Application and Effectiveness of Quality Tools & Techniques in Select Manufacturing Industries

THESIS

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DOCTOR OF PHILOSOPHY

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by

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CANDIDATE'S DECLARATION

I hereby declare that this thesis entitled **APPLICATION AND EFFECTIVENESS OF QUALITY TOOLS AND TECHNIQUES IN SELECT MANUFACTURING INDUSTRIES** by **VIVEK SHARMA**, being submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in MECHANICAL ENGINEERING under Faculty of Engineering & Technology of J.C. Bose University of Science & Technology, YMCA, Faridabad during the academic year 2020-2021, is a bonafide record of my original work carried out under guidance and supervision of **Dr. SANDEEP GROVER, PROFESSOR, DEPARTMENT OF MECHANICAL ENGINEERING, JCBUST, YMCA, FARIDABAD & Dr. S.K.SHARMA, PROFESSOR (retd.), DEPARTMENT OF MECHANICAL ENGINEERING, NIT, KURUKSHETRA** and has not been presented elsewhere.

I further declare that the thesis does not contain any part of any work which has been submitted for the award of any degree either in this university or in any other university.

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CERTIFICATE OF THE SUPERVISOR

This is to certify that this Thesis entitled **APPLICATION AND EFFECTIVENESS OF QUALITY TOOLS AND TECHNIQUES IN SELECT MANUFACTURING INDUSTRIES** by **VIVEK SHARMA**, submitted in fulfillment of the requirement for the Degree of Doctor of Philosophy in **MECHANICAL ENGINEERING** under Faculty of Engineering & Technology of J.C. Bose University of Science & Technology, YMCA, Faridabad, during the academic year 2020-2021, is a bonafide record of work carried out under my guidance and supervision.

I further declare that to the best of my knowledge, the thesis does not contain any part of any work which has been submitted for the award of any degree either in this university or in any other university.

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ABSTRACT

In present scenario, manufacturing organizations leads to the development and innovation of accelerating product in worldwide competition for their quality, functionality and versatility. In other words, it defines the detailed specification and phase development of manufacturing organizations for achieving desired outcomes. The important step to get ahead in this competition is to find a new devastating product which meets the existing customer requirements in today's manufacturing arena; consequently, effective utilization of certain quality tools and techniques (QT&T) becomes highly reliant to overcome the anticipated results in terms of high product quality and variety. Therefore, a total of 152 distinctive QT&T are identified and categorized into 16 groups based on their characteristics of applications, suitability and usages.

Thus, various QT&T have sustained symbolic effect on distinctive quality outcomes. As a result, implementation of QT&T in various manufacturing organizations is not an easy task to accomplished and requires a methodology to evaluate the effectiveness and intensity of individual QT&T in particular organization. A large number of tools, techniques and systematic methodologies are being used in industries for enhancing their performance. In the present exertion, various QT&T are grouped into six different categories namely, new product development tools (NPDT), decision making tools (DMT), data representation and analysis tools (DRAT), lean tools (LT), performance measurement tools (PMT) and software tools (ST) which have been analyzed by using integrated multi-criteria decision making approach based on graph theoretic approach (GTA) and Analytic hierarchy process (AHP) to measure the effectiveness of QT&T in manufacturing organizations.

Afterwards, an integrated model of QT&T has been developed by using interpretive structural Modelling (ISM) and Matriced Impacts Croisés Multiplication Appliquée á un Classement (MICMAC) approach. For this purpose, twelve barriers affecting the execution of QT&T in manufacturing organizations have been identified from literature analysis and expert's opinion (academicians and industrial). This outcome gives an apparent depiction to identify and handle the barriers by computing the effectiveness of each barrier. Barriers like accessibility of time and space, Inability to change organizational Culture and Inadequate coordination and teamwork are found to be the key barriers for utilization of QT&T in manufacturing organization. The developed integrated model will help the manufacturing organizations to effectively utilize QT&T in their organizations.

Then, to accomplish the implementation status of QT&T, administration of survey questionnaire has been done in manufacturing and service organizations. Previous surveys on QT&T emphasized mainly upon performance of products, processes and services of the organizations and have not addressed about implications and adaptability of QT&T categories. The purpose of this survey research is to scrutinize different categories of QT&T and to examine the level of adoption, applicability, benefits and challenges faced by various organizations in NCR region and industrial town Bhiwadi (Rajasthan) India. An exploratory questionnaire survey consisting of three parts was distributed out among 398 organizations. A total of 26.63 percent response rate was received out of 106 organizations. The collected data has been analyzed by using statistical package for social sciences (SPSS 18) software to validate multi-dimensional unfolding test. Categories like problem solving tools, productivity tools and performance measurement tools retain to be most dominant for improving efficiency of organizations contributed by transformational shepard plot.

At last, Exploratory Factor Analysis (EFA) and Confirmatory factor analysis (CFA) have been done to access the effect of QT&T in distinctive organizations. It is evident from the analysis that Performance measurement tools (PMT) retains to be most prevailing category irrespective of the other categorizations. EFA has been deployed for extracting PMT category into three principal components contributed by Statistical Package for Social Sciences (SPSS 18) software. By accommodating extracted components, Analysis of Moment Structures (AMOS) software has been carried out to validate the proposed model through CFA. The three principal components pertaining eight different QT&T formed structured model required to validate PMT category in manufacturing and service organizations.

Keywords: Quality Tool & Techniques, adoption; implementation, Classification, AHP, GTA, Integrated interpretive structural modelling (IISM), MICMAC, QT&T barriers, EFA; CFA and model validation.

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CHAPTER I

INTRODUCTION

1.1 THEORETICAL BACKGROUND

Manufacturing organizations over the past two decades have seen numerous changes in product variety, versatility and sustainability for experiencing fierce market competition in global scenario. In late nineteenth century, F. W. Taylor set up basic inspection procedures on finished goods to determine number of successive phases in product life cycle. Garvin (1988) illustrated foremost areas of organizations in production system whereas Bounds et al. (1994) contributed step wise distributions of these foremost areas. Consequently, new challenges in form of product design, sales, revenue growth, distribution and dumping of unused/defective items were raised that slower down the growth of manufacturing organizations (Crosby, 1980; Deming, 1982; Ishikawa, 1985; Feigenbaum, 1991; Payne et al., 1996). To resolute this crisis, organizations were agreed to replace these primitive inspection procedures by quality control to outperform their opponents. To uphold this task, manufacturing organizations were developing various initiatives and paradigm for improving the quality of products and maintain supplier -buyer relationships.

Previously, the role of quality paradigm was completed in six major divisions viz: machinist quality control, foreman quality control, assessor quality control, arithmetical quality control, total quality control and techno-craft quality. To accomplish the same, distinctive researchers and academicians made frequent efforts for the execution of quality improvement tools and techniques in manufacturing organizations. Beginning with the formation of new product development tools for strategic outcomes (Bowen et al., 1994). Various authors like (Kolarik, 1995; Noori, 1993; Watson, 1998) were integrated philosophical and technological aspect of quality in more than one paradigm. Hence, the need of quality tools and techniques (QT&T) has been felt and development of new QT&T becomes intended in manufacturing organizations. Although tools like quality function deployment (QFD), failure mode and effect analysis (FMEA), design of experiments and benchmarking were the most widely deployed QT&T in manufacturing organizations but the significance of statistical process control (SPC) in production system brings a new change over these primitive used tools and techniques. Evidently, the role of training for making SQC more effective rather than any other methodological approach has been advanced with graphical illustration in the form of control charts to find noticeable changes in every manufacturing organization (Shewhart, 1931).

This new direction requires commencement for substantial training program in statistical process control to imitate achievement (Rockart, 1979). Therefore, Ishikawa (1976) introduced the concept of seven quality control tools to help professionals for maintaining growth. Similarly, Bunney and Dale (1997) and Spring et al. (1998) pointed out problem solving methodology based upon the applications of QT&T crucial for facilitating improvement in manufacturing organizations. In other words, problem solving methodology intended to collect information and records by permitting consumers to recognize precise tool at appropriate time. Hence, QT&T plays an important role to assist the analysis and reached the final outcomes of different manufacturing organizations. For this reason, QT&T has been influenced by many guiding theories and opinions by various quality gurus like Deming, Juran, Feigenbaum and Crosby which plays an essential role in continuous improvement of manufacturing organizations. Table 1.1 describes distinctive definitions of quality presented by various authors.

QT&T theories	Explanations	Year
A. Shewhart	Contributes statistics to explain process variability	(1931)
Juran	Fitness for use, Conformance to specifications	(1964, 1988)
Ishikawa	Emphasis on human side of quality	(1968)
Crosby	Conformance to requirements	(1979)
Fegienbaum	Total composite . . . will meet the expectations of customers	(1983)
Deming	Aims at the needs of the customer, present and future	(1986)
Taguchi	Stress on the losses associated with the product	(1986)
ISO 9000	Totality of features and characteristics of a product or service . . . to satisfy stated or implied need	(1992)
ASQ	Operational techniques and activities used to fulfill requirements for quality.	(1997)

Table 1.1: Definitions of quality

Accordingly, the adequacy of quality for particular products or services depends on the willingness of the customers to visit again and demanding for more products. In the beginning of 1990's, noori identified that customers are the buyers responsible for satisfying cost, delivery, flexibility and service of the products (Noori, 1993). Similarly, (Kano et al., 1984) suggested customer requirements in two-dimension quality model. Figure 1.1 describes the Kano model in two dimensional outcomes.

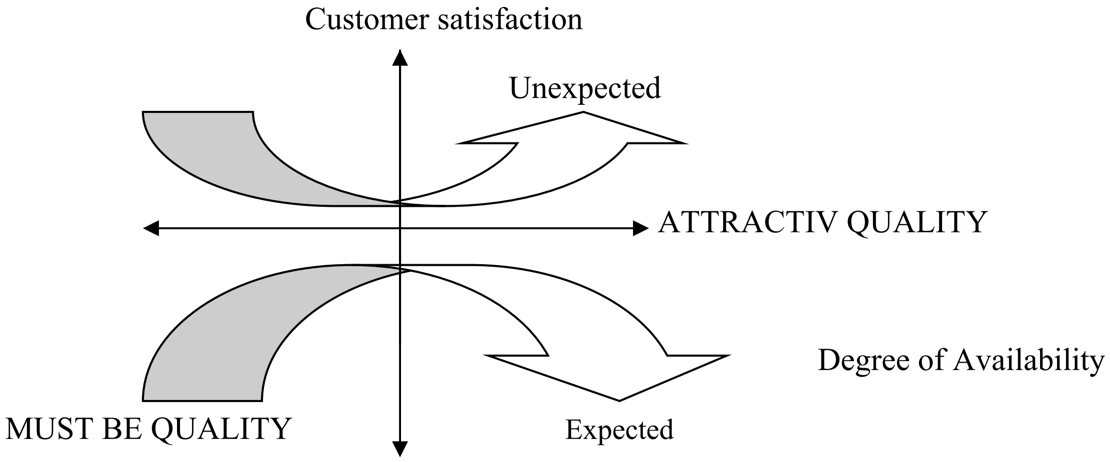


Figure 1.1: Kano's two-dimensional model of quality. (Source: kano et al., 1984)

At present effective utilization of a certain QT&T in manufacturing organizations becomes highly reliant to achieve anticipated results in global customer requirements. So it is essential that manufacturing organization must adopt these valuable tools & techniques for improving and enhancing work culture environment.

It may be concluded that instead of small and medium scale organizations, most of the manufacturing organizations must understand the importance of these QT&T in efficient manner to contribute in data analysis, performance measure and lean methods. Therefore, manufacturing organizations have been developed new categorizations with different tools and techniques that resolved new challenges in current scenario. In the next section the progression of QT&T in manufacturing organizations is described.

1.2 Progression of Quality tools and techniques (QT&T) in manufacturing organizations.

The worldwide scenario allows manufacturers to attain finest capabilities in progression of product delivery, customer demands and cost optimization. Thus, manufacturing practitioners must understand the applicability and importance of these simplistic quality tools and techniques that were crucial to handle problems in manufacturing organizations. Deliberately, QT&T has persistently evolved over the past two decades for improving performance and growth of manufacturing organizations. Quality tools may be defined as the practical applications, means or mechanisms that can be applied to particular tasks to facilitate improvement in positive way. On the other hand, techniques can be thought as the collection of different tools that have broader approach other than tools. Although quality is a framework of time and cost in an organization system, every subsystem has an objective to fulfill within given time and minimum cost. QT&T in manufacturing organizations contributes in following ways:

- Productivity improvement
- Work-culture environment
- Employee satisfaction
- Customer loyalty
- Profitability
- Avenues for diversification

Law and Gunasekaran, (2012) investigated a variety of factors that influence the execution of environmental practices and sustainable product development in manufacturing organizations. The term quality control in manufacturing can be used for:

- Awareness and understanding
- Usage
- Experiences and outcomes
- Economic approach
- Marketing strategies

- Planning
- Resource allocation
- Motivation
- Execution of new strategies
- Succession plans
- Sustainable outcomes
- Component analysis
- Investigating operations
- Realization
- Operation refinement

Also, Groover, (2001) relates that production system considered to being the collections of people, equipment, and procedures organize to accomplished approaches in the manufacturing organizations. However, Arnheiter and Maleyeff (2005) and Bryne et al. (2007) differentiate these approaches rather than clubbing them into distinctive tools and techniques. As a result, only few no of techniques and systematic procedures have been deployed by various academicians and researchers that work in the area of quality improvement.

1.2.1 Execution of QT&T in manufacturing organizations

Twentieth century begins with the elementary change in the expansion and performance of QT&T in manufacturing organizations. The execution of various QT&T in manufacturing organizations has been addressed by Motwani (2001); Summers (2000) and Xie et al. (2001). The utility and expansion of different QT&T in manufacturing organizations can be described in four main steps. The tools and techniques involved with these steps are:

- Introduction of new product: brainstorming, design of experiment (DOE), kano analysis, team profiling and balance scorecard etc.
- Measuring and analysis of product: Pareto chart, histograms, guage R&R, process flow diagrams, and control chart etc.
- Assessing process of product: Scatter diagram, queuing analysis, run charts pie chart and bar chart etc.
- Improving performance of product: Quality loss function, Total productive maintenance, capability indices and weibull analysis etc.

The next section describes the hierarchy structure of already implemented QT&T in manufacturing organizations as shown in figure 1.2.

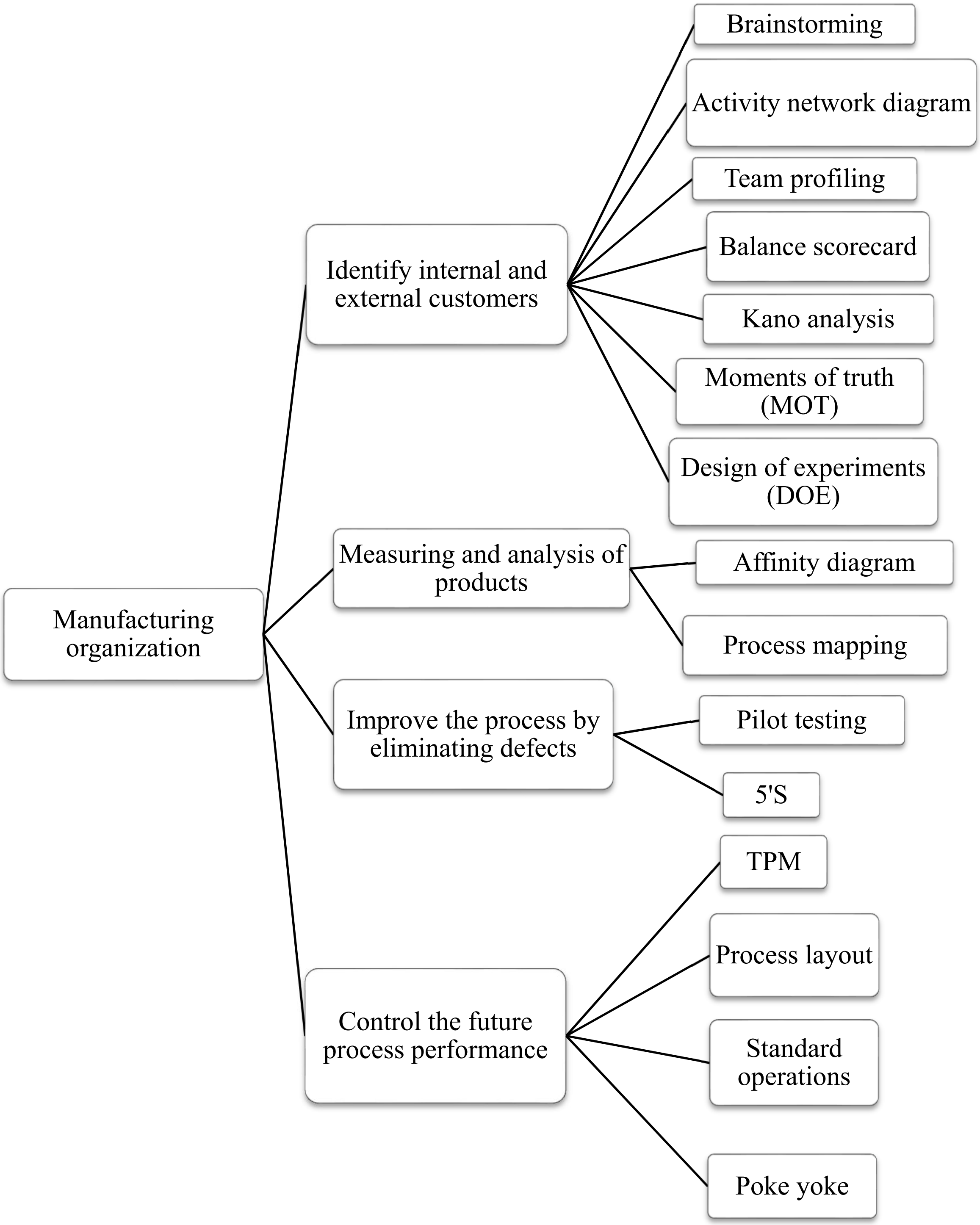


Figure 1.2: Execution of major QT&T in production system.

Figure 1.2 implies the implementation of main QT&T in manufacturing organizations. The next section deals about the benefits and applications of QT&T in manufacturing organizations

1.3 Benefits of QT&T in manufacturing organizations

The benefits of QT&T in particular organization has been enhanced, and integrated with other methodologies to suit new confronts in today's manufacturing arena. Following main benefits of QT&T in manufacturing organizations are listed below:

- QT&T systematically improves the working background by eliminating inefficiencies and wastages within the organizations.
- QT&T improves employee enthusiasm and position with the organization to ascertain objectives in progressive manner.
- QT&T calculates and measures the implementation of auditing process periodically.
- QT&T helps to improve material flow by in cooperating minimal lead time by composing organization profit.
- Establishing each department/activity to encompass visual management and retain standard operating procedures up-to-date.
- QT&T administered awareness and training to hatch superior products in upbringing organizations.
- QT&T allows manufacturers to identify various enablers related to planning and operation of production system.
- QT&T assess the uniqueness of efficient decisions contributed in different stages of production system.
- QT&T provides appropriate investigation to promote buyers for competitiveness and sustainability.
- QT&T administered knowledge valuation by assessing quality for assortment and development of distinctive departments.

1.4 Applications of QT&T in manufacturing organizations

The subject area of applications defines the broad vision of different QT&T used in manufacturing organizations. Figure 1.3 describes the indefinite range of applications of various QT&T.

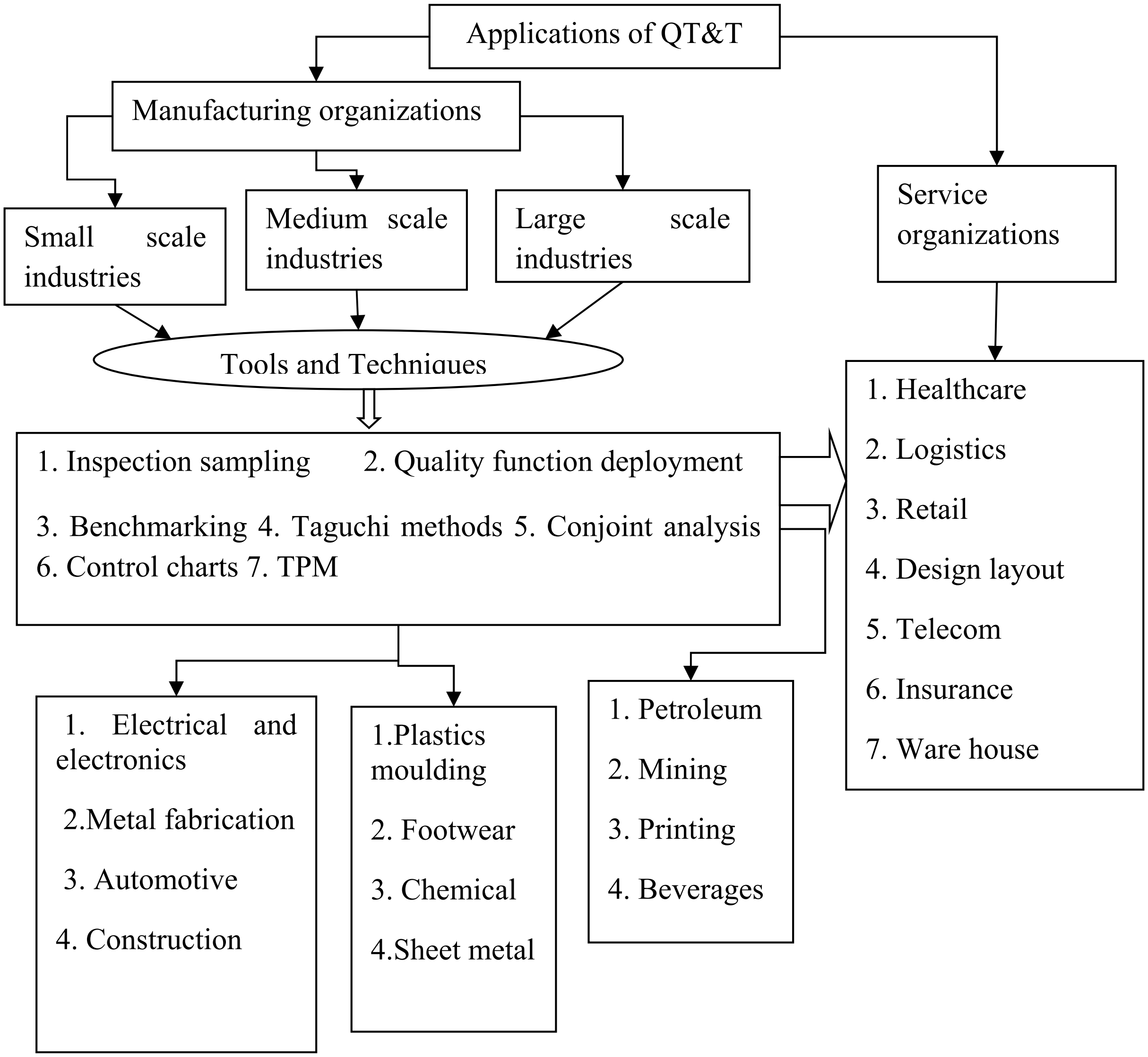


Figure 1.3: QT&T areas of applications

1.5 Objectives of the research

This present work represents the implementation and suitability of different QT&T in manufacturing organizations. For this purpose, categorization of different (QT&T) in various organizations have been made based upon the application of usages and suitability of distinctive work. Various QT&T are classified into varied groups which have been analyzed by using integrated multi-criteria decision making approach for measuring the effectiveness. Also, barriers affecting the execution of QT&T in manufacturing organizations have been analyzed by using interpretive structural Modelling (ISM) and Matriced Impacts Croisés Multiplication Appliquée á un Classement (MICMAC) approach. Afterwards, an exploratory questionnaire survey consisting of three parts was distributed out among organizations to examine the level of adoption, applicability, benefits and challenges faced by various organizations. Finally, factor analysis has been done to assess and validate QT&T model. Following are the list of objectives accomplished during the present work.

(i) To study various quality tools & techniques used in manufacturing organizations.
(ii) To classify quality tools & techniques based on similarity and applicability.
(iii) To assess the effect of quality tools & techniques in different areas.
(iv) To conduct survey for applicability of tools and techniques in different areas.
(v) To apply various MADM techniques for effectiveness and applicability of tools & techniques.

(vi) To assess the effectiveness of various tools and techniques.

1.6 Methodology adopted for present work

The methodology adopted for the present exertion will be deliberated as follows:

Step 1: Study various QT&T deployed in manufacturing organizations.

Step 2: Categorized different QT&T into 16 groups based on their characteristics of applications, suitability and usages.

Step 3: Develop a mathematical model for identified QT&T by using integrated Graph theoretic approach (GTA) and Analytic hierarch process (AHP).

Step 4: Determine single numerical index representing the effectiveness of QT&T in manufacturing organization.

Step 5: Perform pilot survey for preparing of questionnaire.

Step 6: Develop questionnaire with the help of professionals (academic and industrial) to know the implementation status of QT&T categorizations in different organizations.

Step 7: Collect the survey data.

Step 8: Execute data for assessing and finding the level of adoption, applicability and benefits of various QT&T in an organization by Topsis apporach.

Step 9: Perform multi-dimensional unfolding test to detect challenges faced by various organizations.

Step 10: Identify possible barriers which affects the utilization of QT&T in manufacturing organizations

Step 11: Rank those identified barriers by means of integrated interpretive structural modeling (ISM) and MICMAC analysis.

Step 12: Determine driving power & dependence power to compute effectiveness of each barrier.

Step 13: Perform factor analysis to calculate the verifiable assessment range for measuring the effect of QT&T in organizations**.**

Step 14: Develop an assessment model for validating the current status of QT&T in organizations by Exploratory Factor Analysis (EFA) along with Confirmatory factor analysis (CFA).

