Before SPC implementation, the rejection level of the shocker seal was 9.1%. Fish bone diagram was used to identify the root causes defect in shocker seal. X and R charts were applied to study the diameters of shocker seals. Finally, he showed that the level of production rejection has been reduced from 9.1% to 5% and achieved 0.953 of process capability.

A systematic and structured QM with the aid of relevant tools and techniques must be in action with regard to continuous improvement [10], because the tools and techniques play a key role in a company-wide approach to continuous improvement. Reference [15] founded that the implemented quality management tools and techniques at different times, which are presented in Table II.

TABLE II. HISTORY OF APPLICATION OF QUALITY MANAGEMENT TOOLS

| Tools \ Year | *1987* | *1988* | *1989* | *1990* | *1992* | *1993* |
|---|---|---|---|---|---|---|
| Cause and effect | | | ✓ | | | |
| Pareto | | | ✓ | | | |
| SPC | ✓ | | | | | |
| Quality costing | | ✓ | | | | |
| Departmental purpose analysis | | ✓ | | | | |
| Flow chart | | | | ✓ | | |
| FMEA | | | | | ✓ | |
| QFD | | | | | | ✓ |
| Check sheet | | | | ✓ | | |
| Histogram | | | ✓ | | | |
| Scatter | | | ✓ | | | |
| Graphs | | | ✓ | | | |

Reference [21] has mentioned the most widely used tools and techniques by firms as shown in Table III.

TABLE III. COMMONLY USED TOOLS AND TECHNIQUES

| The seven basic control tools | The seven management tools | Techniques |
|---|---|---|
| Cause and effect | Affinity diagram | Benchmarking |
| Check sheet | Arrow diagram | Departmental purpose analysis |
| Control chart | Matrix diagram | Design of experiments |
| Graph | Matrix data analysis | FMEA |
| Histogram | Process decision | Fault tree analysis |
| Pareto diagram | Program chart | Poka yoka |
| Scatter diagram | Relations diagram | Problem solving |
| | Systematic diagram | Quality costing |
| | | QFD |
| | | Quality improvement teams |
| | | SPC |

Reference [10] pointed out a large number of statistical tools and methods that were applied such as seven QC tools including Pareto diagram, histogram, scatter diagram, control charts, cause-and-effect diagrams (fishbone or Ishikawa diagrams), check sheets, and graphs. Seven MP tools should perhaps be called “supplemental seven QC tools” [22]. Nowadays, seven QC tools and seven MP tools are being implemented in many industries for instance, automotive, semiconductor, and industrial equipment [23]. Reference [21] showed that the selected firms with a higher level of implementation of critical factors use the TQM tools and techniques for a higher extent, which has a positive influence on TQM results. Reference [24] stated that the number of TQM tools is mostly 100 and come in various forms such as brainstorming, focus groups, check lists, charts and graphs, and diagrams.

Reference [25] proposed SPC to apply in a glass bottle manufacturing company to decrease process variations. Pareto chart was used to identify the defect, which occurred frequently. The major visual defect was blister defect while the physical defect was pressure failure. The fish bone diagram and action plan tools were constructed for each of the defects. The pressure failure and blister defect were reduced to 572 and 11 bottles respectively.

Reference [15] identified the use of quality management tools and techniques with various functions in Table IV.

TABLE IV. ANALYSIS OF TOOLS AND TECHNIQUES USED WITHIN EACH FUNCTION

| | Function | | | | | | |
|---|---|---|---|---|---|---|---|
| *Tools* | *Purchasing* | *Production* | *Sales* | *Customer Services* | *Marketing* | *Engineering* | *Company wide* |
| Cause and effect | ✓ | ✓ | | | | ✓ | |
| Pareto analysis | ✓ | ✓ | | | | | |
| SPC | | ✓ | ✓ | | | | |
| Quality costing | | | | | | | ✓ |
| Departmental purpose analysis | ✓ | ✓ | ✓ | ✓ | | | |
| Flowcharting | ✓ | | ✓ | ✓ | | | |
| FMEA | | | | | ✓ | ✓ | |
| QFD | | | | | ✓ | | |
| Check sheet | ✓ | ✓ | ✓ | ✓ | | | |
| Histogram | | ✓ | | | | | |
| Scatter plot | | ✓ | | | | | |
| Graphs | ✓ | ✓ | ✓ | | ✓ | ✓ | |

Reference [26] introduced the most common TQM tools as shown in Table V.