1.7 Organization of the proposed thesis

Chapter 1 represents the theoretical background of various QT&T deployed in manufacturing organizations. Also, progression followed by the execution of various QT&T in manufacturing organization has been addressed in this section. Consequently, this chapter confers about the research objectives along with applications and benefits of QT&T in various organizations.

Chapter 2 covers the literature review for the successful implementation of QT&T in manufacturing and service organizations. Various journals and research papers from reputed source such as: Springer, Elsevier, Emerald and Science direct have been reviewed for this purpose. The literature review in this section has been divided into three main divisions namely: (a) Review of literature on implementation of QT&T in manufacturing organizations; (b) Review of literature on applications to choose MADM approaches; (c) Review of literature on the basis survey outcomes for the execution of QT&T in organizations. This uncertainty in execution of various QT&T in different organizations gives clear perception not only in implementation but also in the area of realistic research. Latterly, the gaps in current literature have also been acknowledged in this section.

Chapter 3 describes the introspection and detailed classification of various QT&T in manufacturing organizations. The classification of QT&T into sixteen foremost categories has been defined in this section.

Chapter 4 deals with the investigation of QT&T categories by means of integrated MADM approach like: Graph theoretic analysis (GTA) & Analytic hierarchy process (AHP) to evaluate the effectiveness of each QT&T in manufacturing organizations.

Chapter 5 endorses the execution of QT&T in manufacturing organizations by determining barriers. Barriers affecting the effective utilization of (QT&T) in organizations have been identified and analyzed by using interpretive structural Modelling (ISM) and Matriced Impacts Croisés Multiplication Appliquée á un Classement (MICMAC) approach.

Chapter 6 represents the development and distribution of questionnaire for analyzing survey data. Initially, pilot survey has been utilized to improve the quality of the questionnaire. Later on assessment of QT&T categories by Topsis approach have been analyzed. Also, Multidimensional unfolding test along with transformational shepard plot has been determined to know response rate of dominating categories in this section.

Chapter 7 represents the response rate of former survey results into selective three dominating categories. The analysis and comparison of PST, PT & PMT categories based on extent of usage and impact on organizations has been discussed in this section. In the present study, factor analysis usually employed to accomplish the required objective of the research. Exploratory Factor Analysis (EFA) along with Confirmatory factor analysis (CFA) has been discussed to validate QT&T assessment model.

Chapter 8 covers the summary, implications and major contribution of the research work. At the end limitations and scope of future research has been illustrated in this section.

The current research work has been arranged in nine chapters as stated in figure 1.4 as described below:

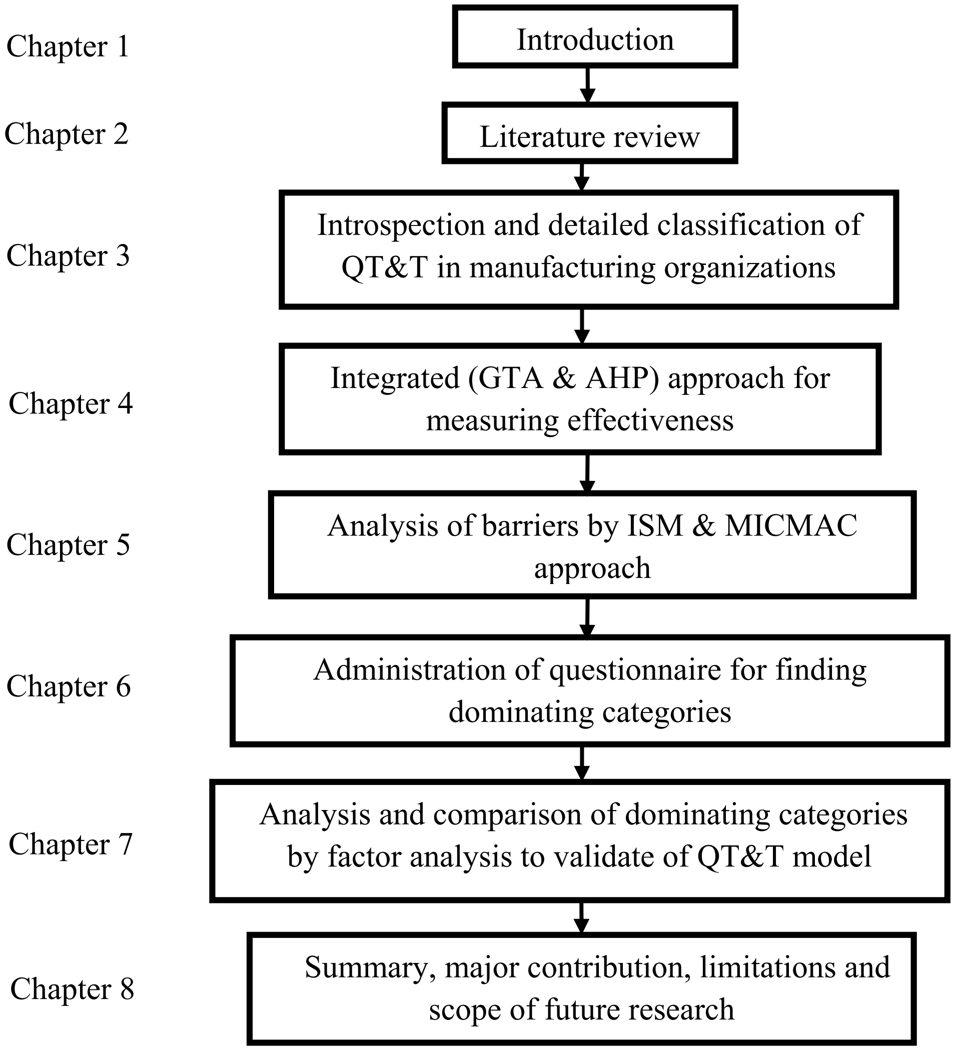


Figure 1.4: Chapter wise organization of proposed thesis

CHAPTER II

LITERATURE REVIEW

Literature has been appraised from three perspectives (Figure 2.1) namely implementation status of QT&T in manufacturing organizations, applications to choose MADM approaches and survey responses for the execution of QT&T in organizations.

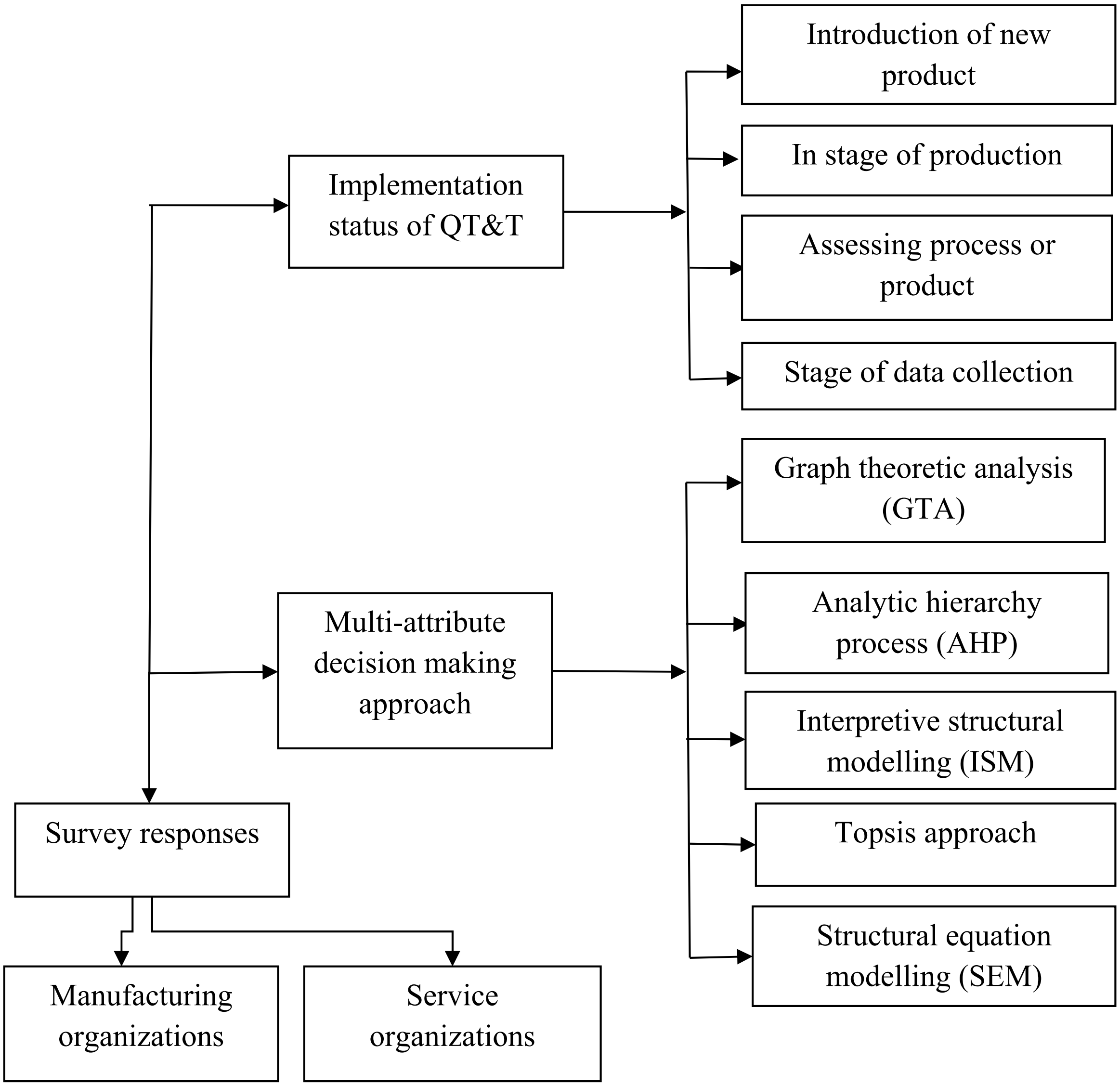


Figure 2.1: Classification of literature survey

2.1 LITERATURE REVIEW ON IMPLEMENTATION STATUS OF QT&T IN MANUFACTURING ORGANIZATIONS

This section describes the appraisal of literature on execution status of distinctive QT&T in manufacturing organizations.

2.1.1 New product introduction

Literature reveals that identification and implementation of QT&T in manufacturing organization has become more prominent and valuable in recent times. Many academicians and researchers improve the performance of organizations (manufacturing and service) by proficient use of QT&T in different areas. The current section shows the introduction of new product for the relevance of QT&T in varied organizations. According to Nakano et al., (2008) the stages for the development of new product in manufacturing organizations are:

- *Primary stage:* This stage involves the establishment of products and services in terms of design, planning and assessment of productivity operation and cost.
- *Secondary stage:* It contributes to reconfiguration and estimation of primary product in organizations.
- *Tertiary stage:* It is also called product change stage which involves re-design, re-planning of process for evaluation of productivity in organizations.
- *Quaternary stage:* It refers to the final stage of production system which describes the abandon of unused products/items.

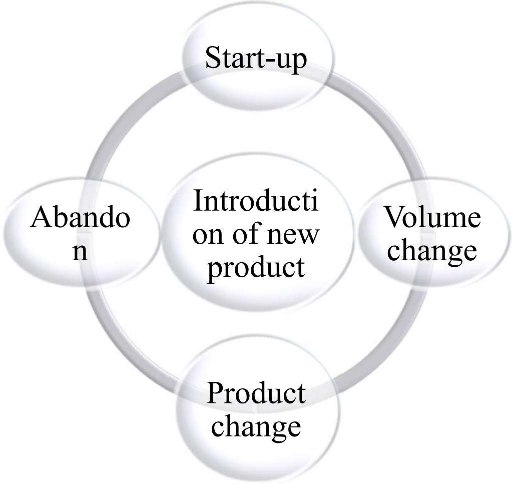


Figure 2.2: Introduction of new product in organization

Authors: Tari, (2005); Dale & McQuater, (1998); Ishikawa, (1985); Imai, (1986); Dale, (1999) and Dean and Evans, (1994) have identified various quality tools and techniques (QT&T) for the development of new product in organizations. For this reason, quality practitioners must utilize suitable QT&T for development and implementation of quality in their organizations.

2.1.2 In stage of production

Methodology / techniques have been adopted for the enhancement of productivity in optimum manner. The overall quality of products concerns with different stages of production system changed drastically for getting desired results. Therefore, QT&T sustained remarkable effect on workforce & work environment of production system. Besterfield et al., (1999) represents following tools consider to be adopted under in stage production are:

- Pareto diagrams
- Cause-and-effect diagrams
- PERT, CPM
- Arrow diagram
- Control charts
- Process flow diagram

These tools provide necessary feedback by monitoring quality activities for improving in stage production. According to (McQuater et al., 1995) a single quality tool have clear role which is often narrow in focus and is usually used on its own, whereas techniques has wider application and is understood as a set of tools. More ever Ishikawa (1985, 1990) and McConnell (1989), Evans and Lindsay (1999), Dale and McQuater (1998) and Dale (1999) have identified seven basic TQM tools which a vital role and usage in today's manufacturing environment. The next section deals with the evaluation and assessment of products or services in manufacturing organizations.

2.1.3 Assessing process or product

Spring et al. (1998) has conferred about the assessment tactic for the use of quality tools and techniques in new product design of any organizations. Similarly, authors like Deming (1982, 1986) introduced the concept of statistical techniques for quality enhancement and proposed Plan-Do-Check-Act (P-D-C-A) cycle and Ebrahimpour and Schonberger (1984) has relate quality control as the origin for future productivity, quality and growth. The tools and techniques responsible to assess the quality of product in manufacturing organizations are:

- Pie chart
- Histogram
- Bar chart
- Design of experiments (DOE)

- Failure mode and effect analysis (FMEA)
- Fault tree analysis (FTA)

On the other hand, Authors like Lam (1996), Curry and Kadasah (2002), Ahmed and Hassan (2003), Vouzas (2004), Sousa et al., (2005), Bamford and Greatbanks (2005), Hagemeyer et al., (2006) and Alsaleh (2007) develop a distinction between quality tools and techniques to provide facility for users to understanding and implementing the concept of quality. Ishikawa (1976, 1985) suggests the utility and importance of quality circle and problem solving diagram (cause and effect) for continuous improvement.

2.1.4 Stage of data collection

Dangayach and Deshmukh, (2003) relates diversity of products for global competition in international market. Crosby (1979) focuses on zero defect philosophy for problem solving, corrective actions and quality measurement. Similarly, Imai (1986), Dean and Evans (1994), Goetsch and Davis (1997), Dale (1999), Evans and Lindsay (1999) contributing the list of quality tools and techniques in product development. More ever Kwok and Tummala (1998) argued that quality tools and techniques are useless and do not work correctly and professionally for receiving preferred outcomes in manufacturing organization. Accordingly, maximum efficiency to avoid the delivery of defective products to customer will optimized procedure and performance in quality provided with minimum effort time and cost for products (Werner & Weckenmann, 2012). Hence, Antony et al. (1998) describe the variety of tools and techniques required for complete the process of new product development are:

- Check sheets
- Capability indices
- Time series graph

The stage of data collection understood the implication of suitable QT&T in varied organizations to identify and solve problems. Amhed and Hassan (2003) relates that quality management cannot be perceived without the applications of QT&T and Amhed et al., (2005) determines effectiveness and improvement of quality management system for quantifying different QT&T viz benchmarking, statistical process control and defect cost analysis. Figure 2.2 donates the orderly use of various QT&T at different stages of production system. The year wise diagrammatically illustration of QT&T by various authors has been presented in figure 2.3.

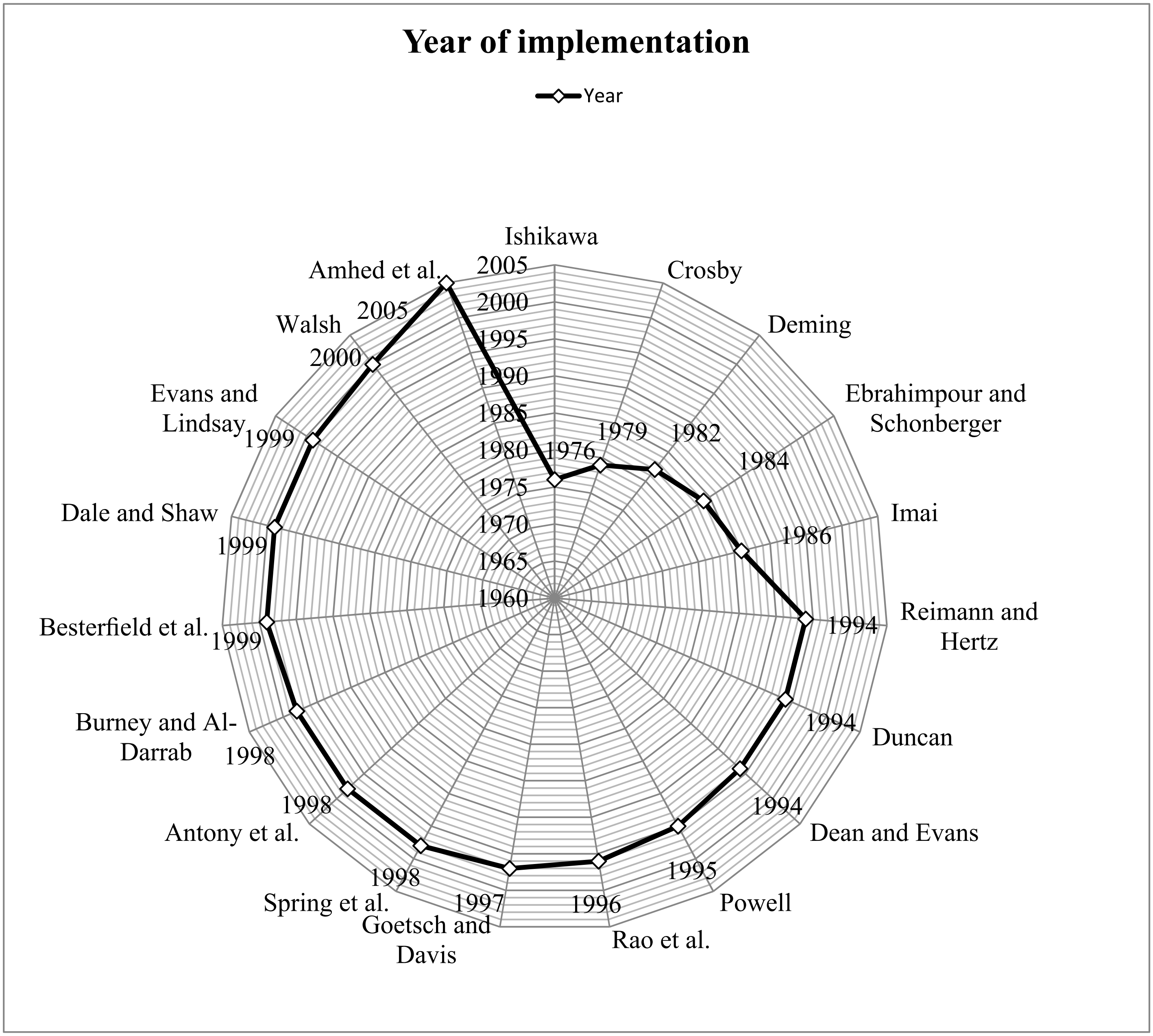


Figure 2.3: Year-wise contribution of different authors in new product development

Hence much progress has been made while adopting these QT&T in different areas of manufacturing for improvement in design and product aspects. From the above literature review it is obvious that many researchers have explored the level of usage & implementation of different QT&T in various organizations. In view of this, the next section addresses the contribution of MADM approaches employed to extract desired outcomes of the research.

2.2 LITERATURE REVIEW ON APPLICATIONS TO CHOOSE MADM APPROACHES

Literature emphasized that exploratory survey of different manufacturing organizations to identify the best practice related to QT&T in order to make comparison between them and to focuses on different aspect related to the application, usage and suitability of QT&T. After exploration the integrative framework, it is revealed that QT&T are not new for improving performance and constantly increasing gains that incessantly striving improvement in manufacturing organizations. Thus, considering the importance of these QT&T in different areas, Multi-attribute decision making approaches (MADM) have been utilized in this chapter.

2.2.1 Graph theoretic approach (GTA)

Grover et al. (2005) have evaluated human resource performance index in TQM environment. Rao and Padmanabhan (2006) have developed criteria for industrial robots by applying GTA methodology to identify and compare factors responsible for selection. Likewise, Grover et al. (2004) have distinguished TQM factors of an organization by systematic digraph approach. Sabharwal and Garg (2013) have addressed the economic viability of organizations concerned with remanufacturing by graph theoretic approach. Grover, Agrawal, and Khan (2004, 2005, 2006); Kulkarni (2005); Raj and Attri (2010); Singh, Khan, and Grover (2012) have been successfully applied graph theoretic approach in distinguished areas of quality for judgment of the barriers affecting the production system. Also, the capability of digraph approach has been utilized in other areas for finding the interdependences and interrelationships between the identified variables. Raj, Shankar and Suhaib (2010a, 2010b) have identified various factors / enablers which affects the sustainability of flexible manufacturing system.

Garg, Agrawal, and Gupta (2006); Garg, Gupta, and Agrawal (2007); Dev, Samsher, and Kachhwaha (2012) and Dev et al. (2013) have analyzed various parameters of thermal power plant responsible to affects the efficiency of boiler system. Prabhakaran, Babu, and Agarwal (2006); Singh and Agrawal (2008); Kumar, Clement, and Agrawal (2010) have identified possible factors to accomplish in certain model by structural equation modelling. Chakladar, Das, and Chakraborty (2009); Gadakh and Shinde (2011); Koulouriotis and Ketipi (2011); Paramasivam, Senthil, and Ramasamy (2011); Singh, Khan, and Grover (2011, 2012); Vinodh, Prasanna, and Selvan (2013) have fallowed their contribution in manufacturing environment by dealing with different factors/enablers /parameters sustained the process of production system. Moreover, for checking the reliability of particular organization authors like: Agrawal, and Shishodia (1991); Sehgal, Gandhi, and Angra (2000) have gave their valuable contribution for identifying measurable properties.

2.2.2 Analytic hierarchy process (AHP)

Analytic hierarchy process (AHP) has wider application to cope with multiple criteria /multi-attribute decision situations. Initially developed and applied by Satty (1977). AHP relates with multilevel hierarchical structure to define criteria, sub criteria and options, in ordinary and pair wise mode (Saaty, 1980, 1994, 2000, 2008). Saaty, (2008); Kumar et al., (2009) have developed rank order to compare vendor selection problem of various alternatives in organizations. Gorvett and Liu, (2007) have addressed about the system of an organizations by quantifying relationships and weights between identified factors. Al Qubaisi et al. (2016) have developed planning-based framework to set up criteria weights for school's inspection. Similarly, Sipahi, S. and Timor, M. (2010) have addressed about the recent applications of Analytic hierarchy process in manufacturing and other sectors.

Dey, P.K. (2002) has used AHP methodology for finding the effectiveness of benchmarking. Similarly authors like: Mangla et al., (2014), Bao et al., (2013); Govindan et al., (2014), Harputlugil et al., (2011) have applied AHP methodology in distinctive fields of organizations to get the optimum results from the identified enablers. Millet and Wedley (2002) contribute assist model indecision and menace situations wherever consistent events do not survive. Although, Ordoobadi, (2010) has reported AHP methodology to apply on wide range events/ situations such as: supply chain management, quality management system, engineering/design, education, healthcare and management etc. Sharma and Bhagwat (2007, 2009) have identified integrated BSC-AHP approach for assessment & performance of supply chain management. Chan (2006) has used AHP methodology for measuring the performance of postal cooperation with their competitors by means of benchmarking method. Wong and Li (2008) have applied AHP approach for investigation of the assortment of intelligent building systems (IB).

2.2.3 Interpretive structural Modelling (ISM)

Warfeld (1974) first introduced the concept of ISM methodology which helps to differentiate complex situations or problems in orderly manner by developing map between identified factors. Moreover, Mohammed et al., (2008) has identified solution to complex situations with the help of trained consultants in organizations. Thakkar et al., (2005) suggests that interpretive structural modelling is a logical methodology which finds connection between system variables. Sage, (1977) has protracted interpretive structural modelling as the decision making approach which finds judgment whether the enablers are interconnected with each other or not. Secondly, it develops structure relationships between recognized enablers. Later on, the developed structure being iterated into partitions tables by identifying level between different enablers and finally the analyzed model of organization converted into well-defined digraph representation.

Saxena et al. (1992) has applied ISM methodology in Indian cement manufacturing by identifying factors pertains to energy-conservation. Although, Saxena et al., (2006) has altered uncertain expressed model of system into well-defined approach of system. Sharma et al. (1995) has used ISM approach to counter ideas of waste management in Indian conditions. Similarly authors like: Mandal and Deshmukh (1994); Ravi and Shankar (2005); Singh et al. (2007) and Singh and Kant (2008) have identified various factors/enablers in different dimensions of organizations to categorize into well-organized structured model. Ramesh et al. (2010) has formulated barriers pertaining to supply chain management by using interpretive structural modelling. Soti et al., (2010) has dignified ISM methodology accountable for analyzing the barriers of Six Sigma. Jindal and Sangwan (2011) relate ISM approach for determining the barrier affecting the accomplishment of reverse logistics in Indian manufacturing organizations.

2.2.4 Topsis approach

Topsis is defined as the approach used to recognize order preferences by considering shortest Euclidean distance from the ideal solution. The concept of Topsis has been primarily originated by Hwang and Yoon. Hwang and Yoon (1981, 1995) and Lai et al. (1994) have discovered multi-attribute decision making approach for finding fixed set of alternatives by evaluating minimize distance from idyllic point and maximize distance from a lowest point. Rao, (2007) has contributed the values of database in imaginary solution of the system. Jothimani and Sarmah (2014) have employed Topsis methodology for measuring the performance of real life situations in supply chain management. Ramezani and Lu (2014) have applied Topsis approach for analyzing the failures associated with maintenance. Kumar and Singh (2012) have contributed Topsis technique for assessing universal supply chain in current scenario. Khanna and Sharma (2011) have identified the rank of critical success factors accountable to affects the realization of quality management system by Topsis approach. Deng et al. (2000) has distinguished performance of upbringing organizations by determining the weighted Euclidean distances instead of developing weighted decision matrix.