TABLE V. TQM TOOLS

| **TQM Tools** |
|---|
| Pie Charts and Bar Graphs |
| Histograms |
| Run Chart |
| Pareto Charts |
| Force Field Analysis |
| Cause and Effect, Ishikawa or Fishbone Diagrams |
| Focus Groups |
| Brainstorming and Affinity Diagrams |
| Tree Diagram |
| Flowcharts and Modeling Diagrams |
| Scatter Diagram |
| Relations Diagram |
| PDCA |

Reference [27] applied SPC in Oil and Gas Company to monitor the difference between the targeted and measured energy consumption. Reference [28] implemented SPC in a tiles manufacturing company to reduce the defect rate of the ceramic tile. The applied Pareto chart showed that the crack was the defect with highest frequency indicated by 60.9%.

Reference [29] listed out 12 tools and techniques as shown in Table VI.

TABLE VI. TWELVE TOOLS AND TECHNIQUES FOR TQM

| **Twelve TQM Tools** |
|---|
| Failure Mode and Effects Analysis (FMEA) |
| Statistical Process Control (SPC) |
| Graphs |
| Histograms |
| Problem-Solving Methodology |
| Pareto Diagrams |
| Cause and Effect Diagrams |
| Quality Costs |
| Internal Audits |
| Flowcharts |
| Scatter Diagram |
| Benchmarking |

## B. *Quality Tools and Techniques in PDCA*

Reference [23] studied on the organizational levels and complexity of QC tools in two types. Type I processes that are independent and static are the proven world of QC circles while type II processes are moderately complex and have static interactions. Tree diagram and matrix data analysis form the basis of QFD and Voice of Customer (VOC) are presented in Fig. 1.

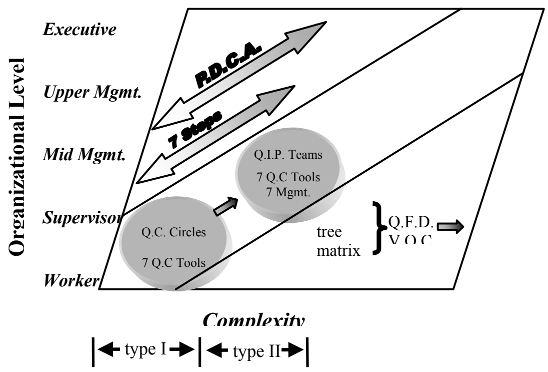


Fig.1. Complexity of 7 QC and 7 M Tools [23]

The PDCA cycle is analyzed using seven-step method and 5W's + 1H including: what, why, when, where, and who + how as shown in Fig. 2 [23].

Deming's PDCA is an excellent technique in monitoring and problem solving for continuous quality improvement where any brilliant ideas of individuals can be accommodated. In fact, any tool or technique should not be taken in isolation for use without a strategic disposition.

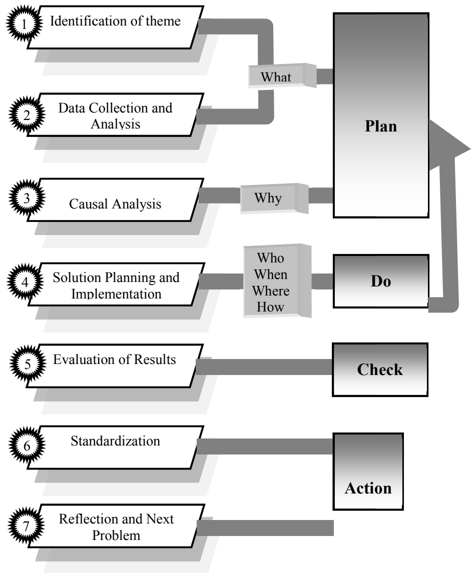


Fig. 2. PDCA and Seven Steps

Fig. 3 illustrates the systematic use of various tools in different operational stages by Deming's PDCA cycle [10].

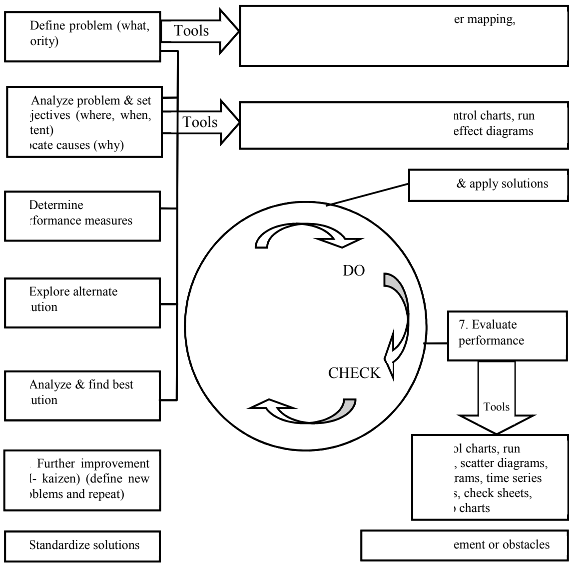


Fig. 3. Tools and Techniques in PDCA

For example, brainstorming and Pareto analysis are assigned to Plan section in PDCA while control charts, check sheets, graphs and diagrams are applied in both sections: Plan and Check.

*C. Five Core techniques of TQM*

All automotive firms should be familiar with the five core techniques of TQM that are used in conjunction with ISO/TS 16949 as shown in Table VII [29].

TABLE VII. FIVE CORE TECHNIQUES

| Five Core Techniques |
|---|
| APQP - Advanced Product Quality Planning |
| PPAP - Production Part Approval Process |
| SPC - Statistical Process Control |
| MSA - Measurement System Analysis |
| FMEA - Failure Modes Effects Analysis |

Reference [30] conducted a process capability analysis for boring operation. X and R chart were constructed to analyze and assess the statistical stability of the boring operation.

Fig 4. presents that how the five core techniques of TQM are related to ISO-9001 and QS-9000 standards [31].

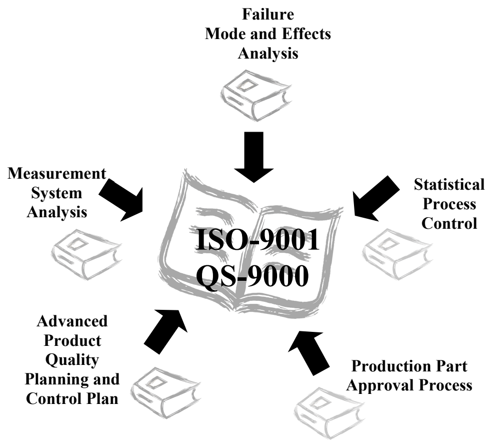


Fig. 4. Five Core Techniques of TQM are related to ISO-9001 and QS-9000

*D. Introduction to TQM critical techniques*

Nine TQM critical techniques are selected considering QS9000 and ISO TS16949:2002 requirements through literature review and survey on the automotive industries. These nine TQM critical techniques are comprised from; five core techniques including APQP, PPAP, SPC, MSA, FMEA, and two lean manufacturing techniques: 5S and Kaizen according to Toyota Production System (TPS), and two other techniques that are QFD and MP. QFD is a powerful tool to identify the customer needs, and MP includes a set of designing and planning tools as a modern quality tool.