However, many authors have applied Topsis technique into their own distinctive manner i.e Hao and Xie (2006) have used Topsis approach for valuation of bidding process in manufacturing enterprise; Wang and Chang (2007) relates Topsis approach for evaluation of aircraft training. Kannan et al. (2009) has distinguished the priorities availed by reverse logistic using Topsis approach; Chen et al. (2011) has used Topsis approach in personnel selection in multi-information surroundings; Latpate (2015) has used Topsis technique in selection of supplier in supply chain management. Jain and Raj (2015) have identified various factors affecting the performance of flexible manufacturing system and Ziaei et al. (2016) has improved the performance of water pump system by Topsis approach.

2.2.5 Structural equation modelling (SEM)

Structural equation modelling (SEM) is highly developed statistical technique used for testing model fit and build up path analysis for proposed model. In other words, structural equation modelling provides an imminent way to deal with complex theoretical issues. Shipley, (1999) has suggested the subsistence of linear and non –linear relationships into developed model with the help of correlations subsist between pragmatic values. Malaeb et al., (2000) has defined SEM as principal instrument which fallows the investigation of theoretical covariance into random variables to define test model. Pugesek and Tomer, (1995) have investigated SEM technique to detect errors and distortions occurred during the analysis of model fit. Similarly, Iriondo et al., (2003) has defined the underlying relationship of SEM model between variables and co-variables. The four main types of relationships exist to make variables co-vary are:

- Straight fundamental relationships: These types of relationships occurred when one variable causes an effect to another variable and vice versa.
- Circuitous fundamental relationships: These types of relationships occurred when one variable causes an effect on another through third variable.
- Counterfeit relationships: These types of relationships occurred when two existed variables have common cause that effects mutually
- Involvement lacking relationships: In this relationship, it is impossible to determine relationship between ordinary variable to previously exist known variables with circuitous or counterfeit relationship.

Moreover, Chin, (1998); Joreskog and Sorbom (1989) and Munck (1979) have established relationship between latent variables to convert into structured model. Although, Bollen and Long, (1993) have distinguished SEM procedure into four basic steps:

1. Identification of model and parameter extermination.
2. Collection of data.
3. Testing of data for model fit.
4. Re-specification of model.

Bhushi, (2007) has donated SEM approach for the analysis of path diagram and Babakus et al., (1987) defined consistency to categorized variables under multivariate normality. Kaplan, (2000) has defined SEM as amalgam approach for donating statistical analyzed parameters into two different sub-techniques i.e factor analysis and regression analysis.

- Factor analysis: It is defined statistical technique which finds distinction between Confirmatory factor analysis (CFA) and Exploratory factor analysis (EFA).
- Regression analysis: It is identified as the technique in which variables extracted from visible set of variances and co variances.

The next section implies the nomenclature of structural equation modeling into sub-techniques.

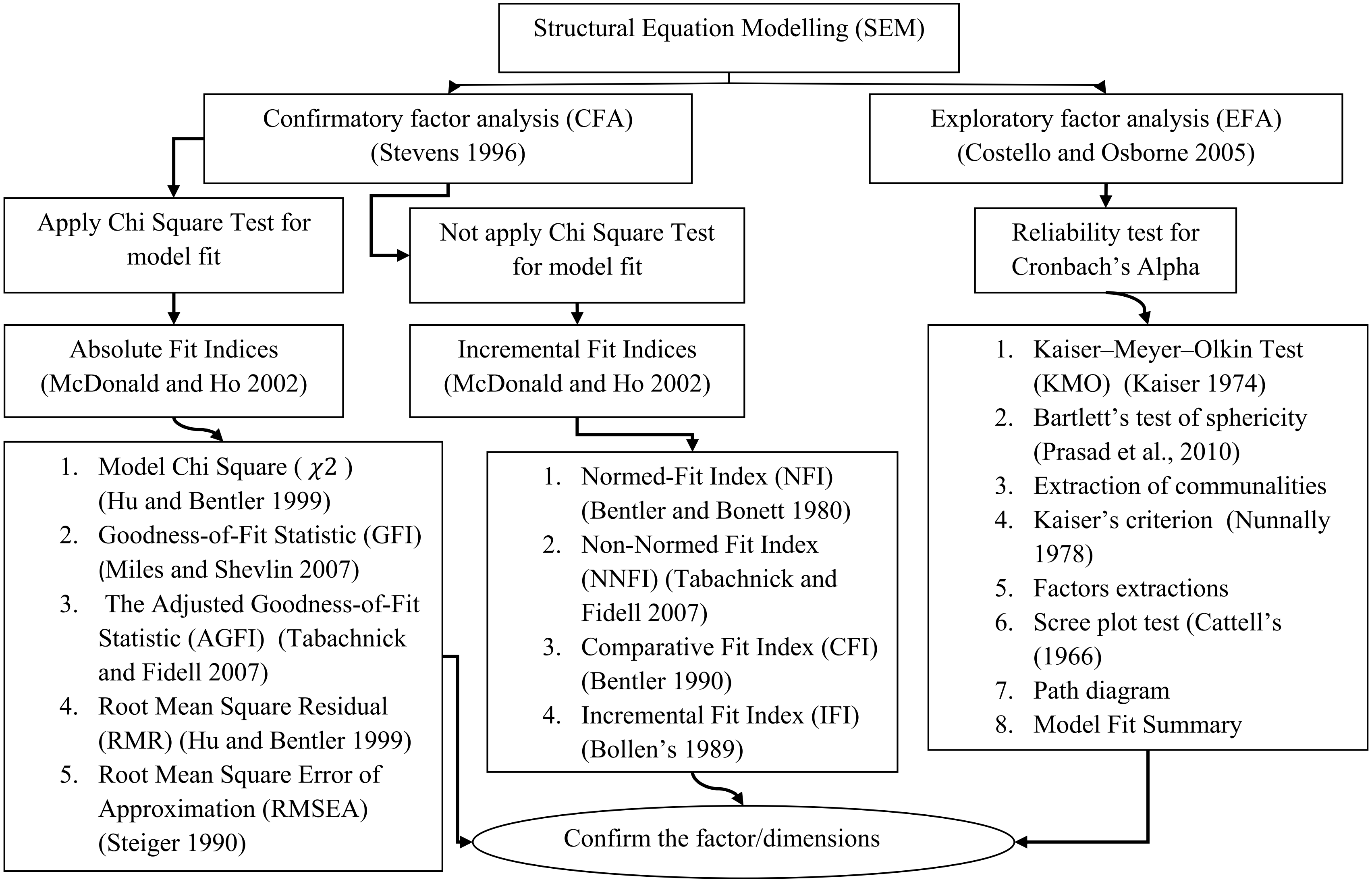


Figure 2.4: Nomenclature of structural equation modelling

2.3 SURVEY RESPONSE

Literature emphasized that investigative survey of different manufacturing and service organizations provides the best outcomes related to implementation of QT&T categories. Therefore, numerous surveys have been carried out to make comparison between applications, usages and suitability of distinctive QT&T's in varied areas. After through exploration of survey framework, it is revealed that QT&T are not new for improving performance of manufacturing and service organizations but are liable to offer optimum results in presiding the growth & development of various organizations. In present research, the output of survey responses has been divided into two main aspects:

1. Status of QT&T in manufacturing organizations.
2. Status of QT&T in service organizations.

2.3.1 Status of QT&T in manufacturing organizations

Mandal and Sohal, (1998) have formulate pronouncement approached to describe quality in a systemic manner. Similarly authors like Curry and Kadasah, (2002) have studied ISO 9001 registered companies in Saudi Arabia. Lam, (1996) has surveyed companies in Hong Kong; Ahmed and Hassan, (2003) have studied Malaysian small and medium enterprise (SME). Sohal et al., (1992); Sohal and Eddy, (1994); Brown, (1995) have pronounced the impact of quality initiatives in Australian manufacturing organizations. Bayazit, (2003) has surveyed Turkish large manufacturing companies. Lagrosen and Lagrosen, (2005) have studied Swedish companies. Tari, (2005) has surveyed ISO 9001 certified companies in Spain. Werner & Weckenmann, (2012) have organized practice and performance of products for time and cost with minimum efforts. Dangayach and Deshmukh, (2003) have admitted assortment techniques for universal competition in manufacturing industries. However, Dale, (2003); Boys et al., (2005) and Amhed et al., (2005) have identified organizations in quality management system with the applications of QT&T. Bayazit, (2003) has surveyed Turkish large manufacturing companies. Drew and Healy, (2006) have conducted survey in Irish companies. Grigg and Walls, (2007) have studied the applications of statistical quality tools in UK food industries. Frankl and Rubik, (2000) have emphasied deals about life cycle assessment of products. Radovilsky et al., (1996) has implemented quality control tools for productivity and growth in order to satisfy cost of quality. Kim and Im, (1993) has surveyed Korean manufacturing organizations randomly for reforming their manufacturing operations. Despite the fact that no of researchers gave their contributions to implicit quality for providing variety of products in global market (Nielsen and Wenzel, 2002; Zhou and Schoenung, 2007; Streimikiene et al., 2009; Bovea and Prez-Belis, 2012; Sarkis et al., 2010; Teixeira et al., 2012). In addition to this, Chikan and Demeter, (1996); Ettlie, (1996); Ferme, (1995) and Videras et al., (2012) addressed facility to provide users for better understanding and implementation of QT&T in various organizations. The year wise graphical illustration of QT&T succession in manufacturing organizations is shown in figure 2.5

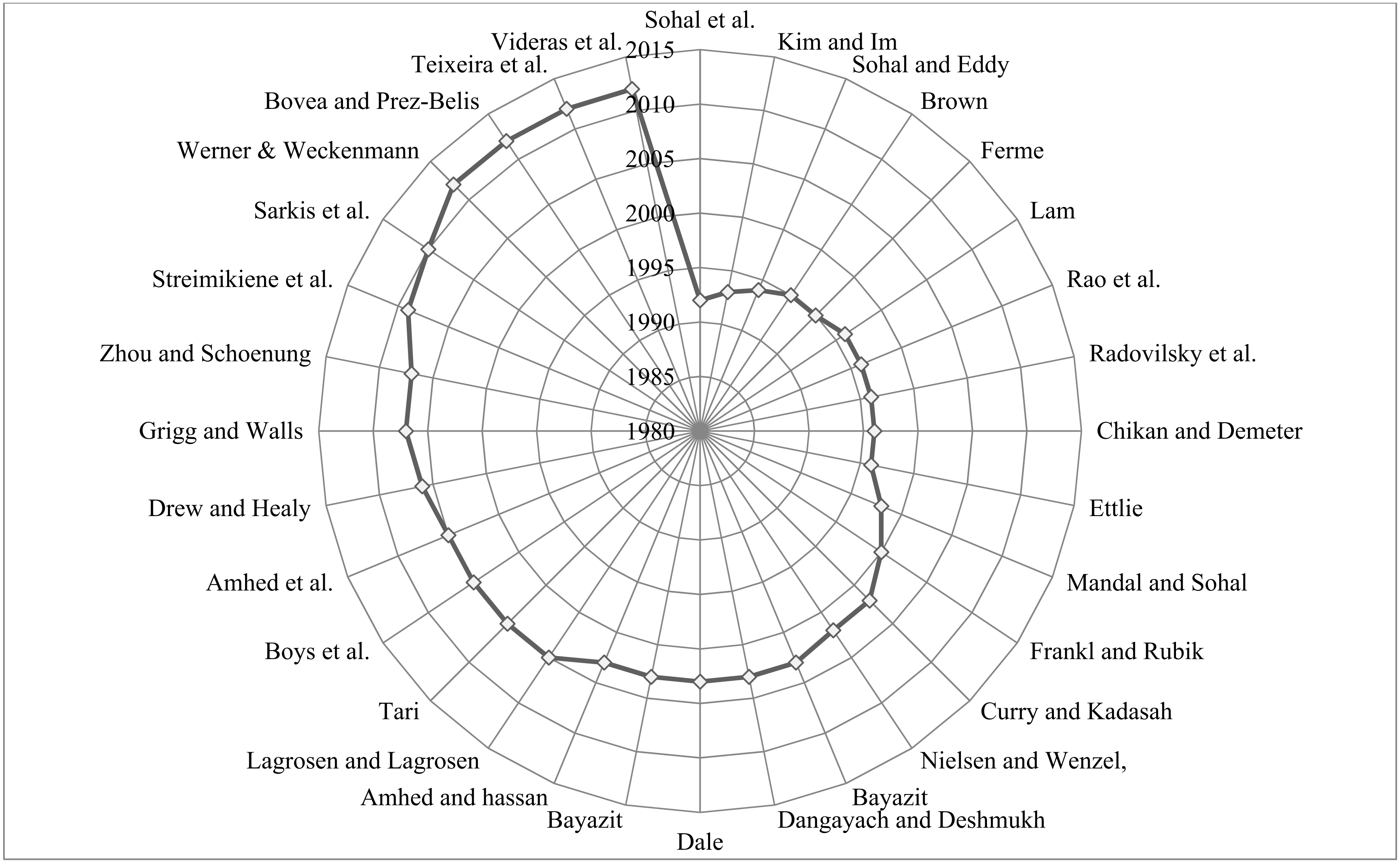


Figure 2.5: Succession of QT&T in manufacturing organizations

2.3.2 Status of QT&T in service organizations

Garg et al., (2002) and Antony et al., (2004) have recommended the increase of products and services for quality enhancement. Also Garg et al., (2005) and Kodali, (2003) have provided the relevancy of management tools in service and public sector organizations; In other words, adaptability of QT&T in service organizations brings higher quality with lower price independently to bring changes in product or service.

As illustrated by various authors about the realistic applicability of QT&T in service organizations: Heizer and Render, (2006) have discovered the powerful discernment of total quality management together with service organizations. Sullivan-Taylor and Wilson, (1996) implies that QT&T applied for both profitable and non-profitable organizations in the service sector. Drew and Healy, (2006) has confirmed that total quality tools and techniques assumed unequally distributed among countries, sectors and product areas. Silvestro, (1998, 2001) has recognized common proponents of TQM implemented in service organizations. Different authors surveyed various countries like Fotopoulos and Psomas, (2009) and Vouzas and Psychogios, (2007) have visited Greece, Al-khalifa and Aspinwall, (2000) have visited Qatar, Khanna, (2009) and Kumar et al., (2009) have visited India, Tari, (2005) has surveyed Eastern spain, Chang and Lu, (1995) have visited Taiwan, Ghosh and Hua, (1996) have visited Singapore, Witcher, (1994) have visited Scotland, Curry and Kadasah, (2002) have visited Saudi Arabia, to know the extent and implementation status of various QT&T in service organizations.

Although authors like Brah et al., (2000) ; Yasin et al., (2004); Sit et al., (2009); Lakhe and Mohanty, (1995); Moriarty (2011); Hong et al. (2012); Singh et al. (2012); El Faiomy and Shaban (2012); Al Owad et al., (2013); Reddy and Al Shammari (2013); Banawi and Bilec (2014); Oguz et al., (2012); Almuharib (2014); Alharthi et al. (2014); Bubshait and Al-Dosary (2014); Amminudin et al. (2011); Al-Sadat and Robertson (2007); Dhafer (2014); Talib, F.et al.,(2011) have supported positive disagreement regarding the definition for QT&T in theory or in practice. Hence literature has offered typical model for presenting both manufacturing and service organizations on the basis of adaptability.

Many researchers and authors used different quality initiatives to summaries empirical research in terms of applicability, usage and implementation of QT&T within the organizations. After ascertain study and screening of literature, subsequent results shows the current implementation succession of various QT&T categorizations in service organizations.

Figure 2.6 refers to the succession of QT&T in service organizations. The current figure provides the valuable insight for year wise allocation of different tools and techniques by various authors.

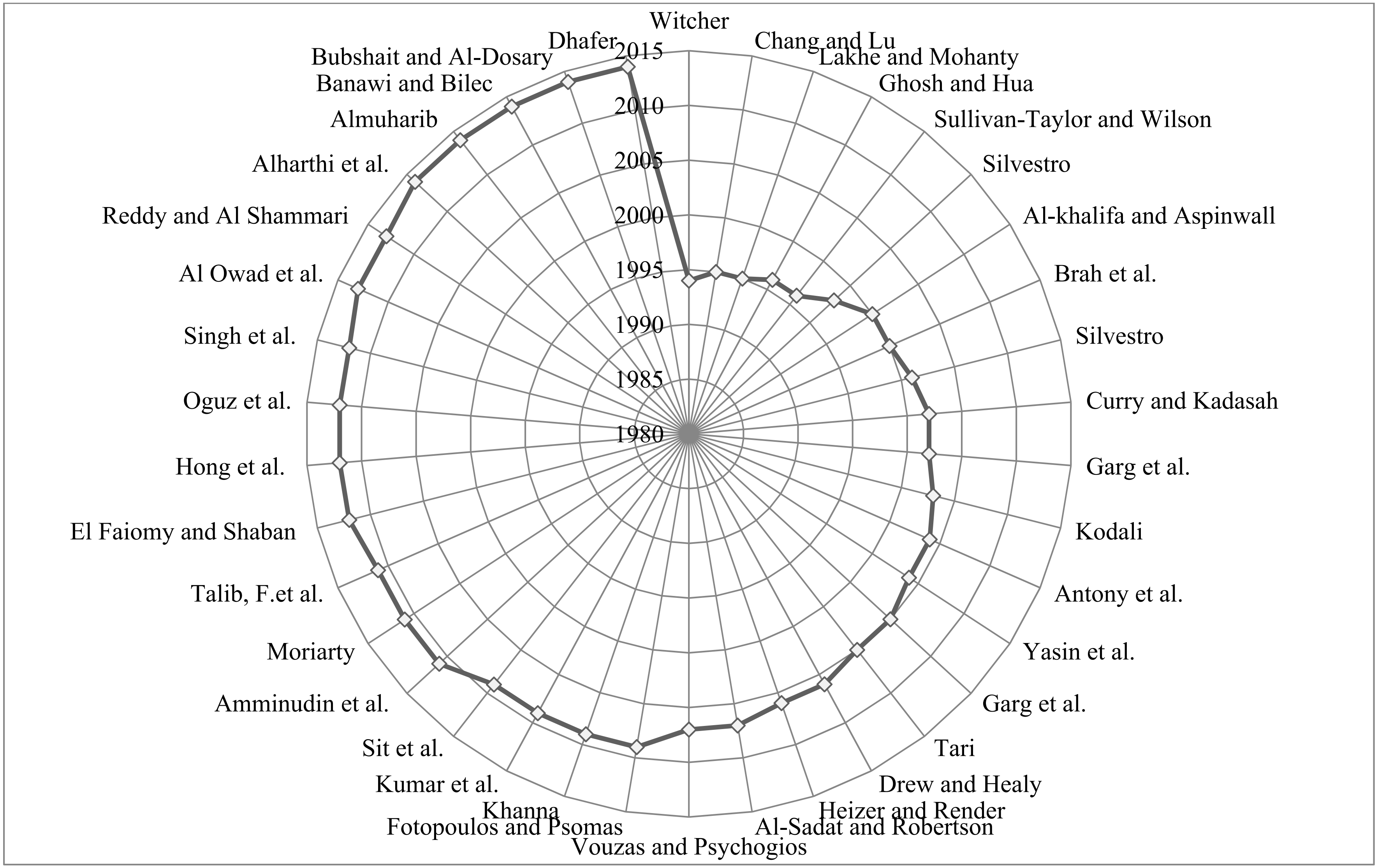


Figure 2.6: Succession of QT&T in service organizations

2.4 GAPS ACKNOWLEDGED FROM LITERATURE ANALYSIS

A widespread review of literature analysis brings out following gaps for the applicability of quality tools and techniques in manufacturing organizations:

- The researcher has not drawn closer to any literature for the grouping of distinctive QT&T in manufacturing organizations based on characteristics of applications.
- Only few numbers of categorizations are available in literature for investigating the implementation rate of QT&T in manufacturing and service organizations.
- In literature the applications of integrated (GTA-AHP) approach for determining effectiveness of QT&T categories through single numerical index has not been recognized.
- In literature, barriers affecting the effective utilization of QT&T in manufacturing organizations have not been carried out.
- Determining the effectiveness of QT&T in varied organizations by integrated (ISM-MICMAC) methodology has still not found in literature analysis.
- The researcher has not come across any literature for finding the level for adoption, applicability, benefits and challenges of various QT&T in manufacturing organizations.
- In literature, analysis of dominating categories by means of shepard plot has not been discovered by any organization.
- The researcher has not come across any literature for assessing the effect of QT&T categories in manufacturing organizations.
- In literature, evidence of developing a structured model between foremost QT&T categories has not been pointed out by any author.

CHAPTER III

QT&T: AN INTROSPECTION AND DETAILED CLASSIFICATION

Manufacturers have been trying to improve the environmental performance of products and services by implementing sustainable development concepts (Ingwersen and Stevenson, 2012). Moreover, law and gunasekaran, (2012) investigated variety of factors that influence the execution of environmental practices for sustainable development of products in manufacturing organizations. Ironically, Superior environmental performance becomes a crucial aspect for delivering goods and services in any organization (Suphunnika and Kayis, 2014). Hence, all organizations (service and manufacturing) undergone significant changes in its definitions, paradigms, approaches, techniques, scope and applications of QT&T in substituent areas. Thus, quality tools and techniques (QT&T) donates means for analyzing problems, performance measurement and diagnostic gaps for enhancing desired improvements in upbringing organization.

3.1 RECOGNITION OF QT&T

In present situation, manufacturing organizations leads to the development and innovation of accelerating product in worldwide competition for their quality, functionality and versatility. It defines the detailed specification and phase development of products for achieving desired results. The important step to get ahead in this competition has to discover new products in order to create differences in global customer requirements. Consequently, effective utilization of particular QT&T in manufacturing organizations becomes prominent for determining their applications and implementation status. To achieve this, organizations must adopt certain problem solving methodologies to accomplish desired improvements in team-oriented manner. So, numerous research & studies for complexity in problem solving techniques have been analyzed to assist the requirements of QT&T in manufacturing organizations.

Rationally, exploratory investigation of manufacturing organizations implements best practices in order to make comparison between different parts related to applications, usages and suitability of distinctive QT&T. Papulova & Papulova, (2006) discussed that industrial organizations must adapt and seeks improvement in quality control with the applicability of QT&T on specified areas. In other words, QT&T has been intended to accomplish various functions & tasks for satisfying customer demands. Deliberately, total 152 distinctive quality tools and techniques are identified and categorized into 16 groups based on their characteristics of applications, suitability and usages. Therefore, to seek the importance of QT&T in varied areas, classification of QT&T into well-defined categories has been made.

The next section of this chapter implies the classification of 152 distinctive QT&T into 16 groups, shown as underneath:

3.2 CLASSIFICATION OF QUALITY TOOLS AND TECHNIQUES

Different QT&T are clubbed into sixteen groups based on their characteristics.

1. Seven basic quality tools (7QT)
2. Management tools (Seven new quality tools) (7MT)
3. Problem solving tools (PST)
4. Software tools (SWT)
5. Statistical tools (ST)
6. Graphical tools (GT)
7. New product development tools (NPDT)
8. Decision making tools (DMT)
9. Productivity tools (PT)
10. Assessment/analysis tools (AT)
11. Combinational tools (CT)
12. Relationship tools (RT)
13. Lean tools (LT)
14. Communicational tools (CMT)
15. Motivational tools (MOT)
16. Performance measurement tools (PMT) (Sharma et al., 2017)

The detailed observation of QT&T categories with subsequent tools have been shown in tables 3.1 to 3.16. The following tables provide an idea about the usage, suitability and major areas of application of various QT&T in distinctive organizations.

3.2.1 Seven basic quality tools (7QT)

Seven basic quality tools are intended to perform imperative role in the development process of manufacturing organizations. These tools are so basic that people with less knowledge & training can easily adapt these tools in diversified areas of manufacturing. Table 3.1 describes the basic quality tools along with their province areas of usages and applications.

3.2.2 Management tools (7MT)

Management tools essentially focuses on work culture environment of the manufacturing organizations. These tools exhibit top to bottom management contribution for the enhancement of various production processes. In other words, managers may persuade a large number of employees to use these tools in a way that benefits the whole firm. Dealing with different managerial aspects, these tools convey different roles in order to demonstrate usages and applications as shown in table 3.2.