FMEA has evolved gradually since its inception in the aerospace industry in the mid-1960s. Like FMEA, the root of the QFD began in the mid-1960s. Both QFD and FMEA address customer requirements in terms of actual and perceived functions of the product or service. QFD and FMEA have been introduced as the specialist and critical techniques in new product design and development process [31].

The TQM critical techniques are useful for designing, planning, analyzing, problem solving, controlling and continuous improvement. In this study, SPC includes the seven quality control tools, and MP tools comprise seven Management tools. The techniques that have direct linkage with the introduction of new products are QFD, FMEA, and fault tree analysis tool [32].

Reference [10] showed usage rate of basic SPC tools in Malaysian SMEs in Table VIII that implement TQM. These results reveal that the basic SPC tools and techniques are significantly understood and applied in the Malaysian firms.

TABLE VIII. USE OF BASIC SPC TOOLS IN MALAYSIAN FIRMS

| SPC tools | Mean rank | Mean (STD) | Median | $X^2$ value |
|---|---|---|---|---|
| Check sheet | 9.06 | 4.89 (0.32) | 5 | 10.89 (1) |
| Process flow diagram | 7.33 | 4 (1.28) | 4 | 6 |
| Cause and effect diagram | 7.03 | 3.89 (1.23) | 4 | 8.11 (4) |
| Histogram | 6.06 | 3.33 (1.61) | 4 | 3.11 (4) |
| Pareto chart | 5.44 | 2.72 (1.27) | 2.50 | 2.56 (4) |
| X-bar chart | 4.61 | 2.44 (1.34) | 2 | 3.67 (4) |
| R-chart | 4.53 | 2.17(1.25) | 2 | 6 |
| P-chart | 4.36 | 2.17 (1.25) | 2 | 6.44 (4) |
| C-chart | 2.75 | 1.39 (0.98) | 1 | 16.33 (2) |
| Scatter diagram | 3.83 | 1.94 (1.11) | 1.50 | 6.44 (3) |

Typically, every tool has its own strengths and weaknesses. The effects and side-effects of each tool must be understandable to succeed, then the integration of tools should be investigated to combine the right tools in the right ways at the right times.

## III. METHODOGY

This study gained data through E-mails, fax, posts and interviews by 30 quality experts of 10 selected companies in ISO-certified firms in Malaysia automotive industry.

The quality experts as decision makers include quality assurance manager, quality control engineer, quality improvement personnel, and other related team such as industrial engineering, quality auditing, quality training. These quality experts play an active role in the quality strategy and possess the knowledge that is required to answer the questionnaire through training.

The questionnaires were mailed directly to quality managers of the selected companies. A cover letter was included in explaining the purpose of the study, along with the questionnaire and a stamped return envelope. The questionnaire was designed with respect to the objectives of study. The process of developing the questionnaire was completed with a pilot study which it was used to modify and eliminate the number of techniques of TQM and the criteria as decision parameters to find the critical techniques and significant parameters in automotive industry by consulting with academic lecturers and quality experts who had experience in TQM implementation. Experts were consulted to ensure that the questions were properly phrased. Then the TQM critical techniques were defined briefly in glossary section of questionnaire to help the respondent to understand the respective items.

The steps of doing this research are illustrated in Fig. 5. This study employed questionnaire including the pairwise comparison matrices. This survey asked about companies' common usage of tools, executives' satisfaction with those tools that they use, and the suitable interaction and interrelationship of these tools and techniques.

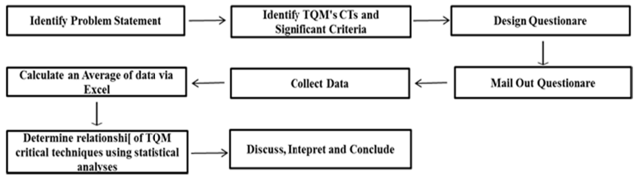


Fig. 5. Research Flowchart

This study used five-point scale as shown in Table IX for finding the relationship and interaction between TQM critical techniques.

TABLE IX. FIVE-POINTS SCALE

| | |
|---|---|
| Very Unimportant | 1 |
| Unimportant | 2 |
| Neutral | 3 |
| Important | 4 |
| Very Important | 5 |

## IV. RESULTS

The questionnaires were answered by three quality skill experts in each automotive company. Most of the selected experts especially for interview were quality assurance manager, quality control engineer, and quality auditor.

### *A Data Analysis*

The categories of automotive factories under this study presents that 70% were large and 30% were as Small and Medium Enterprises (SMEs) as shown in Fig. 6.

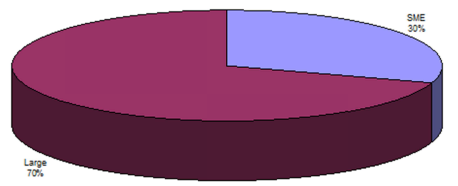


Fig. 6. Categories of Companies

Fig 7 presents that 70% of companies were local and the rest were foreign as shown in Fig. 7.

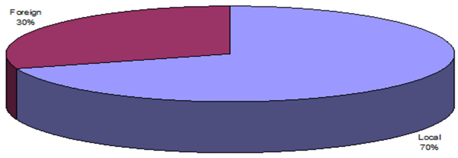


Fig. 7. Types of Companies

The experts' features were significant for this study because their idea were too critical to find the priority and interrelationship of TQM critical techniques. Thus, these features are analyzed through four categories: (1) involved teams' percentage; (2) expert's experience percentage; (3) expert's education percentage; (4) types of experts' designation.

Fig. 8 presented the distribution percentage of teams in this study. It reveals that 47% was related to quality team, 20% to quality auditing, 20% to industrial engineering, and 13% to quality training.

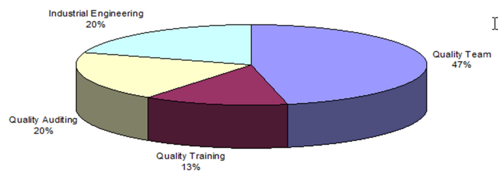


Fig. 8. Category of Teams

The expert's experience percentage is shown in Fig. 9. The majority of experts had 5-7 years' experience, indicated by 30%.

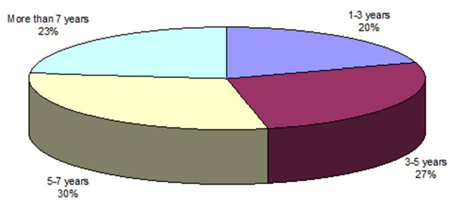


Fig. 9. Experts' Experience

Fortunately 83% of experts were educated with degree level as shown in Fig. 10.

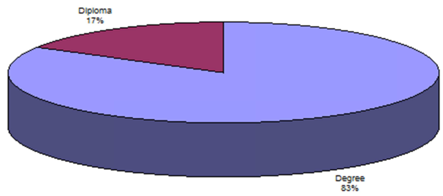


Fig. 10. Experts' Education

Fig. 11 presents the designation types of experts; 26% for quality assurance manager, 20% for quality assurance engineer, 20% as senior quality assurance engineer, 17% as quality assurance executive, 10% as quality control engineer, and 7% as quality improvement member.

Most of experts in quality team had 5-7 years' experience with degree level as quality assurance manager.

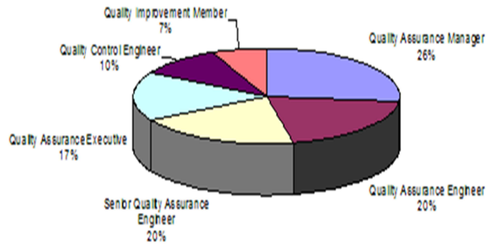


Fig. 11. Experts' Designation

## B. *Interrelationship between each tool with other tools of TQM critical techniques*

36 pairwise comparisons have been conducted from each expert to find the relationship between nine TQM critical techniques. Hence, 1080 pairwise comparisons are completed through 30 experts.