Table 3.1: Usage and application of (7QT)

Basic quality tools	**Usage**	**Major areas of Application**	**Suitability**
1.Cause and effect diagram/fishbone diagram/ishikawa diagram/herringbone diagram/fishikawa diagram	• Analyzing problems • Identify root cause, potential causes & performance reduction. • Process improvement. • Categorization capabilities • Evaluation feature.	• Purchasing • Production • Companywide techniques • Data collection	Manufacturing and service sectors
2. Scatter diagram	• Identify effects causing outcome of process, relationships, measuring capabilities & investigation • Statistical analysis • Input/output criteria	• Production • Problem solving • Customer supplier relationships • Data collection	Manufacturing and service sectors
3. Pareto diagram	• Display relationship results • Differentiate between two outcomes • Concentration results & recourses	• Purchasing • Production • Marketing engineering • Sales fore cast	Manufacturing, Service and process industries
4.Flow chart	• Graphical representation • Easily readable • Problem focus • Displaying trends	• Purchasing • Sales revenue • Customer services • Problem solving	Manufacturing, Service and process industries
5.Control charts (C, $\overline{X}$,R,U,P)	• Control evaluating of processes • Identify special causes • Evaluate effort & process parameters • Effectively adaptable to processes	• Manufacturing • Service industries • Monitoring processes • Performance variability • Purchasing	Manufacturing, Service and process industries

Basic quality tools	**Usage**	**Major areas of Application**	**Suitability**
6. Histogram	• Specify variances • Contributed results • Differentiate data distribution • Displaying results	• Problem solving • Production • Accounting processes • Manufacturing	Manufacturing and service sectors
7.Check sheet and tally Chart	• Recording data • Continuous phase measurement • Results Compilation • Continuous improvement of work environment	• Data collection • Purchasing • Production • Customer services • Sales	Manufacturing and service sectors

Table 3.2: Usage and application of 7MT

Management tools	**Usage**	**Major areas of Application**	**Suitability**
1.Affinity diagram	• Relate creative idea with work • Organize natural framework • Explaining difficult results • Collecting data	• Motion and time study • Logistics • Information technology • Service industries	Manufacturing, Service and process industries
2.Arrow diagram	• Calculate critical path • Scheduling task • Enhance thinking & speed up the project	• Monitoring processes • Business re-engineering • Credit function • Human resources	Manufacturing and service sectors
3.Matrix diagram	• Gather multiple information • Identify & investigate severity of data • Explaining ideas of relationship	• Core competencies • Employee attitudes • Facility management • Manufacturing	Manufacturing sectors
4.Matrix data analysis	• Identify comparative results • Pair wise result evaluation • Judging different strategies	• Accounting processes • Production • Sales and revenue • Problem solving	Manufacturing and service sectors
5.Process decision program chart (PDPC)	• Counteracting potential problems • Systematically identify happenstance • Planning development & avoid risks	• Credit function • Finance • Hotel services • Information technology	Manufacturing, Service and process industries

Management tools	Usage	Major areas of Application	Suitability
6.Relation diagram/inter relationship diagram/network diagram	• Identify different aspect complex situation • Determine phase logical sequence • Implemented to complicated solution	• Marketing • Finance • Pre-project planning • Employee attitudes	Manufacturing and service sectors
7.Systematic diagram/tree diagram/hierarchy diagram	• Step wise Categorization • Planned way result orientation • Analyze outcome capabilities	• Information technology • Logistics • Performance measurement • Career management	Manufacturing sectors

3.2.3 Problem solving tools (PST)

Several unsuccessful attempts diminish due to the execution of problem solving tools in the manufacturing organizations. Systematic procedures have been adopted to find out the solution of specific problems that arises in the manufacturing organizations for the improvement of quality. Different QT&T have been categorized in terms of usage and application to identify the problems arising in various stages of manufacturing as shown in table 3.3.

3.2.4 Software tools (SWT)

Software based results are more easily accessible and formulated in orderly manner. Software tools are indented to create, debug, maintain or support identical programs that help to rationalize errors in automated equipments. For necessary improvement of products in manufacturing organizations, software tools along with respective usages and applications has been shown in Table 3.4

3.2.5 Statistical tools (ST)

QT&T have vast influence in data collection. Re-arranging of data by mathematical techniques requires statistical tool for getting the structured and meaningful results. Table 3.5 covers the representation of statistical tools with major areas of usages and applications.

3.2.6 Graphical tools (GT)

Graphical tools are used to represent data in orderly manner. These tools provide direct insight for the practitioners and industrial experts about the utilization of statistical technique in graphical manner. To know the influence of QT&T in manufacturing organizations various tools exhibits the features of pictographic illustration which facilitates the users to understand situation more easily. Table 3.6 shows the various graphical tools.

3.2.7 New product development tools (NPDT)

Industrialist and researchers have invented new tools for the development of products in order to satisfying performance in manufacturing organization. By identifying possible reasons of adopting NPDT tools in manufacturing organizations, researchers can easily sorted out the problems responsible for the enhancement of products. The domain areas of NPDT tools with respective applications and usages are enlisted in table 3.7.

Table 3.3: Usage and application of problem solving tools

Problem solving tools	**Usage**	**Major areas of Application**	**Suitability**
1. A3 report	• Captured past problem • Introduced new concept • Analyze document & trade-off	• Manufacturing • Core competencies • Finance • Data collection	Manufacturing and service sectors
2.Effective meetings	• Preparing agenda • Task oriented • Encourage work force • Exchange Information	• Change management • Facility management • Information technology • Public sectors	Service and process industries
3. Eight disciplines (8D)	• Defining team objectives • Counter measure problem • Permanent corrective actions	• Marketing • Problem solving • Product development	Manufacturing and process industries
4.Five why's (5w's)	• Identify root cause • Detailed overview of problem statement • Simpler way for defining results	• Manufacturing • Service industries • Operational performance • Purchasing	Manufacturing and service sectors
5.Five why's and one how's (5w1h)	• Evaluate complex situation • Refined way to measure results • Monitor activities	• Manufacturing • Public sector • Research & development	Manufacturing and service sectors

Problem solving tools	Usage	Major areas of Application	Suitability
6.Five why's and two how's (5w2h)	• Exhaustive approach can be simplified • In order distribution of outcome • Planned way to deal situations	• Product development • Service industries • Performance measurement	Manufacturing and service sectors
7.Five why's and five how's (5w5h)	• Handle multiple situations • In depth evaluation of problem • Accuracy in results	• Career management • Core competencies • Service industries	service sectors
8.Impact effort matrix	• Retrieve suggestive solutions • Identify each outcome • Systematic overview of problem statement	• Sales • Production • Companywide techniques	Manufacturing sectors
9.Nine windows	• Break initial and drive solution • Avoid inflexibility & false assumptions • Adaptable easily to other techniques	• Problem solving • Customer services • Marketing • Sales revenue	Process industries
10.Nomial group Technique (NGT)	• Group contribution approach • Identify conflicts between teams • Generate quantities of ideas	• Customer/supplier relationship • New product introduction • Quality awareness	Manufacturing and process industries
11.Problem solving Methodology	• Dealing complex variety of situations • Easy outcome for desired problem • Continuous and sustainable improvement	• Manufacturing • Sales forecast • Service industries • Marketing	Manufacturing, Service and process industries

Problem solving tools	**Usage**	**Major areas of Application**	**Suitability**
12.Problem concentration Diagram	• Determine location based occurrence • Symbolic way for defining problems • Connect events to physical location	• New product development • Credit function • Human resources • Finance	Manufacturing and process industries
13.Quality circles	• Evaluate workforce capabilities • Multiple situations • In order distribution of work	• Performance measurement • Companywide techniques • Employee attitudes	Manufacturing, Service and process industries
14.Sucess and effect diagram	• Immediate attention to problem • Continually improve other processes • Conducted sense full ownership	• Accounting processes • Business re-engineering • Career management	Process industries
15.Pilot testing	• Small scale trial • Eliminating errors • Feedback about performance	• Problem solving • Information technology • Facility management	Process industries
16. Triz	• Accelerate project team ability • Provide repeatability, Predictability & reliability due to structure approach • Scientifically based problem solving approach	• Performance measurement • Logistics • Research & development • Human resource	Service and process industries

Table 3.4: Usage and application of software tools

Software tools	Usage	Major areas of Application	Suitability
1.Anomaly report	• Identify detailed defect/ bug found in software • Find out discrepancy & trouble issues • Document investigation	• Data analysis • Human resource • Public sectors • Service industries	Service and process industries
2.Integrated design for function modeling (IDEFO)	• Organize system analysis • Promote consistency and interpretation between users • Easily compatible with computer integrated manufacturing (CIM)	• Research & development • Career management • Employee attitudes • Product development	Manufacturing, Service and process industries
3.Operational acceptance test (OAT)/operational readiness testing (ORT)	• Maintenance & operation of projects • Verify non-functional aspect of system • Periodically checking security	• Manufacturing • New product development • Retail distribution strategy	Manufacturing and process industries
4.Reliability metrics	• Maximize system reliability • Counting operational failures • Interaction between software and hardware	• Risk management • Sales performance • Small and medium industries • Capability measure	Manufacturing process industries

Software tools	Usage	Major areas of Application	Suitability
5.Simulations	• Mathematical modeling • Performance optimization & safety engineering • Simplifying approximation and assumptions	• Data collection • Performance measurement • Pre-project planning • Education	Process industries
6.Rationale map	• Structure arguments • Analyze reasoning • Identify assumptions	• Public sector • Career management • Research &development	Service and process industries

Table 3.5: Usage and application of statistical tool

Statistical tools	Usage	Major areas of Application	Suitability
1.Acceptance sampling	• Acceptance and rejection of lots • Identify customer supplier relationships • Calculate no of defective items	• New product development • Service industries • Library • Purchasing	Manufacturing and service industries
2. Analysis of Variance (ANNOVA)	• Analysis of means • Easily differentiate between two results • Comparison between material and products	• Data collection • Financial services • Operational management • Sales forecast	Process industries
3.Basic statistics	• Calculate mean, median, mode & standard deviation • Easily accessible large data • Combine with other techniques	• Performance measurement • Risk management • Small and medium industries • Finance	Manufacturing, Service and process industries
4.Hypothesis test	• Determine probability of outcomes • Calculate relationship between two data sets • Specifying parametric limits	• Safety management • Public sector • Pre-project planning • Human resource	Service and process industries
5.Measles chart	• Collecting and analyzing data • Continuously improve defect rate • Cluster marking approach	• Physician workforce • Preventive maintenance • Product development • Data collection	Manufacturing industries

Statistical tools	Usage	Major areas of Application	Suitability
6 .Record sheet	• Identify numerous data • Compile Multiple information • Implemented in almost all areas	• Operational performance • Library • Customer/service relationship	Service and process industries
7.Regression analysis	• Estimate relationship among variables • Modeling technique • Identify location parameter	• Data collection • Facility management • Information technology • Service industries	Service industries
8.Sampling plan	• Selection of subset individual • Simplify data • Identify critical factors	• Logistics • Problem solving • Manufacturing • Design development	Manufacturing and process industries
9.Wei bull analysis	• Predict life of product • Parameterized distribution of data • Identify failure & causes	• New product development • Preventive maintenance • Data analysis	Manufacturing industries
10.Correlation	• Find out dependency between two random variables • Indicate predictive relationship • Demonstrate data	• Data collection • Customer relationship • Companywide techniques • Sales and revenue	Process industries
11.Sequential regression and best sub sets	• Step wise data evaluation • Identify best fitting regression model • Predict future response	• Pre-project planning • Human resource • Employee attitudes • Finance	Process industries

Statistical tools	Usage	Major areas of Application	Suitability
12.Spaghetti diagram	• Identify redundancies in work flow • Continuous flow line tracing approach • Highlight major areas	• Manufacturing • Service industries • Purchasing • Design and development	Manufacturing and service industries
13.Time series	• Successive measurement of data • Calculate distance between two time intervals • Determines records of results	• Data analysis • Performance measurement • Risk management • Travel management	Process industries
14.Questionnaire	• Gathering information from respondents • Design for analysis of responses • Compile data in simpler way	• Preventive maintenance practices • Logistics • Product development • Service industries	Manufacturing and service industries
15.Contingency table	• Display multivariate frequency distribution of variables • Focus on survey & scientific research • Store data in smarter way	• Finance • Purchasing • Research & development • Data analysis	Process industries
16.Taguchi methods	• Development of design for studying variation • Improve mean outcome of process • Make comparative statements	• Performance measurement • Risk management • Core competencies • Public sectors	Service and process industries

Table 3.6: Usage and application of graphical tools

Graphical tools	Usage	Major areas of Application	Suitability
1.Frequency graph	• Schematic displays of project schedule • Find cumulative frequency • Scheduling tools in Microsoft	• Accounting processes • Business re-engineering • Manufacturing • Marketing	Manufacturing and process industries
2.Bar chart	• Group data distribution • Compare size of two quantities • Show cumulative effect	• New product development • Performance measurement • Customer relationship	Manufacturing, Service and process industries
3.Fault tree analysis (FTA)	• Analyzed undesired state of system • Top to bottom deductive approach • Identify causes which effects system	• Preventive maintenance practices • Facility management • Retail distribution	Process industries
4.Line graph	• Mathematical graph theory • Show inter dependencies between variables • Identify multi decision approach	• Operational performance • Business re-engineering • Banks • Information technology	Process industries
5.Run chart	• Display observed data • Find out Performance outcome • Monitor behavior of variable	• Logistics • Manufacturing • Operational management • Banks	Manufacturing, Service and process industries

Graphical tools	Usage	Major areas of Application	Suitability
6.Pie chart	• Divide numeric proportions of data • Make comparative statements • Demonstrate various activities	• Performance measurement • Service industries • Manufacturing • Marketing	Manufacturing, Service and process industries
7.Plan do check act cycle (PDCA)	• Continuous improvement of process and product • Iterative management technique • Repetitive work process	• Career management • Credit functions • Public sectors • Pre-project planning	Service and process industries
8.Dispersion graph	• Display distributed data • Focus each activity • Confirmatory results	• Health and safety measurement • Product development • Employee attitudes	Manufacturing, Service and process industries
9.Box and whisker Plot	• Represents five statistical summaries at a time • Summarizes data from multiple source • Comparison of data	• Data analysis • Financial services • Purchasing • Customer supplier relationship	Process industries

Graphical tools	Usage	Major areas of Application	Suitability
10.Multi-vari chart	• Display patterns & variations among data • Identify groups & sub group among activities • Relationships between factors and response	• Core competencies • Public sectors • Credit functions • Banks	Service and process industries
11.Radar chart	• Display data in two dimensional chart • Represent quantitative variables on axes starting from same point • Compatible easily with software	• Finance • Operational performance • Service industries • Telecommunications	Service and process industries

Table 3.7: Usage and application of NPDT tools

NPDT Tools	Usage	Major areas of Application	Suitability
1.Benchmarking	• Measure organization policies • Analyze performance level • Identify problem areas	• Food and drinks industries • Informational technology • Law courts	Service and process industries
2.Beta testing	• Explore product outcomes • Discover flaws and issues between subordinates • Easily adaptable with software	• Product development • Research &design • Problem solving • Human resource	Manufacturing and process industries
3.Brainstorming	• Identify specific problems • Gather ideas from members • Give creative solution to problem	• Information technology • Purchasing • Supply chain operations • Risk management	Process industries
4.Concept testing	• Evaluate customer response • Generate communication between customers • Introduce new product in market	• Customer/supplier relationship • Manufacturing • Safety management • Marketing	Manufacturing, Service and process industries
5.Conjoint analysis	• Determine different attributes in market • Compatible with statistical technique • Control potential product and services	• Service industries • Public sectors • Education • Library	Service and process industries

NPDT Tools	Usage	Major areas of Application	Suitability
6.Contextual enquiry	• Design ethnographic research method • Semi structured interview method Capture work complexities, information flow and cultural qualities of working environment	• New product introduction • Finance • Retail distribution strategies • Sales performance	Manufacturing and process industries
7.Delphi technique	• Interactive forecasting method • Questionnaire technique • Structured communication method between experts	• Customer/supplier relationship • Law courts • Education • Manufacturing • Information technology	Manufacturing and process industries
8.Design of experiments (DOE)	• Find cause and effect relationship • Manage process input to optimize output • Evaluate and control value of parameters	• Research and development • Manufacturing • Performance measurement • Risk management	Manufacturing, Service and process industries
9.Design for six sigma (DFSS)	• Determine needs of customer and business • Inform design decision and trade offs • Focus on evolutionary and continuous improvement	• Food and drinks industries • Product development • Employee attitudes • Safety management	Manufacturing and process industries

NPDT Tools	Usage	Major areas of Application	Suitability
10.Failure mode and effect analysis (FMEA)	• System reliability study • Identify failure mode by reviewing many components • Evaluation of diagnostic systems	• Problem solving • Sales forecast • Small and medium scale industries • Pre-project planning	Process industries
11.Focus group	• Qualitative research method • Identify survey results • Provide data at lower cost	• Business re-engineering • Research and development • Physician workforce	Service and process industries
12.In-home use test	• Market research method • Gain feedback from consumers • Fallow-up survey technique	• Marketing • Employee attitudes • Customer relationship • Travel management • Purchasing	Process industries
13.Quality function deployment (QFD)	• Translate customer needs into specific plans • Deploy function forming quality • Achieve design quality into subsystem and component parts	• Research and development • New product development • Research and design • Pre-project planning	Manufacturing, Service and process industries

3.2.8 Decision making tools (DMT)

Manufacturing professionals take several decisions regarding machine, material and other aspects related to organization. Decision makers often face diversified and complicated situations for the utilization of various QT&T that effectively engage problem solving methodology for quantifying quality-related issues developed in manufacturing organizations. For this purpose, various decision making tools are adopted by certain practitioners as shown in table 3.8.

3.2.9 Productivity tools (PT)

Majority of manufacturing organizations offer higher productivity and efficiency for satisfying global competition market. The utilization of productivity tools encounters various difficulties related to the quality of product. To overcome this difficulty, many tools and techniques have been intended to increase the performance of varied products than average firms by enhancing the growth of manufacturing organizations. Table 3.9 describes the usages and applications of various productivity tools.

3.2.10 Specific analysis/assessment tools (AT)

As name indicates, these tools allow specific judgment to address and measure quality by means of different analysis methods in the manufacturing organization. These tools distinctively evaluate and focus on possible procedures that evaluate the effectiveness of manufacturing organizations. The role of major applications, usages and suitability of different assessment tools have been illustrated in table 3.10.

3.2.11 Combinational tools (CT)

QT&T's are intended to combine with other tools for enhancing their performance and getting desired results in the manufacturing organizations. These tools contribute in same manner like an individual tool performs in combined form. These tools are shown in table 3.11.

3.2.12 Communicational tools (CMT)

Communicational tools are used to convey information regarding improvement and growth of manufacturing organization. These tools help to identify efforts and deficiencies responsible to insist financial transactions in manufacturing organizations. Table 3.12 shows the possible communicational tools with their respective usages and applications in subsequent areas.

3.2.13 Relationship tools (RT)

Relationship tools are utilized for determining the relationship between different elements related to an issue. Moreover, these tools are widely utilized in all stages of product development and production process with the goal to minimize cost and increased customer satisfaction. Relationship tools are shown in table 3.13.

Table 3.8: Usage and application of decision making tools

Decision making tools	Usage	Major areas of Application	Suitability
1.Break even chart	• Firm manufacturing of compact disk • Identify profit and loss statement • Determine relationship between sales ,costs and profits	• Cost evaluation • Accounting processes • Manufacturing • Operational performance • World class manufacturing	Manufacturing and process industries
2.Decision matrix	• Evaluates list of options • Discuss and refine list of criteria • Identify rate of performance and relationships	• Logistics • Food and drinks industries • Employee attitudes • Hotel services	Service and process industries
3.Force field analysis	• Analyze force against change • Communicate reason behind change • Employed for social situations	• Employee attitudes • Physician workforce • Credit functions • Change management • Pre-project planning	Process industries
4.Gantt chart	• Illustrate project scheduled • Show activities which display against time • Scheduled complex projects	• Education • Public sector • Telecommunications • Sales forecast	Service and process industries

Decision making tools	Usage	Major areas of Application	Suitability
5.Multi voting	• List larger possibilities into narrow one • List priorities and finalize selection • Discuss remaining ideas	• Safety management • Operational performance • Employee attitudes • Core competencies	Process industries
6.Prioritization matrix	• Multiple project completion • Determine order sequence of factors • Focus team recourses	• Career management • Product development • Information technology • Public sectors	Service and process industries

Table 3.9: Usage and application of productivity improvement tools

Productivity improvement tools	**Usage**	**Major areas of Application**	**Suitability**
1.Concurent engineering	• Design and development of products • Improve productivity and reduced cost • Bring new product in market	• Research and design • New product development • Pre-project planning • Facility management	Manufacturing and process industries
2.Enterprise resource planning (ERP)	• Collect, store & interpret data • Control product planning, marketing, sales & inventory management • Widely compatible with software	• Career management • Change management • Sales performance • Retail distribution strategies • Marketing	Manufacturing, Service and process industries
3.Evalutionary operation (EVOP)	• Experimental design improvement • Manufacturing process optimization technique • Introduce small change in process	• Manufacturing • Service industries • Public sectors • Medium and small scale industries	Manufacturing and Service industries
4.Group technology (GT)	• Identification of similar parts • Maximize production efficiencies • Reduced recurring problems and task	• Product evaluation • Operational performance • Spare parts logistics • World class manufacturing	Manufacturing industries

Productivity improvement tools	**Usage**	**Major areas of Application**	**Suitability**
5.Just in time (JIT)	• Reduce flow time between production • Improve procurement policies and manufacturing process • Production scheduling & interchanging data	• Manufacturing • Service industries • Preventive maintenance • Safety management	Manufacturing, Service and process industries
6.Kaizen activities	• Improve every function of business • Aim to eliminate waste • Continual improvement and aspects of life	• World class manufacturing • Health and safety management • Research and development	Manufacturing and Service industries
7.Kano model	• Classify customer preferences • Translate and transforms results • Create profitable products or services	• New product development • Core competencies • Performance measurement • Pre-project planning	Manufacturing and Service industries
8.Business process re- engineering (BPR)	• Refocus company values on customer needs • Information technology to enable improvements. • Analysis and redesign of work flow	• Customer/supplier relationship • Credit function • Logistics • Risk management	Service and process industries

Productivity improvement tools	**Usage**	**Major areas of Application**	**Suitability**
9.Supply chain management	• Movement and storage of raw materials • Interconnected with other network and channels • Build competitive infrastructure	• World class manufacturing • Physician workforce • Finance • Information technology	Manufacturing, Service and process industries
10.Total productive maintenance (TPM)	• Maintain & improve integrity of production • Add business value to an organization • Prefect production with no break downs	• Performance measurement • Safety management • Product development • Small and medium industries	Manufacturing industries
11.Zero defect (ZD)	• Eliminate defects in industrial production • Generate output within specified limits • Sampling and comparing lots	• Accounting processes • Performance measurement • Defect prevention • World class manufacturing	Manufacturing industries

Table 3.10: Usage and application of specific analysis/assessment tools

Analysis/assessment tools	**Usage**	**Major areas of Application**	**Suitability**
1.Consensus analysis	• Answer series of related questions • High level of consistency among informants • Homogeneity analysis	• Data analysis • Change management • Education • Library • Information technology	Process industries
2.Internal audits	• Design and add value improvement • Evaluate effectiveness • Provide recommendations for assessments	• Retail distribution strategies • Employee attitudes • Operational performance • Information technology	Service and process industries
3.Personality profiling	• Evaluate employee personal attributes • Maximize and contribute job performance • Design to seek out top to bottom management effort	• Law courts • Education • Physician work force • Customer relationship	Process industries
4.Self-assessment	• Focus on revenue & customs • Self-verification& enhancement • Deductions of taxes	• Accounting process • Business re-engineering • Credit function • Change management	Process industries
5.Stake holder analysis	• Identify groups that affected proposed action • Weigh & balance competing demands • Analyze attitude by mapping	• Food and drinks industries • Hotel services • Logistics • Retail distribution strategies	Service and process industries

Analysis/assessment tools	**Usage**	**Major areas of Application**	**Suitability**
6.Supplier survey	• Collect information to satisfy social and environmental criteria • Strength company mission • Evaluate performance through questionnaire	• Customer/supplier relationship • Risk management • Supply chain operations • Travel management	Process industries
7.Survey design and analysis	• Illuminate new opportunities • Obtain information from large aggregate • Focus on customer, employee & market needs	• Research and development • Human resource • Operational performance • Public sectors	Service and process industries
8. Accelerated life test	• Testing product by subjecting conditions of stress & strain. • Uncover faults and potential mode of failure • High longevity of product	• Product development • Pre-project planning • Operational performance • Physician workforce	Manufacturing and process industries
9.Architectural design evaluation tool	• Highlight the strength and weakness of design • Evaluate refurbishment scheme • Analysis and feedback response	• Facility management • Change management • Risk management • Design development	Service and process industries

Analysis/assessment tools	**Usage**	**Major areas of Application**	**Suitability**
10.Customer satisfaction assessment	• Support strategic decision making • Analyze data & share findings • Valuable customer research program	• Customer supplier relationship • Business re-engineering • Career management • Employee attitudes	Service and process industries
11.SWOT analysis (strength, weakness, Opportunities and threats)	• Evaluates elements of project or business • Identify internal external factors • Specifying objectives	• Business re-engineering • Manufacturing • Supply chain operation • Research and development	Manufacturing, and process industries

Table 3.11: Usage and application of combinational tools

Combinational tools	Usage	Major areas of Application	Suitability
1.Economic analysis	• Determine optimum scarce recourses • Comparison between alternatives • Assess policy & program	• Accounting processes • Change management • Credit function • Employee attitudes • Facility management	Process industries
2.Process capabilities	• Compare the output of stable processes • Hold tolerance and customer requirements • Choose most competing process	• Operational performance • Preventive maintenance practices • Public sector	Service and process industries
3.Statistical process control (SPC)	• Measuring & controlling quality during manufacturing process • Ensure process operates with full potential • Early detection & prevention of problem	• Data analysis • Performance measurement • Information technology • Accounting processes	Process industries
4.Analysis of quality cost	• Finding & correcting defective work • Compatible with software analysis • Identify area keywords of different costs	• Credit function • Purchasing • Sales forecast • Performance measurement	Process industries

Combinational tools	**Usage**	**Major areas of Application**	**Suitability**
5.Suppliers, Input, process, Output, and customers	• Summarize input/output in table form • Identify relevant elements of process improvement • Process mapping	• Logistics • Operational performance • Physician workforce • Change management	Process industries
6.Cross functional teams (CFT'S)	• Assign specific task to teams • Multi-disciplinary approach • Create new package company products	• Information technology • Marketing • Supply chain operation • Retail distribution strategies	Service and process industries
7.Out of control action plan (OCAP)	• Guides employee's reaction to out of control situations • Identify assignable causes for product monitoring • Guide operators for repeatable &defined responses	• New product development • Spare part logistics • Research and development • Small and medium scale industries	Manufacturing industries
8.Market test	• Gauge viability of product or service • Judge acceptability of variations in market • Promotion and distribution of product	• Business re-engineering • Facility management • Finance • Sales and revenue • Purchasing	Service and process industries

Combinational tools	Usage	Major areas of Application	Suitability
9.Six sigma	• Eliminating defects between processes • Minimize variability in manufacturing process • Train employee & provide valuable skills	• New product development • Research and design • Core competencies • Performance measurement	Manufacturing, Service and process industries
10.PEST analysis (political, economic, Social, technological)	• Describe macro environmental factors • Analysis of market research • Focus on ecological aspects	• Operational performance • Supply chain operation • Physician workforce • Sales performance	Service and process industries

Table 3.12: Usage and application of communicational tools

Communicational tools	Usage	Major areas of Application	Suitability
1 Process mapping	• Measure and compare objectives • Aligned company values and capabilities • Focus on critical areas of process	• Problem solving • Core competencies • Career management • Human resource	Process industries
2.Quality costing	• Identify efforts and deficiencies • Categorize financial transactions into revenue & expense • Determine potential savings by implementing process improvements	• Logistics • Marketing • Product development • Sales forecast • Treasury • Supply chain operations	Manufacturing and process industries
3.Smart matrix	• Identify specifics of actions or tasks • Capture key points of team project objectives • Summarize data in efficient manner	• Data analysis • Business re-engineering • Accounting processes • Public sector	Process industries
4.Standard operating Procedure (SOP)	• Focus on variety of different contexts • Describe regular recurring operation revenant to quality of investigation • Drafting the document	• Supply chain operations • Career management • Employee attitudes • Operational performance	Process industries

Communicational tools	Usage	Major areas of Application	Suitability
5.Business plan	• Background information about organization • Target changes in perception & branding of customer • Plan new strategies	• Marketing • Purchasing • Risk management • Sales performance • Treasury	Service and process industries
6.Customer voice	• Feedback report from customers • Focus on customer needs & expectations • Give multi source insight program for product improvement	• Human resource • Pre-project planning • Sales performance • Spare parts logistics • Marketing	Service and process industries
7.Critical incident	• Collect direct information from humans • Identify perceived threats between organization • Investigate critical incidents	• Data collection • Information technology • Risk management • Travel management • Physician workforce	Process industries
8.Visual management	• Immediate action for eliminating waste • Identify errors &discern • Highlighted problem areas	• Manufacturing • Hotel services • Law courts • Library • Education	Manufacturing and service industries

Table 3.13: Usage and application of relationship tools

Relationship tools	Usage	Major areas of Application	Suitability
1.Departmental purpose analysis (DPA)	• Align departments in orderly manner • Identify staff requirements • Highlight opportunity for improvement	• Career management • Operational management • Retail distribution strategies • Risk management	Process industries
2.House of quality (HOQ)	• Focus on customer desires & product capabilities • Identify outcomes related to customer wants versus product features • Provide conceptual map for planning & communications	• Customer/supplier relationship • New product development • Service industries • Employee attitudes	Manufacturing and service industries
3.Service blue printing/moments of truth (MOT)	• Service innovation • Conceptualize structural change • Copy large architectural and construction drawings	• Information technology • Human resource • Operational performance • Service industries	Service and process industries

Relationship tools	**Usage**	**Major areas of Application**	**Suitability**
4.Input/output analysis	• Identify interdependence between various productive sectors • Focus inter-industry relationship with economy • Show brief information about each sector	• Accounting processes • Purchasing • Companywide techniques • Credit functions	Service and process industries
5.Gap model	• Identify gap between service specification & service delivery • Integrated company customer relationship • Focus on customer expectations	• Problem solving • Service industries • Customer/supplier relationship • Sales forecast	Service industries

3.2.14 Performance measurement tools (PMT)

Performance measurement tools are utilized for assessing and measuring the performance of manufacturing organizations. These tools increase the consistency, capability, effectiveness of the organizational performance as shown in table 3.14.

3.2.15 Lean tools (LT)

Lean tools are utilized by manufacturing and service organizations for eliminating the waste. Lean tools acted as the finish pointer of products to amplify productivity, quality, lead time, customer satisfaction and the growth of the employees' capabilities. Following tools fall under the category of lean tools as illustrated in table 3.15.

3.2.16 Motivational tools (MT)

Encouraging work force leads to tackle the different situations in manufacturing organizations. QT&T's requires persistence empowerment and motivation for developing self-improvement in manufacturing organizations. Motivational tools have been described in table 3.16 along with their domain areas of usage and applications.

Table 3.14: Usage and application of PMT tools

Performance measurement Tools	Usage	Major areas of Application	Suitability
1.Evaluation of measurement/inspection system	• Increase consistency between quality management system • Capability for measuring effectiveness • Comparing quality performance criteria	• Operational performance • Performance measurement • Physician work force • Public sector	Process industries
2.Gauge repeatability and reproducibility/gauge (R&R)	• Determine viability of measurement system • Finding problems in current system • Optimize performance	• Research and development • Spare parts logistics • Product development • Risk management	Manufacturing and service industries
3.Management by objectives (MBO)	• Defining objectives of organization • Measure employee actual performance • Identify common goals	• Human resource • Career management • Credit functions • Accounting processes	Service and process industries
4.Pair wise comparison	• Judging each entity of system • Pair wise comparison for measurement • Easily assessable with statistical technique	• Small and medium scale industries • Telecommunications • World class manufacturing • Sales performance	Manufacturing, Service and process industries
5.Balanced scorecard	• Balance financial perspective • Support design &automation tools • Track executive activities	• Strategic planning management • Credit function • Logistics • Retail distribution strategies	Service and process industries

Performance measurement Tools	Usage	Major areas of Application	Suitability
6.Critical to quality (CTQ) Tree	• Measure characteristics of product • Align improvements in design with customer requirements • Improve interactions among customers	• Product development • Small and medium scale industries • Supply chain operations • Pre-project planning	Manufacturing and service industries
7.Control plan	• Improved process at current level • Focus training requirements and human recourse • Describe and check contingency plan	• Manufacturing • Service industries • Research and development • Public sector • Marketing	Manufacturing, Service and process industries
8.Key performance indicator (KPI)	• Evaluate success of organization • Focus on progress towards strategic goals • Compare financial matters	• Performance measurement • Strategic planning • Information technology • Operational performance	Service and process industries
9.OEE analysis (overall equipment effectiveness)	• Describe labor efficiencies • Compare between different manufacturing units • Identify scope for processes	• Sales forecast • Pre-project planning • Retail distribution strategy • World class manufacturing	Manufacturing and process industries

Table 3.15: Usage and application of lean tools

Lean tools	Usage	Major areas of Application	Suitability
1. 5'S	• Simplify design • Identify defects • Enhance enterprise image to customers	• Product development • Research and design • World class manufacturing	Manufacturing and service industries
2.Hei-junka (level out the work load)	• Reduce waste in production & interpersonal processes • Achieve smoother production flow • Leveling type & quality of production	• New product development • Operational performance • Safety management • Business re-engineering	Manufacturing and process industries
3.Kanban	• Improve and maintain high level of production • Control logistical chain for production • Manage work with efficient manner	• Manufacturing • Service industries • Strategic planning • World class manufacturing • Spare parts logistics	Manufacturing, Service and process industries
4.One piece flow	• Efficient movement of work parts between stations • Reduced time in change over • Systematic approach of work parts selection	• Research and development • Manufacturing • Information technology • Human resource	Manufacturing and process industries

Lean tools	**Usage**	**Major areas of Application**	**Suitability**
5.Poka Yoke	• Eliminating error in manufacturing • Identify and correcting defects • Focus on customer service and procurement	• Product development • Safety management • Risk management • Customer/supplier relationship • Service industries	Manufacturing, Service and process industries
6.Preventive maintenance	• Systematic inspection • Prevent sudden failures • Avoid unplanned maintenance	• Performance measurement • Pre-project planning • Logistics	Service and process industries
7.Quenining analysis	• Quantitative analysis technique • Focus on delays • Rapid &inexpensive selection	• Customer /supplier relationship • Food and drinks industries • Public sectors	Service and process industries
8.Single minute Exchange of dies (SMED)	• Rapid & efficient way of converting one product into another • Reduce production lot size • Focus on revolutionary product design	• Spare parts logistics • Research and design • Small and medium scale industries • Supply chain operations	Manufacturing and service industries

Lean tools	Usage	Major areas of Application	Suitability
9.Time and motion studies	• Repetitive tasks • Improving planning and scheduling • Optimize performance of products	• Career management • Supply chain operations • Retail distribution strategies	Manufacturing and process industries
10.Value stream mapping	• Improve flow of information or materials • Analyze and design future state of events • Diagrammatically detailing of step of processes	• Accounting processes • Design and development • Manufacturing • Public sector • Travel management	Manufacturing and service industries
11.Hoshin kanri	• Find strategic goals • Design to ensure mission, vision and goal • Interpreted direction management for entity	• Supply chain operations • World class manufacturing • Marketing • Design and development	Manufacturing industries

Table 3.16: Usage and application of motivational tools

Motivational tools	Usage	Major areas of Application	Suitability
1.Recognisation & reward	• Motivate employee to change work habits • Support mission, value and goal • Focus on employee satisfaction	• Employee attitudes • Human resource • Travel management • Treasury • Banks	Service and process industries
2.Quality improvement Team	• Invariable involve multiple work system • Carry out improvement efforts • Divide responsibilities to each employee	• Business re-engineering • Performance measurement • Research and development • Information technology	Process industries
3.Training	• Focus on skills and knowledge related tasks • Enhance team effort • Identify weak points in workforce units	• Library • Education • Hotel services • Safety management • Small and medium enterprise	Service and process industries

Motivational tools	Usage	Major areas of Application	Suitability
4.Team profiling	• Boost self-awareness • Focus on teamwork • Maximize individual effectiveness	• Core competencies • Facility management • Human resource • World class manufacturing	Manufacturing, Service and process industries
5.Employee suggestion Schemes (ESS)	• Improve safety and reduction in waste • Introduce high level production criteria • Generate financial saving	• Employee attitudes • Pre-project planning • Operational performance • Sales forecast	Service and process industries

3.3 CONCLUDING REMARKS

- Manufacturing organizations needs to improve their working environment by effective and efficient usage of QT&T in distinctive manner.
- Idiosyncratic 152 quality tools and techniques are identified and categorized into 16 groups based on their characteristics of applications, suitability and usages.
- QT&T makes optimistic relationship with quality indicator to imitate techniques for the contribution of employee's in the expansion of manufacturing organizations.
- The role of QT&T in manufacturing and service organizations enumerates distinctive key features responsible for enhancing performance and growth of the organizations.
- Subsequent surrounding changes have been detected and in cooperated to stay in present challenging environment.
- Integrated methods must be applied to scrutinize the effect of QT&T in manufacturing organizations for finding effectiveness.

CHAPTER IV

MEASURING EFFECTIVENESS OF QT&T BY INTEGRATED (AHP-GTA) APPROACH

In today's manufacturing environment, advancement in application of quality tools and techniques (QT&T) has enhanced the conventional manufacturing aspects. Modern manufacturing organizations that wish to be successful and to achieve world-class manufacturing must utilize the deployment of QT&T more effectively. The concept and methodology of QT&T have been expanded and integrated with other concepts in the present era. Thiagaragan et al. (2001) has discussed that for fulfilling the needs of consumers many corporate entities give priorities to quality for satisfying global competitive environment.

4.1 EXISTENCE OF QT&T GROUPING IN MANUFACTURING ORGANIZATIONS

Dale (2003) suggested that application of QT&T provide direct and immediate least problematic aspects for quality improvement. McQuater et al. (1995) suggested that QT&T are practical methods, skills, means or mechanisms that can be applied to particular tasks. Moreover, QT&T has been described by many theories and guiding principles from various quality gurus like Deming, Juran, Feigenbaum and Crosby for enhancement of performance in manufacturing organizations.

Every manufacturing organization opt systematic procedures and techniques for improvement and effectiveness of variety of products. Many researchers and practitioners over the last two decades revels the outcome of QT&T into different area of manufacturing best suited according to application. It is commendable that many of these QT&T are simple but these QT&T needs to be clubbed into different aspects for accessing the combined effect of their application and usages in manufacturing arena.

From literature analysis, it is revealed that limited number of authors e.g. Hellsten & Klefsjo, (2000); Mehra et al. (2001); Chin et al. (2002); Grover et al. (2004) have categorized these QT&T into different groups. Hence there is requirement of elaborated classification of QT&T. In view of this, QT&T have been classified and categorized into different groups as illustrated in Table 4.1 (Sharma et al., 2020).

1. New product development tools (S_1) (Thia et al.2005)
2. Decision making tools (S_2) (Grover et al.2007)
3. Data representation and analysis tools (S_3) (Bamford et al.2005)
4. Lean tools (S_4) (Kovach et al.2011)
5. Performance measurement tools (S_5)
6. Software tools (S_6)

Table 4.1: Grouping of QT&T

Sr no.	**Grouping of QT&T**	**Quality tools and techniques (QT&T)**
1.	New product development tools (NPDT)	• Benchmarking (BM) • Beta testing (BT) • Focus group (FG) • Conjoint analysis (CA) • Contextual enquiry (CE) • Teaming (TE) • Design of experiments (DOE) • Failure mode and effect analysis (FMEA) • Quality function deployment (QFD)
2.	Decision making tools (DMT)	• Questionnaire (QU) • Delphi technique (DT) • Suggestion scheme (SS) • Break even chart (BEP) • Gantt chart (GC) • Customer satisfaction assessment (CSA)
3.	Data representation and analysis tools (DRAT)	• Pie chart (PC) • Pareto analysis (PA) • Cause and effect diagram (CED) • Scatter diagram (SD) • Histogram (HG) • Control chart (CC)

	Grouping of QT&T	**Quality tools and techniques (QT&T)**
4.	Lean tools (LT)	• Value stream mapping (VSM) • 5S • Single minute exchange of dies (SMD) • Standardized work (SW) • Poke-yoke (PY) • Kanban (KA) • Hei-junka (HJ)
5.	Performance measurement tools (PMT)	• Gauge repeatability and Reproducibility (R&R) • Management by objectives (MBO) • Pair wise comparison (PWC) • Critical to quality (CTQ) tree • Key performance indicator (KPI) • Balanced scorecard (BS) • Overall equipment effectiveness (OEE)
6.	Software tools (SWT)	• Anomaly report (AR) • Integrated design for functional modeling (IDM) • Operational acceptance test (OAT) • Reliability metrics (RM) • Simulations (SIM) • Rationale map (Rm)

Based on their usage, 41 different QT&T have been clubbed into 6 groups. The next section deals with the analysis of different QT&T categories by integrated Graph theoretic approach (GTA) and analytical hierarchy process (AHP) to find out the interactions among individual QT&T.

4.2 GRAPH THEORETIC APPROACH (GTA)

Graph theoretic approach is a logical and systematic approach useful for modelling and analysis of various kinds of systems and problems in numerous fields of science and technology (Chen 1997, Jense and Gutin 2000). Basically it is the study of directed graph which consists of set of nodes and directed edges to indicate interrelation and relative importance to one another. Previously block diagrams, flow charts and cause and effect diagrams do not suitable for further analysis to show relative importance among factors and cannot be represent into mathematical form (Raj and Attri, 2010). In other words, graphs are represented graphically by drawing a dot for every vertex and drawing an arc between two vertices (Rao and Padmanabhan, 2006). GTA is an organized methodology for adaptation of qualitative factors to quantitative values, and mathematical modelling gives the periphery to the premeditated technique over conventional methods like cause– effect diagrams, flow charts, etc (Gambhir and Grover,2015). Graph theory approach (GTA) consists of three main components:

4.2.1 Digraph representation: A digraph donated by set of nodes and directed edges which represent inheritance and relative importance among QT&T. Digraph for a six element is shown in figure 4.1.

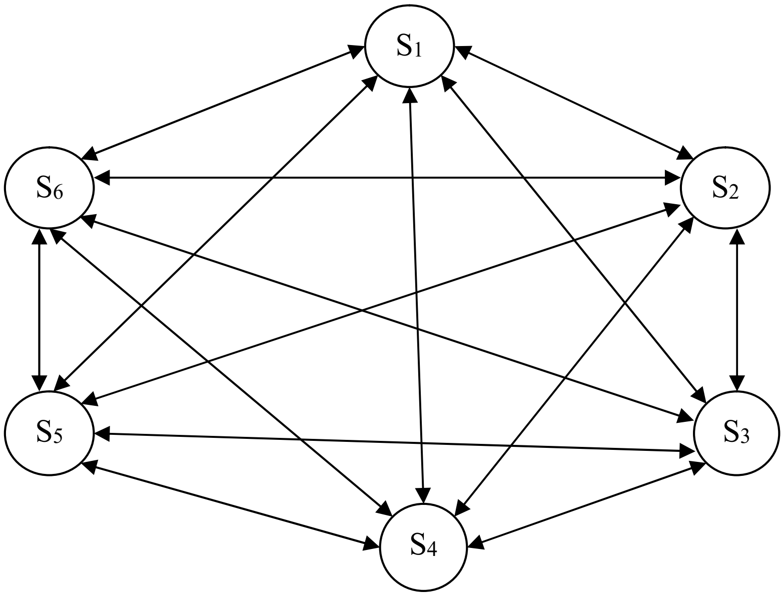


Figure 4.1: Digraph for a six system elements

4.2.2 Matrix representation:

4.2.2 Matrix representation: Although digraph relates with visual representation and helps in limited manner for analyzing the problems. To establish an expression in terms of mathematical analysis and computer processing, it is represented in N x N matrix form for further analysis. Matrix representation for grouping of 6 QT&T gives one to one representation and shown in equation 4.1.

$$A = \begin{bmatrix} S_1 & c_{12} & c_{13} & c_{14} & c_{15} & c_{16} \\ c_{21} & S_2 & c_{23} & c_{24} & c_{25} & c_{26} \\ c_{31} & c_{32} & S_3 & c_{34} & c_{35} & c_{36} \\ c_{41} & c_{42} & c_{43} & S_4 & c_{45} & c_{46} \\ c_{51} & c_{52} & c_{53} & c_{54} & S_5 & c_{56} \\ c_{61} & c_{62} & c_{63} & c_{64} & c_{65} & S_6 \end{bmatrix} \qquad (4.1)$$

In this matrix A, the diagonal elements S_1, S_2, S_3, S_4, S_5 and S_6 represent the impact of different categories of QT&T in an organization and c_{ij} represents the relative importance between QT&T, represented by edge for QT&T *i* and *j*.

4.2.3 Permanent function representation: The permanent function of matrix [i.e. equation 4.1] donates mathematical expression in symbolic notation. These terms are arranged in groupings for obtaining desired results. In general, it is standard matrix function and is used in combinatorial mathematics [Jurkat, 1966]. Permanent function is obtained in a similar manner in which the determinant of a matrix can be calculated except the positive sign replaces negative sign so that no information is lost on account of negative sign. The permanent function for matrix A will be written as:

$$\begin{aligned} Per(A^*) = \prod S_i &+ \sum_i \sum_j \sum_k \cdots\cdots \sum_m \sum_n c_{ij}^2 S_k S_l S_m S_n \cdots\cdots + 2\sum_i \sum_j \sum_k \cdots\cdots \sum_m \sum_n \left(c_{ij} c_{jk} c_{ki}\right) S_l S_m S_n \cdots\cdots \\ &+2\sum_i \sum_j \sum_k \cdots\cdots \sum_m \sum_n \left(c_{ij} c_{jk} c_{kl} c_{li}\right) S_m S_n \cdots\cdots + \sum_i \sum_j \sum_k \cdots\cdots \sum_m \sum_n \left({c^2}_{ij} {c^2}_{ij}\right) S_m S_n \cdots\cdots \\ &+2\sum_i \sum_j \sum_k \cdots\cdots \sum_m \sum_n \left(c_{ij} c_{jk} c_{kl} c_{lm} c_{mi}\right) S_n \cdots\cdots + 2\sum_i \sum_j \sum_k \cdots\cdots \sum_m \sum_n \left(c_{ij} c_{jk} c_{ki}\right) c_{lm}^2 S_n \cdots\cdots \\ &+\sum_i \sum_j \sum_k \cdots\cdots \sum_m \sum_n \left({c^2}_{ij}\right)\left({c^2}_{kl}\right)\left({c^2}_{mn}\right) \cdots\cdots + 4\sum_i \sum_j \sum_k \cdots\cdots \sum_m \sum_n \left(c_{ij} c_{jk} c_{ki}\right)\left(c_{lm} c_{mn} c_{ln}\right) \cdots \\ &+2\sum_i \sum_j \sum_k \cdots\cdots \sum_m \sum_n \left(c_{ij} c_{jk} c_{kl} c_{li}\right)\left({c^2}_{mn}\right) \cdots\cdots \end{aligned} \qquad (4.2)$$

4.3 ANALYTIC HIERARCHY PROCESS

Analytic hierarchy process (AHP) is a decision making tool developed by Satty (1980, 1985, 1990), Satty and Kearns (1991) suggested hierarchy development and validation at the Wharton School of Business. AHP is a technique used for dealing with problems which involve the consideration of multiple criteria simultaneously.

It allows comparison of both tangible and intangible factors and sets of priorities among alternative course of action for synthesis (Foreman and Gass, 2001). AHP allows alteration of complex or unstructured situations into hierarchical order and converts these situations into numerical values that can be expressed and compared over the complete range of the problem. The most important distinguish capability of AHP approach from other decision-making techniques is to compare incommensurable elements to one another in a rational and consistent way by assigning numerical weights or priorities (Sharma et al.2015).

AHP involves four major steps:

- Structure the hierarchy problem and build an AHP decision model.
- Breakdown problem into interrelated decision elements by placing overall goal at the top priority and bottom level contain the list of alternatives.
- Collect data and organize pair wise comparison of decision elements.
- Construct a pair wise comparison matrix (N x N) which represents intermediate importance values between two adjacent judgments by rated using a scale with the values 1- 9.
- Determine the normalized priority weight of individual factors and sub factors. At each level of the hierarchy aggregate relative weights of decision elements and sum all weighted eigenvector entries corresponds to the next lower level of the hierarchy.

4.4 INTEGRATED GTA-AHP APPROACH

The effectiveness of QT&T relationship depends upon the degree of inheritance and the amount of interactions among various factors present between them, which could be directional dependent or independent. Proposed methodology intended to utilize two complementary techniques - GTA and AHP for recognition of levels of criteria and digraph for interrelationship between variables. AHP formulates QT&T connection in the form of priority weights and GTA establishes an index for calculating effectiveness of QT&T in manufacturing organization. In this research, GTA showed the interdependency between distinctive QT&T categories that are equally dependent and analogous to the same category. The anticipated integrated method can aid in decision making by providing more instructive, precise and an enhanced choice of methodology than using either GTA or AHP in isolation.

The main steps involved in integrated GTA-AHP approach for measuring effectiveness of QT&T in a manufacturing organization are as follows:

1. Identify the various QT&T affecting the manufacturing organization. The effectiveness of these QT&T may differ from organization to organization depending on the size of organization and product configuration.
2. Group the various QT&T into different categories depending upon their applications.

3. Develop digraph between different QT&T categories (at system level) on the basis of their relative importance among QT&T. This is the digraph at the system level.
4. After the development of digraph between main categories, developed digraph for the individual categories for each QT&T in same manner as done in step (3). This is the digraph at the sub-system level.
5. Develop sub matrix for each category of QT&T. This will be of size NXN, with diagonal elements representing QT&T attributes and the off-diagonal elements representing relative importance among QT & T.
6. Substitute the value of inheritance and relative importance in sub matrix of each QT&T category. The value of inheritance (diagonal elements) of these classifications is to be calculated by using AHP approach as explained earlier and value of relative importance to one another is determined purely by the experts (academia and industries) opinion on the basis of scale given in Table 4.2.

Table 4.2: Quantification of Q_{IJ}

Sr no	Class description	Relative importance of quality groups	
		Q_{IJ}	$Q_{JI}= 1\text{-}Q_{IJ}$
1	Two groups are of equal importance.	.5	.5
2	One group is slightly important over the other.	.6	.4
3	One group is very important over the other.	.7	.3
4	One group is most important over the other.	.8	.2
5	One group is extremely important over the other.	.9	.1
6	One group is exceptionally important over the other.	1	0

7. Compute the value of permanent functions for each category of QT&T.
8. Develop QT&T matrix at the system level.
9. Substitute the value of inheritance and relative importance in QT&T matrix at system level. At the system level, the permanent value of each sub matrix provides inheritance of QT&T and relative importance value among QT&T is decided on the basis of Table 4.2.
10. Find the value of permanent function for the system. This value of permanent function will provide the effectiveness of QT&T in manufacturing organization. This value is known as QT&T effectiveness index.

    QT&T effectiveness index = QTTEI = f (QT&T)
    = Permanent function of QT&T matrix
11. Based on the above-discussed methodology, the manufacturing organization can evaluate the effectiveness of each QT&T based on their applications. The procedure for finding the effectiveness of QT&T by using integrated graph theoretic analysis (GTA) and Analytic hierarchy process (AHP) approach is illustrated in next section.

4.5 EXAMPLE

For the illustration of proposed integrated methodology, a manufacturing organization is taken as an example whose effectiveness is to be computed. The organization is producing steel tubes and is having turnover of 50 million dollars. The steps involved for computation of QT&T effectiveness index are as follows:

1. Various QT&T affecting the manufacturing organization are identified as shown in Table 4.1.
2. Different QT&T are grouped into six different groups based upon their application.
3. Digraph is developed for the six main categories of QT&T (shown in Figure 4.1)
4. Digraph for each QT&T category is developed in (Figures 4.2–4.7). In the digraph, nodes represent the sub QT&T and edges represent their relative importance.