The findings from this survey have shown the interrelationship between each tool with other TQM critical techniques. For example, the interrelationship between QFD and others is exhibited in Fig. 12. It shows QFD has highest interrelationship with APQP.

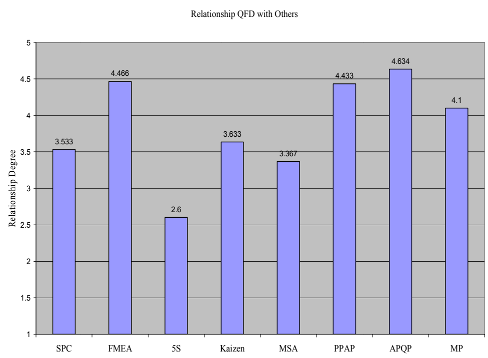


Fig. 12. Interrelationship QFD with other TQM critical techniques

## C. *Highest relationship between TQM critical techniques*

The highest levels of relationship between nine TQM critical techniques are presented in Fig. 13.

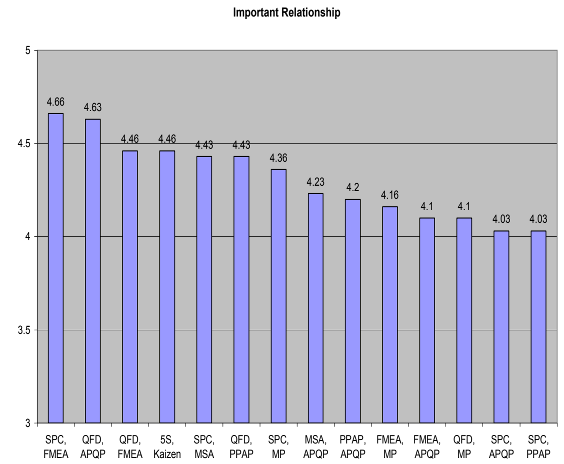


Fig. 13. *Highest Relationship between TQM Techniques*

For example, SPC with FMEA, QFD with APQP, and QFD with FMEA have the highest degree of relationship rather than other techniques.

## V. CONCLUSION AND RECOMMENDATION

This study identified nine critical techniques of total quality management in automotive factories as a means of increasing awareness of implementation of total quality management's tools and techniques. The results have displayed that the degree of interaction and relationship of these TQM techniques for implementing together. The relationship between TQM critical techniques has a significant role for increasing productivity and reducing costs. The integration of them can generate a sustainable competitive advantage. It helps making a higher performance of quality management system. This study recommended implementing all nine TQM critical techniques as an integrated model based on their relationship to have more effective implementation. This is the efficient way for achieving a higher value and surviving in World class competitive markets. Thus, top quality manager can make an appropriate strategy for successfully implementing the TQM Techniques with respect their relationship in order to reduce cost and increase productivity.

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## BIOGRAPHY

**Amir Azizi** is a senior lecturer at Universiti Malaysia Pahang. He received BSc. degree from Iran in 2005, MSc. from Universiti Putra Malaysia in 2007, and Ph.D. in industrial engineering from Universiti Sains Malaysia. He has published journal and conference papers more than 40. He has the industrial working experiences since 2002. He is a member of editorial and advisory board of five international journals and he also is a reviewer of some international journals. He was the chairperson of several international conferences too. His research interests are on lean production system, total quality management, supply chain management, operation management, project management and manufacturing systems for modelling under uncertainties of production environments. He gained ASME award for the best paper at international student conference in 2006, and doctorate fellowship award in 2008. He is a member of ASME, IIE, and IAENG, IE-OR, and international society on multiple criteria decision making.