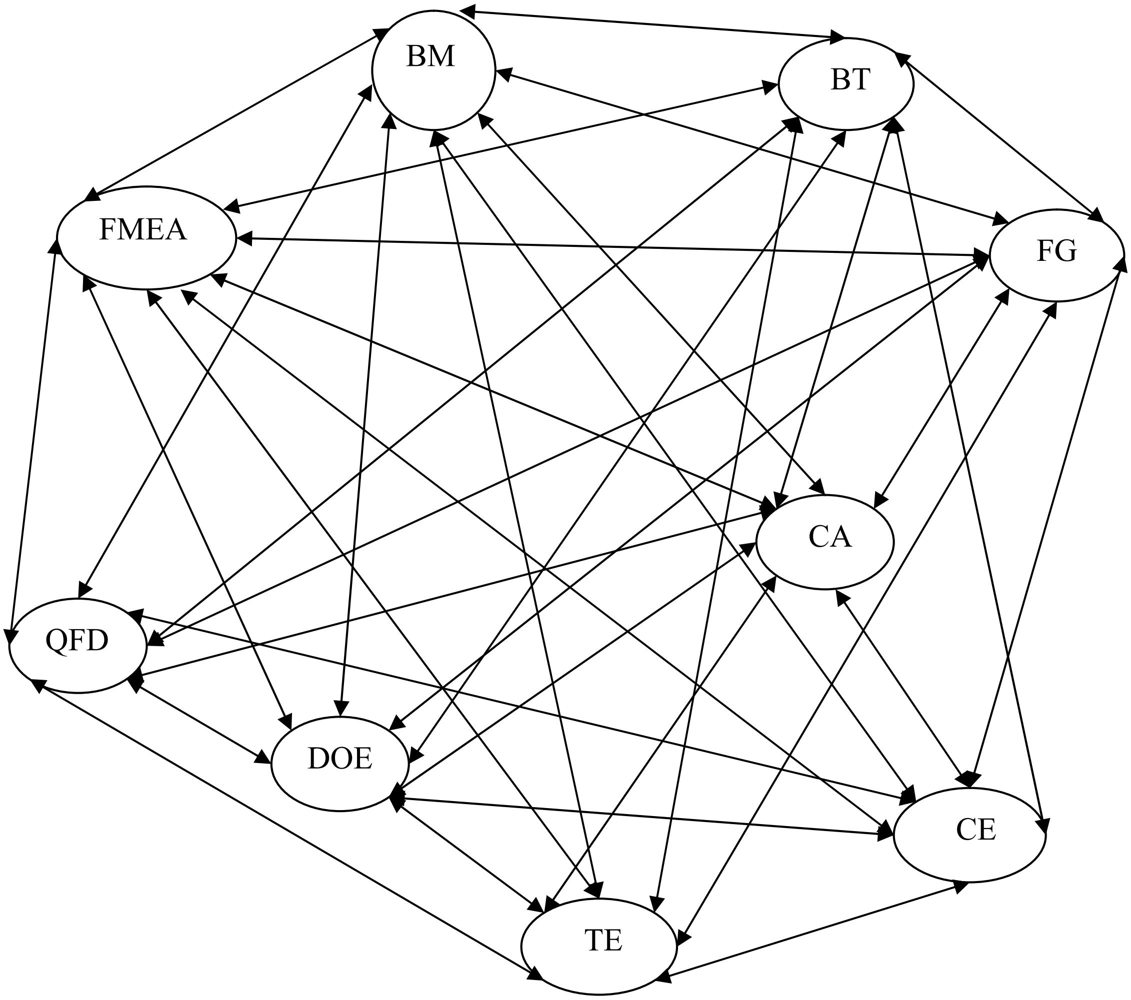


Figure 4.2: Digraph for New product development tools (NPDT)

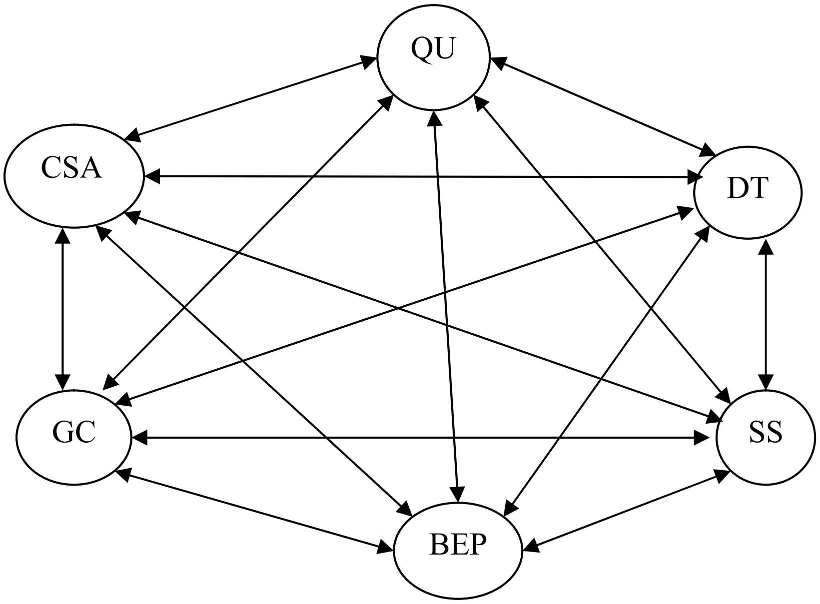


Figure 4.3: Digraph for decision making tools (DMT)

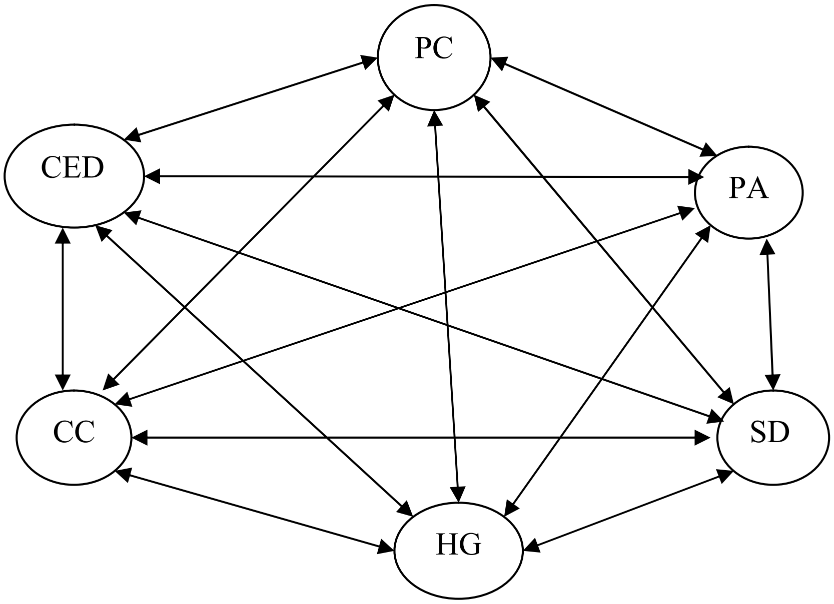


Figure 4.4: Data representation and analysis tools (DRAT)

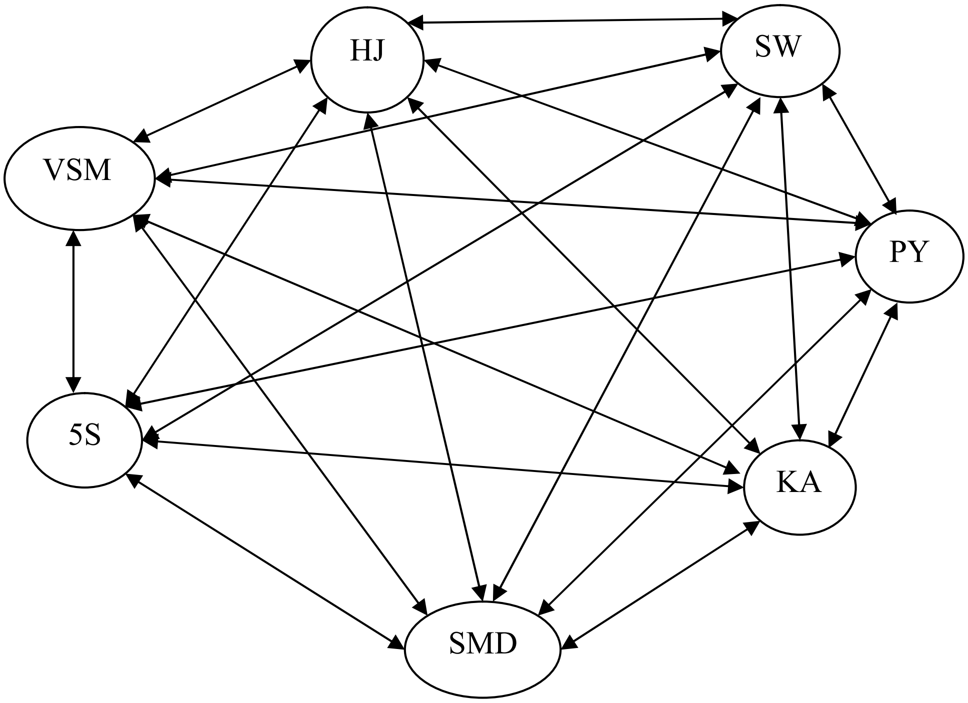


Figure 4.5: Digraph for lean tools (LT)

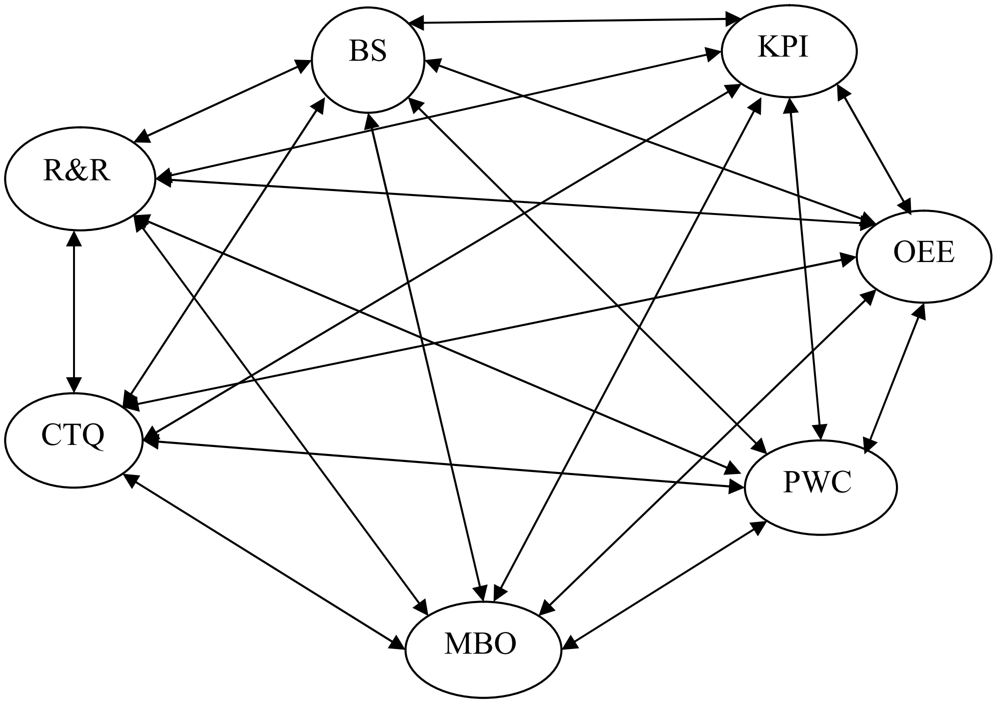


Figure 4.6: Digraph for performance measuring tools (PMT)

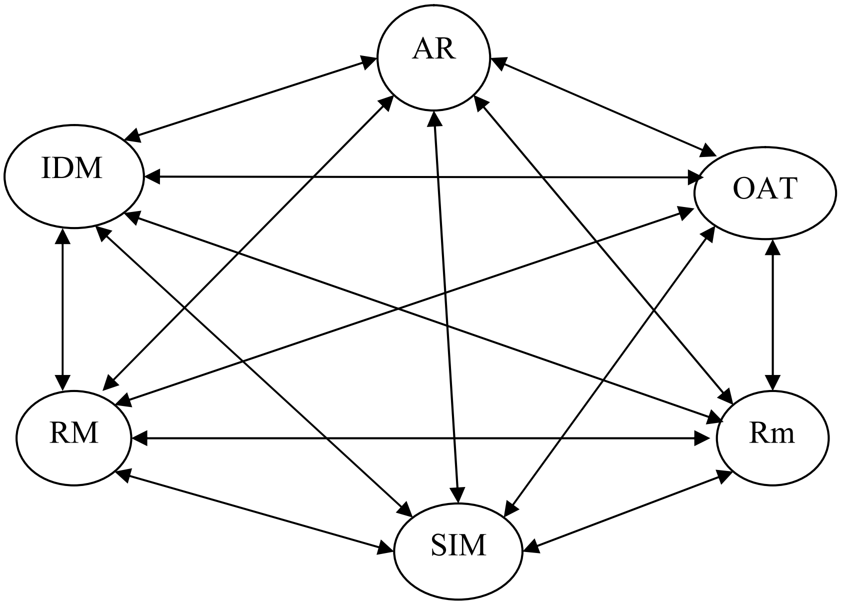


Figure 4.7: Digraph for software tools (ST)

5. Matrix for digraph for each sub-system is written through table (4.3–4.8). For this, interrelation of sub QT&T is computed by AHP approach and their relative importance is taken from Table 4.2.

The values of inheritance of all QT&T catergories is to be calculated individually by using AHP approach. For first category, NPDT tools. Let decision maker makes the following matrix as shown in Table 4.3 for AHP analysis:

Table 4.3: Pair wise comparison matrix (NPDT) Tools

	BM	BT	FG	CA	CE	TE	DOE	FMEA	QFD	PV
BM	1	3	2	3	1/3	3	4	5	1/3	.142
BT	1/3	1	3	3	1/3	3	3	5	1/3	.119
FG	1/2	1/3	1	3	1/3	3	3	3	1/3	.091
CA	1/3	1/3	1/3	1	1/3	3	3	3	1/3	.071
CE	3	3	3	3	1	3	3	3	1/3	.176
TE	1/3	1/3	1/3	1/3	1/3	1	1/2	3	1/7	.039
DOE	1/4	1/3	1/3	1/3	1/3	2	1	5	1/7	.051
FMEA	1/5	1/5	1/3	1/3	1/3	1/3	1/5	1	1/7	.026
QFD	3	3	3	3	3	7	7	7	1	.284
Total	8.95	11.53	13.33	17	6.33	25.33	24.7	35	3.095	CR=.0913

The values found by using AHP approach are as follows: $W_{BM} = 0.142$, $W_{BT} = .119$, $W_{FG} = .091$, $W_{CA} = .071$, $W_{CE} = .176$, $W_{TE} = .039$, $W_{DOE} = .051$, $W_{FMEA} = .026$, $W_{QFD} = .284$.

These values are being put in matrix (4.3) for compuation of permanent function.

$$\begin{array}{c|ccccccccc|c} & S_1 & S_2 & S_3 & S_4 & S_5 & S_6 & S_7 & S_8 & S_9 & QT\&T \\ \hline & 0.142 & .4 & .6 & .5 & .6 & .3 & .4 & .7 & .2 & S_1 \\ & .6 & 0.119 & .2 & .6 & .4 & .3 & .8 & .4 & .1 & S_2 \\ & .4 & .8 & 0.091 & .8 & .4 & .6 & .5 & .2 & .3 & S_3 \\ & .5 & .4 & .2 & 0.071 & .6 & .4 & .8 & .2 & .5 & S_4 \\ NPDT = & .4 & .6 & .6 & .4 & 0.176 & .3 & .5 & .8 & .9 & S_5 \\ & .7 & .7 & .4 & .6 & .7 & 0.039 & .8 & .6 & .4 & S_6 \\ & .6 & .2 & .5 & .2 & .5 & .2 & 0.051 & .2 & .6 & S_7 \\ & .3 & .6 & .8 & .8 & .2 & .4 & .8 & 0.026 & .7 & S_8 \\ & .8 & .9 & .7 & .5 & .1 & .6 & .4 & .3 & 0.284 & S_9 \end{array} \tag{4.3}$$

Similarly, the pair wise comparison of remaining (DMT), (LT), (SWT), (DRAT) and (PMT) tools have been calculated as given below:

Table 4.4: Pair wise comparison matrix (DMT) Tools

	QU	DT	SS	BEP	GC	CSA	PV
QU	1	2	2	2	1/6	1/3	.137
DT	1/2	1	2	2	1/2	1/3	.123
SS	1/2	1/2	1	2	1/2	1/3	.098
BEP	1/2	1/2	1/2	1	1/2	1/3	.076
GC	6	2	2	2	1	1/2	.249
CSA	3	3	3	3	2	1	.319
Total	11.5	9	10.5	12	4.66	2.83	CR=.0879

Table 4.5: Pair wise comparison matrix (DRAT) Tools

	PC	PA	CED	SD	HG	CC	PV
PC	1	1/3	1/5	1	1/6	1/2	.070
PA	3	1	2	2	1/2	1/3	.155
CED	5	1/2	1	2	1/2	1/3	.143
SD	1	1/2	1/2	1	1/2	1/3	.082
HG	6	2	2	2	1	1/2	.233
CC	2	3	3	3	2	1	.317
Total	18	7.33	8.7	11	4.66	3	CR=.0844

Table 4.6: Pair wise comparison matrix (LT) Tools

	VSM	5S	SMD	SW	PY	KA	HJ	PV
VSM	1	2	2	2	1	3	3	.233
5S	1/2	1	2	2	1/2	3	3	.167
SMD	1/2	1/2	1	2	1/2	3	3	.139
SW	1/2	1/2	1/2	1	1/2	3	3	.115
PY	1	2	2	2	1	3	3	.223
KZ	1/3	1/3	1/3	1/3	1/3	1	1/5	.049
HJ	1/3	1/3	1/3	1/3	1/3	5	1	.084
Total	4.166	6.66	8.166	9.66	4.166	21	16.2	CR=.0715

Table 4.7: Pair wise comparison matrix (PMT) Tools

	R&R	MBO	PWC	CTQ	KPI	BS	OEE	PV
R&R	1	7	4	3	6	9	8	.444
MBO	1/7	1	2	2	1/2	3	3	.121
PWC	1/4	1/2	1	2	1/2	3	3	.108
CTQ	1/3	1/2	1/2	1	1/2	3	3	.093
KPI	1/6	2	2	2	1	3	3	.142
BS	1/9	1/3	1/3	1/3	1/3	1	1/5	.033
OEE	1/8	1/3	1/3	1/3	1/3	5	1	.060
Total	2.12	11.66	10.16	10.66	9.16	27	21.2	CR=.0878

Table 4.8: Pair wise comparison matrix (ST) Tools

	AR	IDM	OAT	RM	SIM	Rm	PV
AR	1	1/2	1/6	1	1/7	1/3	.063
IDM	2	1	2	2	1/2	1/3	.145
OAT	6	1/2	1	2	1/2	1/3	.148
RM	1	1/2	1/2	1	1/2	1/3	.082
SIM	7	2	2	2	1	1/2	.237
Rm	3	3	3	3	2	1	.325
Total	20	7.5	8.66	11	4.64	2.83	CR=.0784

The remaining matrices for AHP analysis are represented in tables (4.3 to 4.8). Later on, their required weighted values are being substituted into respective matrices to find out the values of permanent function of diversified categories. In a similar way, matrices for other categories of QT&T can be written as:

$$DMT = \begin{array}{cc} \begin{array}{cccccc} S_1 & \mathrm{S}_2 & \mathrm{S}_3 & \mathrm{S}_4 & \mathrm{S}_5 & \mathrm{S}_6 \end{array} & QT\,\&\,T \\ \begin{bmatrix} 0.137 & .4 & .4 & .7 & .1 & .5 \\ .6 & 0.123 & .8 & .5 & .2 & .3 \\ .6 & .2 & 0.098 & .5 & .4 & .6 \\ .3 & .5 & .5 & 0.076 & .2 & .7 \\ .9 & .8 & .6 & .8 & 0.249 & .3 \\ .5 & .7 & .4 & .3 & .7 & 0.319 \end{bmatrix} & \begin{array}{c} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \end{array} \end{array} \qquad (4.4)$$

$$DRAT = \begin{array}{cc} \begin{array}{cccccc} S_1 & \mathrm{S}_2 & \mathrm{S}_3 & \mathrm{S}_4 & \mathrm{S}_5 & \mathrm{S}_6 \end{array} & QT\,\&\,T \\ \begin{bmatrix} 0.070 & .5 & .6 & .2 & .3 & .8 \\ .5 & 0.155 & .5 & .9 & .6 & .7 \\ .4 & .5 & 0.143 & .5 & .4 & .6 \\ .8 & .1 & .5 & 0.082 & .1 & .6 \\ .7 & .3 & .6 & .9 & 0.233 & .4 \\ .2 & .3 & .4 & .3 & .6 & 0.317 \end{bmatrix} & \begin{array}{c} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \end{array} \end{array} \qquad (4.5)$$

$$LT = \begin{array}{cc} \begin{array}{ccccccc} S_1 & \mathrm{S}_2 & \mathrm{S}_3 & \mathrm{S}_4 & \mathrm{S}_5 & \mathrm{S}_6 & \mathrm{S}_7 \end{array} & QT\,\&\,T \\ \begin{bmatrix} 0.223 & .8 & .6 & .3 & .6 & .7 & .3 \\ .2 & 0.167 & .3 & .4 & .2 & .6 & .4 \\ .4 & .7 & 0.139 & .5 & .2 & .7 & .9 \\ .7 & .6 & .5 & 0.115 & .8 & .3 & .2 \\ .4 & .8 & .8 & .2 & 0.223 & .6 & .5 \\ .3 & .4 & .3 & .7 & .4 & 0.049 & .6 \\ .7 & .6 & .1 & .8 & .5 & .4 & 0.084 \end{bmatrix} & \begin{array}{c} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \\ S_7 \end{array} \end{array} \qquad (4.6)$$

$$PMT = \begin{array}{c} \\ \\ \\ \\ \\ \\ \\ \end{array}\begin{array}{cccccccc} S_1 & S_2 & S_3 & S_4 & S_5 & S_6 & S_7 & QT\&T \\ 0.444 & .3 & .9 & .2 & .9 & .2 & .4 & S_1 \\ .7 & 0.121 & .6 & .5 & .4 & .3 & .6 & S_2 \\ .1 & .4 & 0.108 & .4 & .6 & .7 & .7 & S_3 \\ .8 & .5 & .6 & 0.093 & .5 & .3 & .1 & S_4 \\ .1 & .6 & .4 & .5 & 0.142 & .2 & .8 & S_5 \\ .8 & .7 & .3 & .7 & .8 & 0.033 & .7 & S_6 \\ .6 & .4 & .3 & .9 & .2 & .3 & 0.060 & S_7 \end{array} \quad (4.7)$$

$$ST = \begin{array}{ccccccc} S_1 & S_2 & S_3 & S_4 & S_5 & S_6 & QT\&T \\ 0.063 & .5 & .3 & .7 & .5 & .3 & S_1 \\ .5 & 0.145 & .5 & .4 & .5 & .7 & S_2 \\ .7 & .5 & 0.148 & .5 & .3 & .8 & S_3 \\ .3 & .6 & .5 & 0.082 & .9 & .4 & S_4 \\ .5 & .5 & .7 & .1 & 0.237 & .5 & S_5 \\ .7 & .3 & .2 & .6 & .5 & 0.325 & S_6 \end{array} \quad (4.8)$$

6. The permanent functions of each sub system QT&T classification is determined as illustrated below:
    - The permanent function contains terms arranged in (N+1) groups. The first group measures set of N variables as it contains only one term.
    - The second group is absent due to non-existence of self-interaction loop.
    - Third grouping holds set of two QT&T attributes distinguish by measuring (N-2) variables.
    - Fourth group symbolizes set of three QT&T attributes and measures of (N-3) variables.
    - The fifth group holds two QT&T sub-groups. First sub group restrain set of two QT&T attributes and the measures of (N-4) variables and second subgroup donates set of four QT&T attributes and measures rest of (N-4) variables.

- Sixth grouping also contains two QT&T sub-groups. First subgroup represented by set of three QT&T attributes relative importance loop and two variable importance loop and measures (N-5) variables. Second subgroup contains set of five QT&T attributes and measures (N-5) variables.

Likewise, vales of permanent function have been calculated by considering all terms for matrix NxN as positive. For ease of lengthened calculations, a software program in C++ was developed to evaluate different values of permanent function as described below:

- *Per (NPDT) = 296.591*
- *Per (DMT) = 5.3329*
- *Per (DCAT) = 4.9218*
- *Per (LT) = 18.7657*
- *Per (PMT) = 19.0134*
- *Per (ST) = 6.03264*

7. QT&T matrix at the system level (9) is developed by taking the values of diagonal elements from sub-system level i.e. permanent function value for each QT&T comes to be 822.017.

$$
\begin{array}{c}
\begin{array}{cccccc} S_1 & S_2 & S_3 & S_4 & S_5 & S_6 \end{array} \quad QT\&T \\
= \begin{bmatrix} 296.591 & .8 & .4 & .3 & .5 & .1 \\ .2 & 5.332 & .4 & .7 & .3 & .7 \\ .6 & .6 & 4.921 & .2 & .9 & .4 \\ .7 & .3 & .8 & 18.765 & .5 & .7 \\ .5 & .7 & .1 & .5 & 19.013 & .9 \\ .9 & .2 & .6 & .3 & .1 & 6.032 \end{bmatrix}
\begin{array}{c} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \\ S_6 \end{array}
\end{array}
$$

(4.9)

This value indicates the value of system QTTEI in the organization under consideration. The above proposed methodology can be utilized by the managers to find the effectiveness of QT&T in their organizations.

4.6 CONCLUDING REMARKS

- A methodology is developed for calculating the effectiveness of QT&T in various areas of manufacturing through a systematic approach.
- The suggested integrated methodology is based upon the combined analysis of (GTA-AHP) approach that has been adopted to set up the intricate or cluster relationships between different QT&T employed in varied manufacturing organizations. By knowing the effectiveness of various QT&T, some tactics may be employed by the managers to tackle them competently.
- The expression for finding effectiveness of manufacturing organization has been donated in terms of an index, called the QTTEI (QT&T effectiveness index). This index value depends on the significance of quality tools and techniques adopted and their interdependencies.
- The suggested approach for quantifying categories like: NDPT, DMT, DRAT, LT, PMT and ST tools has been established by assigning derived weighted values diagonally with each QT&T category for determining permanent function of system matrix.
- The value of permanent function of foremost category helps the professionals to evaluate and compare effectiveness of different manufacturing organizations through single numerical index.

CHAPTER V

ANALYZING BARRIERS OF QT&T: INTEGRATED (ISM-MICMAC) APPORACH

Manufacturing organizations largely enables speedy, smooth and economical manufacture of products. During the last two decades, superior manufacturing recital has led to sustainable improvement in quality tools and techniques (QT&T) to support the manufacturer aspects. Evidently, manufacturers have been trying to improve their performance together by aiming manufacturing systems and products for immense development (Baumgartner and Zielowski, 2007; Kara et al., 2007; Gehin et al., 2008; Ingwersen and Stevenson, 2012). Hence manufacturing organizations must improve the quality of their product for achieving spirited advantage, and shifted to the path of growth and excellence. Many researchers and practitioners have focused on effective utilization of QT&T to accomplish the demands of manufacturing organizations. For this purpose, numerous identified QT&T and systematic methodologies are adopted for enhancing the performance of manufacturing organizations.

5.1 GENERALIZATION OF BARRIERS IN MANUFACTURING ORGANIZATIONS

A variety of factors are involved in today's manufacturing arena for improved quality and productivity. These factors perceive different action on different manufacturing organizations. Kara et al., (2005); Kaebernick and Kara, (2006) have suggested that five major factors namely environmental aims; environmental performance; early stage product development implementation; implementation from top to down and bottom to up; and simplicity are responsible for successful implementation of product development concepts and methodologies.

Each phase of conversion i.e. raw materials into finished products requires a scrupulous production planning that contribute the requisite production target and optimize the resources utilization (Muhammad and Jeng Feng, 2014). In order to achieve and apprehend the required task, manufacturing organizations must identify certain barriers that affect the effective utilization of QT&T. The manufacturing organizations prompt to find barriers which help them in achieving effectiveness. Researchers put their efforts to recognize and classify these barriers in orderly manner to recognize the best suited barrier which influence the most for effective utilization of QT&T. Consequently, various barriers have been acknowledged in text with different authors but no work is available to allocate the effectiveness of QT&T in an organization. This could be done by proposing an integrated interpretive structural modeling (IISM) and MICMAC analysis which bridges the gap between different organizations.

Furthermore, in this chapter, assessment and interactions among various barriers of QT&T will clarify an IISM-MICMAC model to evaluate effectiveness in a manufacturing organization. In view of this, twelve barriers have been recognized from extensive literature review, opinions of academic & industrial experts. These identified barriers are analyzed by

IISM- MICMAC in order to build up a categorized structural model. Finally, effectiveness of each barrier has been computed by subtracting dependence power from driver power. The foremost purpose of using IISM-MICMAC in this chapter is as follows:

- To identify and rank the barriers affecting the utilization of QT&T in manufacturing organizations;
- To find out the interaction between identified barriers affecting the utilization of QT&T using IISM-MICMAC approach;
- To organize barriers into different categories;

5.2 IDENTIFICATION OF QT&T BARRIERS

Barriers can be considered as obstructions posed to avert the successful utilization of QT&T in manufacturing organizations. These barriers diminish the effectiveness of the nimbleness, adaptability, intellect shape and knowledge-driven capabilities that they are the building blocks for any manufacturing organizations. Some experts from academic & industries were asked to recognize the key barriers affecting the manufacturing organizations (Sharma et al., 2017). From literature, an improved and authenticate list has been prepared with the help of experts' opinion. The details of these barriers are as follows:

1. **Employee's resistance to change (B_1):** Manufacturing organizations intended to counter out the pressure for gradually more globalized and competitive environment and rapidly change conditions and demands responsible for quick decision-making and innovation activity (Abuelmaatti and Rezgui, 2008). Employees working in the manufacturing organization must educate for the successful implementation of the program (Khurana, 2009).

2. **Motivational technique and Recipient organizations (B_2):** Employees who work within a defined frame take less attention towards motivational techniques concerning the utilization of QT&T in manufacturing organizations. (Raj and Attri, 2011) have emphasized that motivation allows change in the behavior of employees towards work from pessimistic to optimistic approach.

3. **Lack of continuous communication (B_3):** Lack of continuous communication is critical to assist knowledge flow in manufacturing organizations. It leads to affect lack of coordination, cooperation and team work which may obstruct the utilization of QT&T. Improved communication prevents misunderstandings and trim down the costs of quality by avoiding mistakes (Cohen and Brand, 1993; Talib et al., 2011).

4. **Inability to change organizational Culture (B_4):** Organizational framework is associated to the right business environment and conditions. The arrangement of the venture divides its labor into distinct tasks and then achieves coordination (Abuelmaatti and Rezgui, 2008). Top management must be able modify organizational culture for civilizing performance and competence.

5. **Inadequate coordination and teamwork (B_5):** Inadequate coordination and teamwork is the most important barrier existing in the Indian manufacturing organizations. It becomes extremely tough to execute any improvement program while their employees not succeed to work jointly as a team and determines the implementation of nature and extent of quality program (Sureshchandar et al., 2001).

6. **Dilemma about organization policies (B_6):** Employees working in manufacturing industries have impasse towards the development of proper policies at the organizational level for effectual implementation of QT&T. Policies and accomplishment plan should be appropriately communicated to all the employees working in that organization.

7. **Lack of proper training and education (B_7):** Newall and Dale (1990); Ljungström and Klefsjö (2002); Talib et al., (2011); revels that deprived learning acts as a key barrier in the growth and completion of quality program. Improper training and education leads to failure while implement ting QT&T in manufacturing organizations. Thus, training programs are effectively intended and correctly implemented.

8. **Lack top Management Support (B_8):** Top management should bring continual support for properly utilization of QT&T in manufacturing organizations. Lack of top-management commitment empowers lack of experience, training, resistance to change, and hesitation in initiating development programs. It also tackles with acquaintance arrangement and support system that facilitates sharing and request of knowledge (Huang and Lin 2010).

9. **Divergence with other quality management system (B_9):** The quality systems like Poka-Yoke, Six Sigma and ISO 9000 varies in terms of requirements from different departments to different organizations (Liker and Hoseus, 2008). This disparity in the requirements of quality systems overwhelms to choose programs for completion and engage their employees in improvement activities.

10. **Deficient planning and implementation (B_{10}):** The lack of strategic planning leads to unproductive improvement in quality. This is leading barrier while implementation quality enhancement programs in Indian manufacturing organizations (Warwood and Knowles, 2004). It also shares rise in knowledge for flow utilization.

11. **Accessibility of time and space (B_{11}):** Manufacturing organizations requires time and space for face-to-face communication and the amalgamation of knowledge (Herrgard 2000; Cheng, Yeh, and Tu 2008). This is the essential barrier which motivates worker to generate their cooperative relationship with others by the convenience of time and space.

12. **Keen to share knowledge (B_{12}):** There should be appropriate loom for convey knowledge within and outside the manufacturing organizations. Knowledge sharing defined as the synergistic process by which the employers and the employees getting advantage from renewed knowledge (Capó-Vicedo, Mula, and Capó 2011). Eagerness to contribute knowledge acts as an enabler of knowledge surge in the organization.

In the next section, administration of questionnaire with corresponding results is presented. The important points for implementation of QT&T barriers have been reported and described in next sections.

5.3 DEVELOPMENT OF SURVEY QUESTIONNAIRE

After discussion with industrial experts and academicians, the barriers influencing the utilization of QT&T in manufacturing organizations have been validated by using questionnaire based survey. For this reason, a questionnaire was developed on 5 point Likart scale.

Numeral 1 donates barrier with least importance while numeral 5 represent barrier with most importance. The questionnaires were directed to 270 manufacturing organization for knowing the impact of identified barriers for utilization of QT&T. Out of those 270 questionnaires only 102 completely filled questionnaires were received and have been used for further analysis. Survey suggested that no new barrier was found in the study. The data of the responding organizations is given in table 5.1.

Table 5.1: Data of responding organizations

Sr no	Description of data	Range	No. of organizations	Percentage (%)
1	Type of organization	Automobile	30	29.41
		Refrigeration	20	19.60
		Electrical	13	12.74
		Sheet metal	18	17.64
		Others	21	20.58
		Total organizations	102	99.97*
2	Number of employees	Less than 100	18	17.64
		100-250	15	14.70
		251-500	28	27.45
		501-1000	21	20.58
		1001 and above	20	19.60
		Total employees	102	99.97*
3	Turnover (in Rs crores)	Less than 50	17	16.66
		51-100	23	22.54
		101-150	26	25.49
		151-200	21	20.58
		More than 200	15	14.70
		Total Turnover	102	99.97*
4	Department	Quality	29	28.43
		Production	23	22.54
		Marketing	19	18.62
		PPC	17	16.66
		Others	14	13.72
		Total Departments	102	99.97*

*Considering only two digits' fractional decimals

Table 5.1 illustrates the percentagewise breakup of participated organizations i.e (automobile sector donates 29.41% fallowed by other sectors 20.1% and rest of refrigeration, electrical and sheet metal which involves contribution of 19.60%, 12.74% and 17.64% respectively. Moreover, the involvements of departments like quality and production dominates 28.43% & 22.54% of the total contribution than rest of the other departments. Also, the no of employees and annual turnover plays an integral role for the assessment of survey questionnaire in distributed data form. The contribution of employees ranging (251-500) with annual turnover (151-200) crores concludes most significant participation of particular organization for statistically identified QT&T barriers.

5.3.1 Analysis of survey data

This section deals with the analysis of survey data of different manufacturing organizations by statistical software SPSS 18. The survey data of respondents was statically analyzed by using SPSS software. Result statistics of survey data is shown in Table 5.2. Afterwards, Spearman's rho Correlation Coefficient test among the barriers of QT&T is conducted to check the existence of any multi-co linearity occurrence. Table 5.3 donates the correlation coefficients between barriers of QT&T and signifies no occurrence of multi- co linearity. The next section shows the response rate of different barriers participated in survey questionnaire.

5.3.2 Analysis of data for checking multi-co linearity

Table 5.2 to 5.3 covers the data of various barriers of QT&T for occurrence of any multi-co linearity between various barriers.

Table 5.2: Statistics of QT&T barriers

	B_1	**B_2**	**B_3**	**B_4**	**B_5**	**B_6**	**B_7**	**B_8**	**B_9**	**B_{10}**	**B_{11}**	**B_{12}**
Mean	1.87	1.97	1.96	2.14	2.39	2.16	2.47	2.36	2.57	2.59	2.61	2.26
Median	2.00	2.00	2.00	2.00	2.00	1.00	2.00	2.00	2.00	2.00	2.00	1.00
Mode	2	2	2	2	1	1	1	1	1	1	1	1
Std. Deviation	.804	.710	.878	1.135	1.470	1.447	1.527	1.553	1.479	1.451	1.470	1.567
Variance	.647	.504	.771	1.288	2.162	2.094	2.331	2.412	2.188	2.106	2.162	2.454
Range	3	3	4	4	4	4	4	4	4	4	4	4

Table 5.2 describes the evaluation of different barriers identified from survey results. Barrier (B_{11}) i.e accessibility of time and space with corresponding values of mean=2.6, standard deviation=1.470 and variance=2.162 contributes to the most significant barrier affecting the utilization of QT&T in manufacturing organizations fallowed by barrier deficient planning and implementation which donates mean=2.59, standard deviation=1.451 and variance=2.106 values for the deliberation of particular QT&T barrier among rest of the other barriers. Similarly, barriers like divergence with other quality management system (mean=2.57, standard deviation=1.479), lack of proper training and education (mean=2.47, standard deviation=1.527) and inadequate coordination and teamwork mean=2.39, standard deviation=1.470) provides the adequacy of QT&T barrier to evaluate both the manufacturing process and organizational culture in the firm. The next table describes the correlation coefficients for various QT&T barriers in manufacturing organizations.

Table 5.3: Correlation Coefficients for QT&T barriers

	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}	B_{11}	B_{12}
B_1	1.000	.603**	.421**	-.029	.265**	.078	.024	-.067	.103	-.133	-.049	-.033
B_2	.603**	1.000	.599**	.177	.348**	.080	-.052	.015	.063	-.067	.090	.116
B_3	.421**	.599**	1.000	.500**	.169	-.089	.003	.054	-.107	-.143	-.046	-.151
B_4	-.029	.177	.500**	1.000	.438**	.035	-.104	-.092	-.205*	.003	.030	.032
B_5	.265**	.348**	.169	.438**	1.000	.648**	.262**	.025	-.065	-.113	-.132	-.204*
B_6	.078	.080	-.089	.035	.648**	1.000	.562**	.252*	-.047	-.184	-.214*	-.216*
B_7	.024	-.052	.003	-.104	.262**	.562**	1.000	.527**	.128	-.233*	-.206*	-.354**
B_8	-.067	.015	.054	-.092	.025	.252*	.527**	1.000	.555**	.088	.145	-.110
B_9	.103	.063	-.107	-.205*	-.065	-.047	.128	.555**	1.000	.530**	.407**	.178
B_{10}	-.133	-.067	-.143	.003	-.113	-.184	-.233*	.088	.530**	1.000	.868**	.671**
B_{11}	-.049	.090	-.046	.030	-.132	-.214*	-.206*	.145	.407**	.868**	1.000	.764**
B_{12}	-.033	.116	-.151	.032	-.204*	-.216*	-.354**	-.110	.178	.671**	.764**	1.000

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

In the current chapter, integrated (ISM-MICMAC) model has been developed for identified barriers affecting the effective utilization of QT&T in manufacturing organizations. The next section covers the outline of ISM approach implemented in manufacturing organizations.

5.4 ISM METHODOLOGY

In the present framework, ISM methodology integrated with MICMAC analysis used to identify the barriers prominence to effective utilization of QT&T in manufacturing organizations. Interpretive structural modelling (ISM) is a decision making tool that can identify various variables categorizing a problem (Warfield 1974; Sage 1977). It includes structured approach of set of variables or barriers identifying relationships among specific items which define a problem or an issue (Jharkharia and Shankar 2004). In other words, it gives planned and well defined summary of framework for challenging issues and thoughts for researchers to get obvious picture of the system. The challenge of recent scenario is to assemble the barriers affecting the utilization of QT&T in manufacturing organizations.

Manufacturing organizations use to understand and implement QT&T in most effective manner in accordance to their applications and usages. Therefore, it becomes necessary to practice a hierarchy model to recognize certain barriers for effective utilization of QT&T. ISM approach is helpful for determining complex relationships among the various barriers involved in manufacturing organizations. Also ISM methodology helps the decision makers to find out the order and magnitude by identifying the relationships among the elements

(Yin et al., 2012; Govindan et al., 2015). Many researchers have used blend of ISM and MICMAC approach in different areas such as operational management, logistics and scheduling for systematic structured analysis.

5.4.1 Major applications of ISM- MICMAC approach

- For analysis of complexity of system to underneath maintainability analysis.
- For analysis of factors influencing lean remanufacturing practices.
- Providing framework for mass customization enablers.
- Implementation of emission trading system in the building sector.
- Identification and analysis of key factors for waste management in humanitarian response.
- Analysis of interactions among critical success factors to implement green supply chain management towards sustainability. (Kumar et al.,2016)
- Analyze supply chain risks in apparel retail chains for risk prioritization model.
- Analyzing the scheduling system stage of PSLC. (Attri and Grover, 2015a)
- For finding contextual relationship among the QEFs of inventory control system stage. (Attri and Grover, 2015b)

5.4.2 Benefits of ISM –MICMAC approach

Some important benefits of ISM methodology are given below:

- Discover different barriers affecting utilization of QT&T in manufacturing organizations.
- Identify relationships between factors by plotting a digraph model.
- Involves both group and individual learning by carried out complex problem-solving procedure.
- Examine different barriers involved in manufacturing organizations in terms of order and direction.
- To understand the relative contact and involvement of each barrier responsible for diagnosing relationships between suppliers and buyers.
- To identify coefficient of likeness and divergence for manufacturing organizations to find out the degree of dissatisfaction exists among distinctive barriers.
- To know the effectiveness of organizations based upon the nature of driver and dependence power.
- It provides the basis for categorize barriers into respective ranks by determining lower triangular matrix.

Figure 5.1 discovers process sequence diagram of ISM model used in manufacturing organizations.

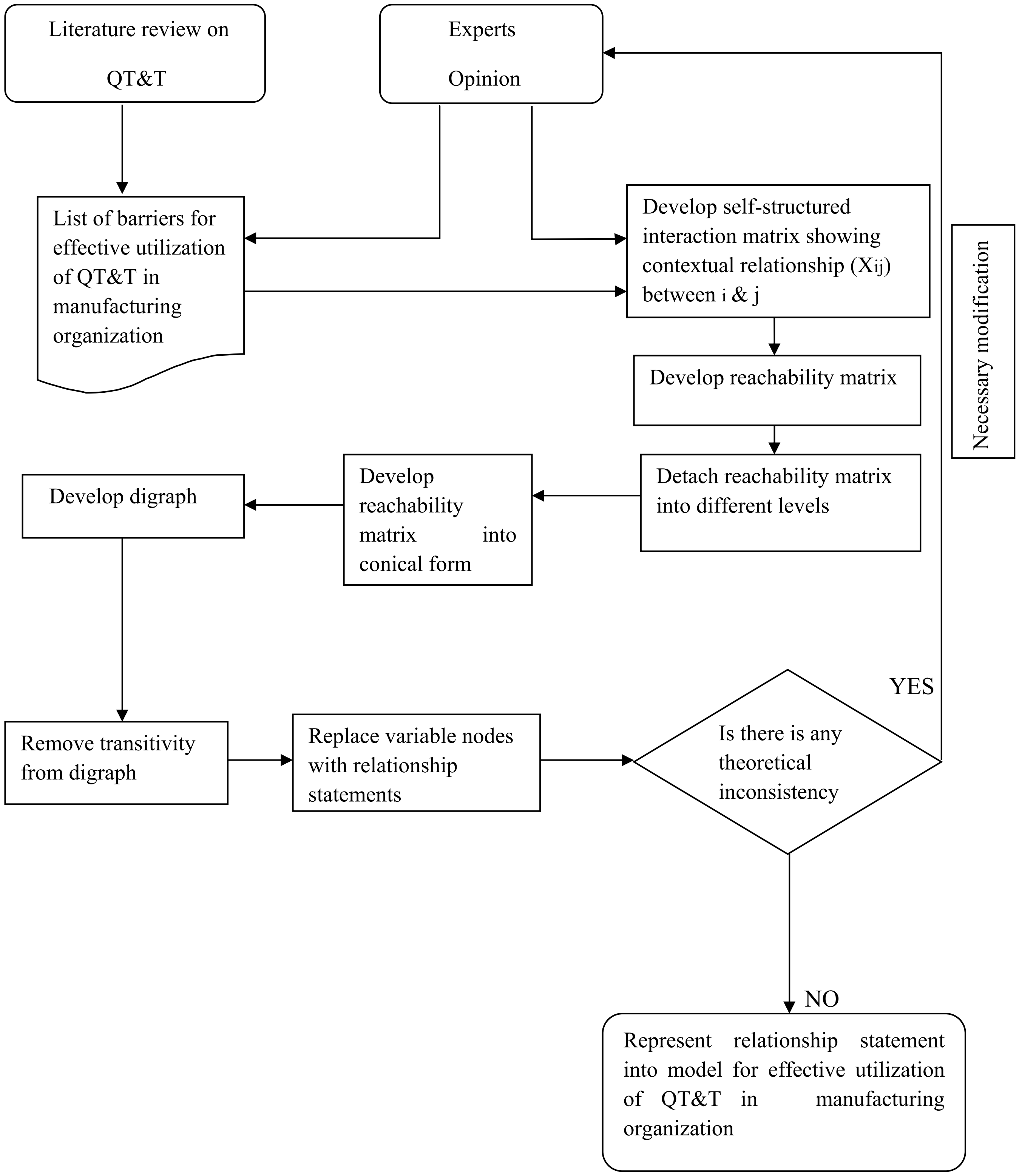


Figure 5.1: Process sequence of ISM model (adapted from govindan et al. 2012)

Various steps involved in ISM methodology are discussed below:

1. Analyze the literature and get expert opinion to identify the various barriers affecting the utilization of QT&T in manufacturing organizations by group problem-solving method or by survey;
2. Among the identified barriers, develop contextual relationships;
3. Build up a structural self-interaction matrix (SSIM) of elements. This matrix indicates the pair wise relationship among barriers considered for analysis;
4. Development of initial and final reachability matrix from SSIM and checking it for transitivity;
5. Partitioning of final reachability matrix into different levels and convert into lower triangular matrix (conical matrix);
6. Building the ISM-based directed graph (digraph) on the basis of relationships given in final reachability matrix after the removal of transitive links;
7. Perform MICMAC analysis after converting digraph into an ISM model;
8. Review of developed ISM model for theoretical inconsistency, and necessary modifications are carried out, if required.

5.5 BUILD UP STRUCTURAL SELF-INTERACTION MATRIX (SSIM)

In order to explore the barriers affecting utilization of QT&T, a contextual relationship of “give rise to” is used in this work. The expert panel was utilized for pair-wise comparisons to identify the contextual relationship among the barriers. Following four symbols have been used for describing relationship between the barriers i and j.

- V- when barrier i will give rise to barrier j;
- A- when barrier j will give rise to barrier i;
- X-when barriers i and j will give rise to each other;
- O-when barriers i and j have no relationship;

On the basis of contextual relationship among different barriers, SSIM has been obtained as shown in Table 5.4.

The next section describes the development of Structural self-interactive matrix of distinctive QT&T barriers under consideration. It is prepared on the basis of pair wise comparison of QT&T barriers.

Table 5.4: Structural self-interactive matrix (SSIM)

Barriers with codes	B_{12}	B_{11}	B_{10}	B_9	B_8	B_7	B_6	B_5	B_4	B_3	B_2
Employee's resistance to change **(B_1)**	O	O	A	O	A	A	A	V	V	A	A
Motivational technique and Recipient organizations **(B_2)**	O	O	A	O	A	A	A	V	V	O	
Lack of continuous communication **(B_3)**	X	A	A	V	A	A	A	V	V		
Inability to change organizational Culture **(B_4)**	O	O	A	O	A	A	A	A			
Inadequate coordination and teamwork **(B_5)**	O	O	A	O	A	A	A				
Dilemma about organization policies **(B_6)**	A	A	A	V	A	V					
Lack of proper training and education **(B_7)**	O	A	A	O	A						
Lack top Management Support **(B_8)**	O	A	V	V							
Divergence with other quality management system **(B_9)**	O	A	A								
Deficient planning and implementation **(B_{10})**	O	A									
Accessibility of time and space **(B_{11})**	O										
Keen to share knowledge **(B_{12})**											

5.5.1 Development of initial and final Reachability matrix

ISM methodology transforms the symbols V, A, X, O into binary numbers i.e. '0' and. '1' (known as initial reachability matrix) as illustrate in table 5.5. Following are the rules employed for creation of initial reachability matrix:

- The existence of V in SSIM reveals to apply '1' in (i, j) entry and '0' in the (j, i) entry in the reachability matrix.
- The existence of A in SSIM reveals to apply '0' in (i, j) entry and '1' in the (j, i) entry in the reachability matrix.
- The existence of X in SSIM reveals to apply '1' in both (i, j) and (j, i) entries in the reachability matrix.
- The existence of O in SSIM reveals to apply '0' in both (i, j) and (j, i) entries in the reachability matrix.

On the basis above mentioned rules, initial reachability matrix is accomplished as stated in Table 5.5.

Table 5.5: Initial reachability matrix

Barriers	**B_1**	**B_2**	**B_3**	**B_4**	**B_5**	**B_6**	**B_7**	**B_8**	**B_9**	**B_{10}**	**B_{11}**	**B_{12}**
B_1	1	0	0	1	1	0	0	0	0	0	0	0
B_2	1	1	0	1	1	0	0	0	0	0	0	0
B_3	1	0	1	1	1	0	0	0	1	0	0	1
B_4	0	0	0	1	0	0	0	0	0	0	0	0
B_5	0	0	0	1	1	0	0	0	0	0	0	0
B_6	1	1	1	1	1	1	1	0	1	0	0	0
B_7	1	1	1	1	1	0	1	0	0	0	0	0
B_8	1	1	1	1	1	1	1	1	1	1	0	0
B_9	0	0	0	0	0	0	0	0	1	0	0	0
B_{10}	1	1	1	1	1	1	1	0	1	1	0	0
B_{11}	0	0	1	0	0	1	1	1	1	1	1	0
B_{12}	0	0	1	0	0	1	0	0	0	0	0	1

After the development of initial reachability matrix (Table 5.6), final reachability matrix is obtained by the prologue of transitivity concept (as specify in step of ISM methodology) in the initial reachability matrix.

Table 5.6: Final reachability matrix

Barriers	**B_1**	**B_2**	**B_3**	**B_4**	**B_5**	**B_6**	**B_7**	**B_8**	**B_9**	**B_{10}**	**B_{11}**	**B_{12}**	**Driving power**
B_1	1	0	0	1	1	0	0	0	0	0	0	0	3
B_2	1	1	0	1	1	0	0	0	0	0	0	0	4
B_3	1	0	1	1	1	1*	0	0	1	0	0	1	7
B_4	0	0	0	1	0	0	0	0	0	0	0	0	1
B_5	0	0	0	1	1	0	0	0	0	0	0	0	2
B_6	1	1	1	1	1	1	1	0	1	0	0	1*	9
B_7	1	1	1	1	1	0	1	0	1*	0	0	1*	8
B_8	1	1	1	1	1	1	1	1	1	1	0	1*	11
B_9	0	0	0	0	0	0	0	0	1	0	0	0	1
B_{10}	1	1	1	1	1	1	1	0	1	1	0	0	10
B_{11}	1*	1*	1	1*	1*	1	1	1	1	1	1	0	12
B_{12}	1*	1*	1	1*	1*	1	1*	0	1*	0	0	1	9
	9	7	7	11	10	6	6	2	8	3	1	7	77/77

Note: 1* indicates transitivity check

In addition, it represents the indirect relationship between the barriers which clarifies that if barrier i give rise to barrier j and barrier j give rise to barrier k, then barrier i also give rise to barrier k.

5.5.2 Levels partitioning

Level partitioning enforce to disclose the levels of the barriers and to detach the barriers according to their levels. Reachability set contains the barrier itself and all the barriers which are driven by it but antecedent set contains the barrier itself and all the other barriers which drive it. The unlike sets of intersection and antecedent for all the barriers are obtained by partitioned final reachability matrix. In ISM methodology, level 1 is assigned to the barrier which attains same reachability and intersection sets and is situated at the top position of ISM model as shown in Table 5.7.

Table 5.7: Iteration 1

Barriers (B_i)	**Reachability set R (B_i)**	**Antecedent set A (B_i)**	**Intersection set $R(B_i) \cap A(B_i)$**	**Level**
B_1	B_1, B_4, B_5	B_1, B_2, B_3, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_1	
B_2	B_1, B_2, B_4, B_5	B_2, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_2	
B_3	B_1, B_3, B_4, B_5, B_6, B_9, B_{12}	B_3, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_3, B_6, B_{12}	
B_4	B_4	B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_4	**I**
B_5	B_5	B_1, B_2, B_3, B_5, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_5	
B_6	B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_9, B_{12}	B_3, B_6, B_8, B_{10}, B_{11}, B_{12}	B_3, B_6, B_{12}	
B_7	B_1, B_2, B_3, B_4, B_5, B_7, B_9, B_{12}	B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_7, B_{12}	
B_8	B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_8, B_9, B_{10}, B_{12}	B_8, B_{11}	B_8	
B_9	B_9	B_3, B_6, B_7, B_8, B_9, B_{10}, B_{11}, B_{12}	B_9	**I**
B_{10}	B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_9, B_{10}, B_{12}	B_8, B_{10}, B_{11}	B_{10}	
B_{11}	B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_8, B_9, B_{10}, B_{11}, B_{12}	B_{11}	B_{11}	
B_{12}	B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_9, B_{12}	B_3, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_3, B_6, B_7, B_{12}	

The top-level barriers would not help to achieve any other barrier above their own level in the model. Once the top-level barriers are recognized, they are alienated out from the rest of the barriers list and then the same procedure is adopted to find out the next level of barriers, and so on. These recognized levels help in building the directed graph as well as ISM model.

Thakkar et al. (2005) suggested that factors and precedence relationships are carried out by level partitioning process in topological order. In the present work, partitioning of the final reachability matrix (for the recognition of level of barriers) in the current task is carried out by nine iterations stated in Tables 5.7-5.15.

Table 5.8: Iteration 2

Barriers (B_i)	**Reachability set R (B_i)**	**Antecedent set A (B_i)**	**Intersection set R (B_i)∩ A (B_i)**	**Level**
B_1	B_1, B_5	B_1, B_2, B_3, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_1	
B_2	B_1, B_2, B_5	B_2, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_2	
B_3	B_1, B_3, B_5, B_6, B_{12}	B_3, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_3, B_6, B_{12}	
B_5	B_5	B_1, B_2, B_3, B_5, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_5	**II**
B_6	B_1, B_2, B_3, B_5, B_6, B_7, B_{12}	B_3, B_6, B_8, B_{10}, B_{11}, B_{12}	B_3, B_6, B_{12}	
B_7	B_1, B_2, B_3, B_5, B_7, B_{12}	B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_7, B_{12}	
B_8	B_1, B_2, B_3, B_5, B_6, B_7, B_8, B_{10}, B_{12}	B_8, B_{11}	B_8	
B_{10}	B_1, B_2, B_3, B_5, B_6, B_7, B_{10}, B_{12}	B_8, B_{10}, B_{11}	B_{10}	
B_{11}	B_1, B_2, B_3, B_5, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_{11}	B_{11}	
B_{12}	B_1, B_2, B_3, B_5, B_6, B_7, B_{12}	B_3, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_3, B_6, B_7, B_{12}	

Table 5.9: Iteration 3

Barriers (B_i)	**Reachability set R (B_i)**	**Antecedent set A (B_i)**	**Intersection set R (B_i)∩ A (B_i)**	**Level**
B_1	B_1	B_1, B_2, B_3, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_1	**III**
B_2	B_1, B_2	B_2, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_2	
B_3	B_1, B_3, B_6, B_{12}	B_3, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_3, B_6, B_{12}	
B_6	B_1, B_2, B_3, B_6, B_7, B_{12}	B_3, B_6, B_8, B_{10}, B_{11}, B_{12}	B_3, B_6, B_{12}	
B_7	B_1, B_2, B_3, B_7, B_{12}	B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_7, B_{12}	
B_8	B_1, B_2, B_3, B_6, B_7, B_8, B_{10}, B_{12}	B_8, B_{11}	B_8	
B_{10}	B_1, B_2, B_3, B_6, B_7, B_{10}, B_{12}	B_8, B_{10}, B_{11}	B_{10}	
B_{11}	B_1, B_2, B_3, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_{11}	B_{11}	
B_{12}	B_1, B_2, B_3, B_6, B_7, B_{12}	B_3, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_3, B_6, B_7, B_{12}	

Table 5.10: Iteration 4

Barriers (B_i)	**Reachability set R (B_i)**	**Antecedent set A (B_i)**	**Intersection set R (B_i)∩ A (B_i)**	**Level**
B_2	B_2	B_2, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_2	**IV**
B_3	B_3, B_6, B_{12}	B_3, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_3, B_6, B_{12}	**IV**
B_6	B_2, B_3, B_6, B_7, B_{12}	B_3, B_6, B_8, B_{10}, B_{11}, B_{12}	B_3, B_6, B_{12}	
B_7	B_2, B_3, B_7, B_{12}	B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_7, B_{12}	
B_8	B_2, B_3, B_6, B_7, B_8, B_{10}, B_{12}	B_8, B_{11}	B_8	
B_{10}	B_2, B_3, B_6, B_7, B_{10}, B_{12}	B_8, B_{10}, B_{11}	B_{10}	
B_{11}	B_2, B_3, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_{11}	B_{11}	
B_{12}	B_2, B_3, B_6, B_7, B_{12}	B_3, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_3, B_6, B_7, B_{12}	

Table 5.11: Iteration 5

Barriers (B_i)	**Reachability set R (B_i)**	**Antecedent set A (B_i)**	**Intersection set R (B_i)∩ A (B_i)**	**Level**
B_6	B_6, B_7, B_{12}	B_6, B_8, B_{10}, B_{11}, B_{12}	B_6, B_{12}	
B_7	B_7, B_{12}	B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_7, B_{12}	**V**
B_8	B_6, B_7, B_8, B_{10}, B_{12}	B_8, B_{11}	B_8	
B_{10}	B_6, B_7, B_{10}, B_{12}	B_8, B_{10}, B_{11}	B_{10}	
B_{11}	B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_{11}	B_{11}	
B_{12}	B_6, B_7, B_{12}	B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_6, B_7, B_{12}	**V**

Table 5.12: Iteration 6

Barriers (B_i)	**Reachability set R (B_i)**	**Antecedent set A (B_i)**	**Intersection set R (B_i)∩ A (B_i)**	**Level**
B_6	B_6	B_6, B_8, B_{10}, B_{11}	B_6	**VI**
B_8	B_6, B_8, B_{10}	B_8, B_{11}	B_8	
B_{10}	B_6, B_{10}	B_8, B_{10}, B_{11}	B_{10}	
B_{11}	B_6, B_8, B_{10}, B_{11}	B_{11}	B_{11}	

Table 5.13: Iteration 7

Barriers (B_i)	**Reachability set R (B_i)**	**Antecedent set A (B_i)**	**Intersection set R (B_i)∩ A (B_i)**	**Level**
B_8	B_8, B_{10}	B_8, B_{11}	B_8	
B_{10}	B_{10}	B_8, B_{10}, B_{11}	B_{10}	**VII**
B_{11}	B_8, B_{10}, B_{11}	B_{11}	B_{11}	

Table 5.14: Iteration 8

Barriers (B_i)	**Reachability set R (B_i)**	**Antecedent set A (B_i)**	**Intersection set R (B_i)∩ A (B_i)**	**Level**
B_8	B_8	B_8, B_{11}	B_8	**VIII**
B_{11}	B_8, B_{11}	B_{11}	B_{11}	

Table 5.15: Iteration 9

Barriers (B_i)	**Reachability set R (B_i)**	**Antecedent set A (B_i)**	**Intersection set R (B_i)∩ A (B_i)**	**Level**
B_{11}	B_{11}	B_{11}	B_{11}	**IX**

Table 5.16: Combined level partitions table

Barriers (B_i)	**Reachability set R (B_i)**	**Antecedent set A (B_i)**	**Intersection set R (B_i)∩ A (B_i)**	**Level**
B_1	B_1	B_1, B_2, B_3, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_1	**III**
B_2	B_2	B_2, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_2	**IV**
B_3	B_3, B_6, B_{12}	B_3, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_3, B_6, B_{12}	**IV**
B_4	B_4	B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_4	**I**
B_5	B_5	B_1, B_2, B_3, B_5, B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_5	**II**
B_6	B_6	B_6, B_8, B_{10}, B_{11}	B_6	**VI**
B_7	B_7, B_{12}	B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_7, B_{12}	**V**
B_8	B_8	B_8, B_{11}	B_8	**VIII**
B_9	B_9	B_3, B_6, B_7, B_8, B_9, B_{10}, B_{11}, B_{12}	B_9	**I**
B_{10}	B_{10}	B_8, B_{10}, B_{11}	B_{10}	**VII**
B_{11}	B_{11}	B_{11}	B_{11}	**IX**
B_{12}	B_6, B_7, B_{12}	B_6, B_7, B_8, B_{10}, B_{11}, B_{12}	B_6, B_7, B_{12}	**V**

5.5.3 Development of lower triangular matrix

Afterwards, the barriers of same level across the rows and columns are clubbed together from the final reachability matrix in order to develop lower triangular matrix. This rearrangement of barriers into lower triangular form leads to the computation of both driver and dependence power for allocation of barriers according to their respective levels by calculating ranks. Driver power is obtained by adding up the number of 1s in equivalent rows and dependence power is obtained by adding up the number of 1s in equivalent columns. Table 5.17 shows the driver and dependence power of each barrier. It is concluded that barrier (B_4, B_9) with level I attains at the top position and barrier (B_{11}) with level IX placed at the bottom and resulting the formation of structured model form digraph.

Table 5.17: Lower triangular matrix

Barriers	**B_4**	**B_9**	**B_5**	**B_1**	**B_2**	**B_3**	**B_7**	**B_{12}**	**B_6**	**B_{10}**	**B_8**	**B_{11}**	**Driver power**	**Rank**
B_4	1	0	0	0	0	0	0	0	0	0	0	0	1	10
B_9	0	1	0	0	0	0	0	0	0	0	0	0	1	10
B_5	1	0	1	0	0	0	0	0	0	0	0	0	2	9
B_1	1	0	1	1	0	0	0	0	0	0	0	0	3	8
B_2	1	0	1	1	1	0	0	0	0	0	0	0	4	7
B_3	1	1	1	1	0	1	0	1	1	0	0	0	7	6
B_7	1	1	1	1	1	1	1	1	0	0	0	0	8	5
B_{12}	1	1	1	1	1	1	1	1	1	0	0	0	9	4
B_6	1	1	1	1	1	1	1	1	1	0	0	0	9	4
B_{10}	1	1	1	1	1	1	1	1	1	0	1	0	10	3
B_8	1	1	1	1	1	1	1	1	1	1	1	0	11	2
B_{11}	1	1	1	1	1	1	1	1	1	1	1	1	12	1
Dependence Power	11	8	10	9	7	7	6	7	6	2	3	1		
Rank	1	4	2	3	5	5	6	5	6	8	7	9		

5.5.4 Development of digraph and ISM-based model

On the basis of lower triangular matrix (Table 5.17), initial digraph comprising of transitive or indirect links is constructed by nodes and line of edges. Final digraph is developed by eliminating the indirect links from initial digraph and is transformed into an ISM model as shown in Figure 5.2. This hierarchy model represents connection between the barriers along with their associated direction as illustrated and discussed in next section of this chapter.

5.5.5 Development of digraph and ISM-based model

On the basis of lower triangular matrix (Table 5.17), initial digraph comprising of transitive or indirect links is constructed by nodes and line of edges. Final digraph as illustrated in figure 5.2 is developed by eliminating the indirect links from initial digraph and is transformed into an ISM model which has been presented in figure 5.3. This hierarchy model represents connection between the barriers along with their associated direction as described below:

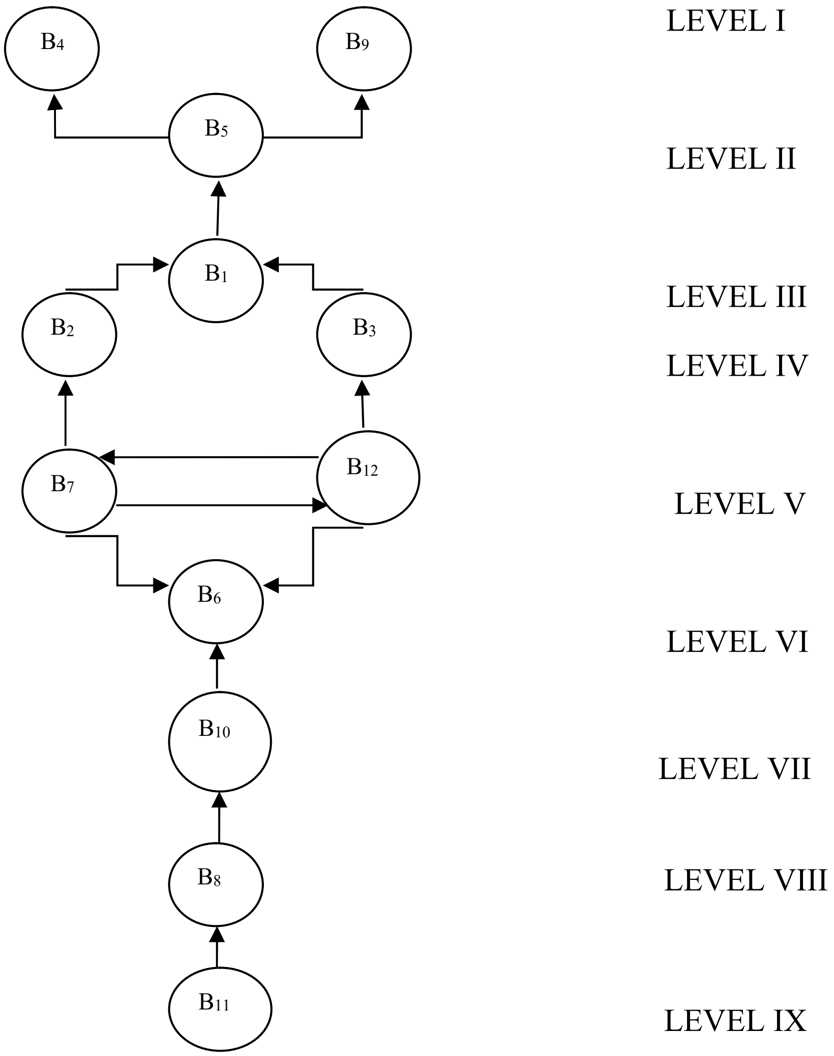


Figure 5.2: Digraph of barriers affecting utilization of QT&T in manufacturing organization

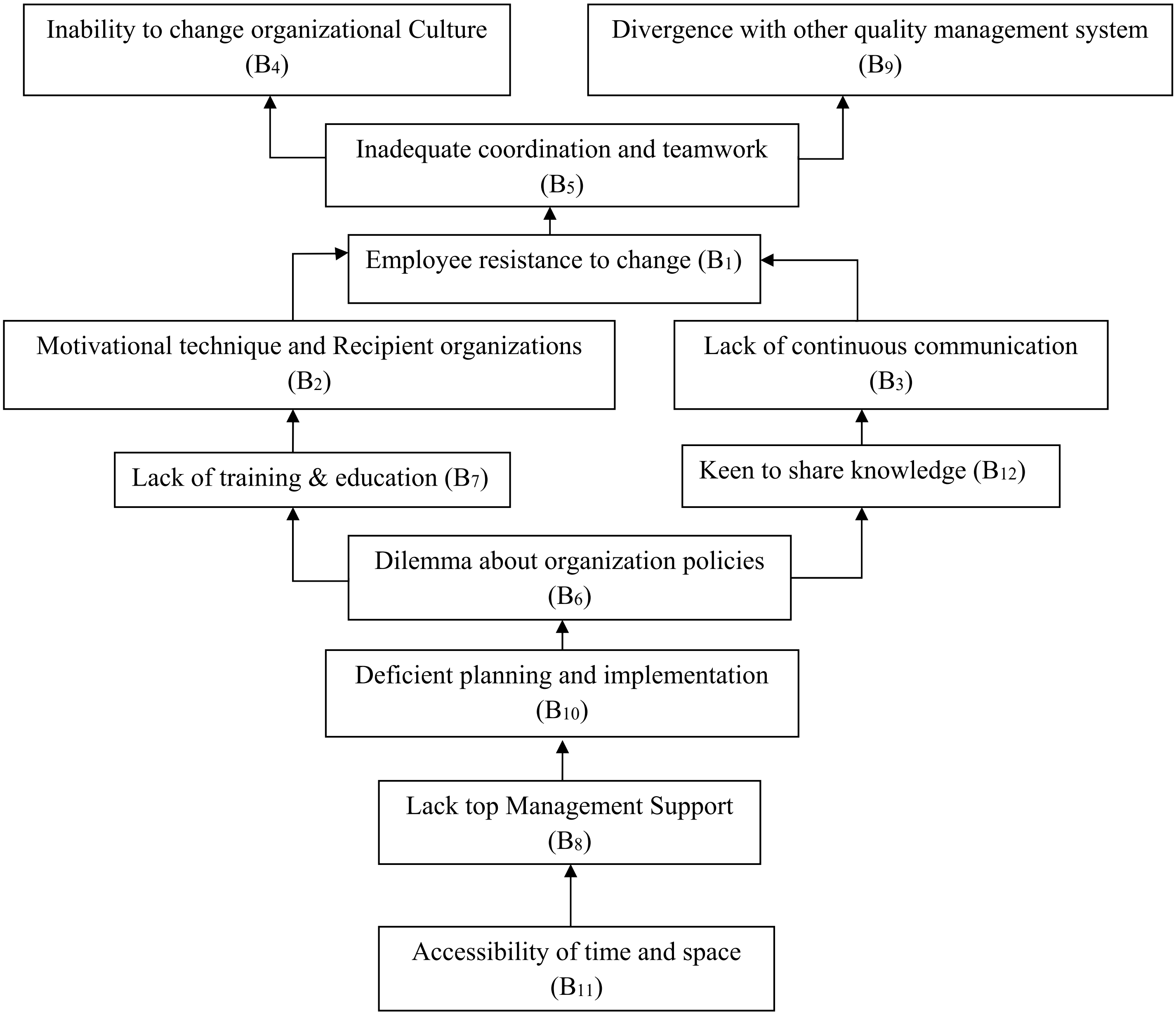


Figure 5.3: Interpretive structural model showing levels of barriers affecting QT&T

5.6 MICMAC ANALYSIS

MICMAC is known as cross-impact matrix multiplication applied to classification derived from (Matriced'Impacts croises-multipication appliqué and clasment). It is based upon multiplication properties of matrices (Sharma et al., 1995). MICMAC analysis helps to analyze the barrier on the basis of their driver and dependence power and to group them accordingly (Singh et al., 2014). It starts with the calculation of both driver and dependence power for each barrier and categorizes the barrier into following four quadrants:

- **Autonomous barriers (Ist quadrant):** These barriers lie in first quadrant and signify their presence with weak driver and dependence power. They are promptly detached with few links.
- **Dependent barriers (IInd quadrant):** These barriers lie in second quadrant and have weak driver power but strong dependence power. They are significantly exaggerated by various barriers
- **Linkage barriers (IIIrd quadrant):** These barriers lie in third quadrant and have strong driver power along with the strong dependence power. Being an important quadrant the action made by these variables will affects others and vice versa.
- **Independent barriers (IVth quadrant):** These barriers lie in forth quadrant and have strong driver power but weak dependence power. They have greater driver power above several barriers.

The driver power & dependence power diagram is constructed in figure 5.4. Abscissa represents dependence power and ordinate relates with driver power. The diagram so generated helps to conquer the classification of different barriers affecting the utilization of QT&T in manufacturing organizations.

This diagram is alienated into four quadrants. Bottom left contains autonomous barriers, bottom right consists of dependent barriers, top right and left quadrants comprises with linkage and Independent barriers collectively. From figure 5.4, it is concluded that there is no barrier under autonomous variable's quadrant. Two barriers drop under linkage variable's quadrant, five barriers beneath dependant quadrant and rest of it fall under independent barrier variable's quadrant. The driver and dependence power obtained through MICMAC analysis give visions about the relative significance and the interdependencies for effective utilization of QT&T in manufacturing organizations and provide valuable understandings that can efficiently deploy these QT&T for to persist effectiveness.

The next section of this chapter deals with the partitions of barriers into four quadrants. The level exhibited by different barriers in terms of driver and dependence power has been described in figure 5.4 as underneath:

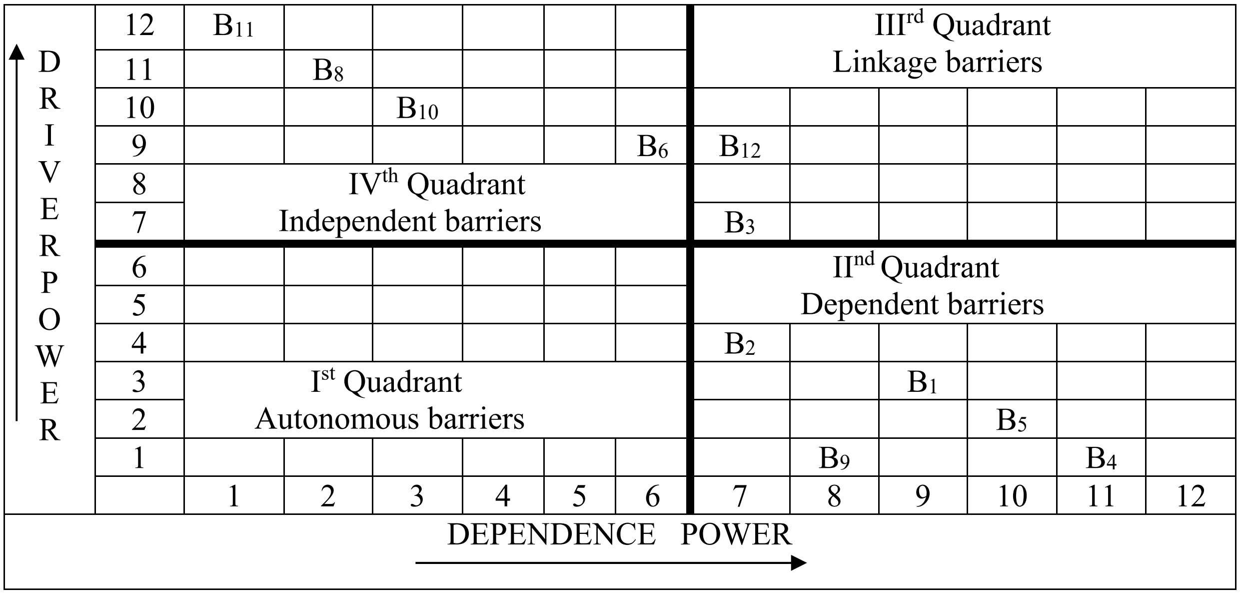


Figure 5.4: Driver power-dependence graph

5.7 DEVELOPMENT OF INTEGRATED MODEL

For perceived effectiveness, better and more refined approach has been used to upgrade the basic ISM model. Integrated model as shown in figure 5.5 is the hierarchical order of barriers which approximately analogous to that of conventional ISM model. An integrated model has been developed from MICMAC analysis by means of the driver and dependence powers of the barriers. Table 5.18 illustrates the calculation of effectiveness *(E)* for each barrier by subtracting the dependence power from the driver power. The barriers having higher effectiveness are placed at the bottom and the barriers with lower effectiveness are placed at the top of the model on to other barriers.

Table 5.18: Difference in driver power and dependency power

Barriers	Driver power	Dependence power	*E*=(driver power-dependence power)
B_1	3	9	-6
B_2	4	7	-3
B_3	7	7	0
B_4	1	11	-10
B_5	2	10	-8
B_6	9	6	3
B_7	6	8	-2
B_8	11	3	8
B_9	1	8	-7
B_{10}	10	2	8
B_{11}	1	12	-11
B_{12}	9	7	2

The integrated model described in figure 5.5 implies to be more reliant and sophisticated for the representation of barriers affecting the utilization of QT&T.

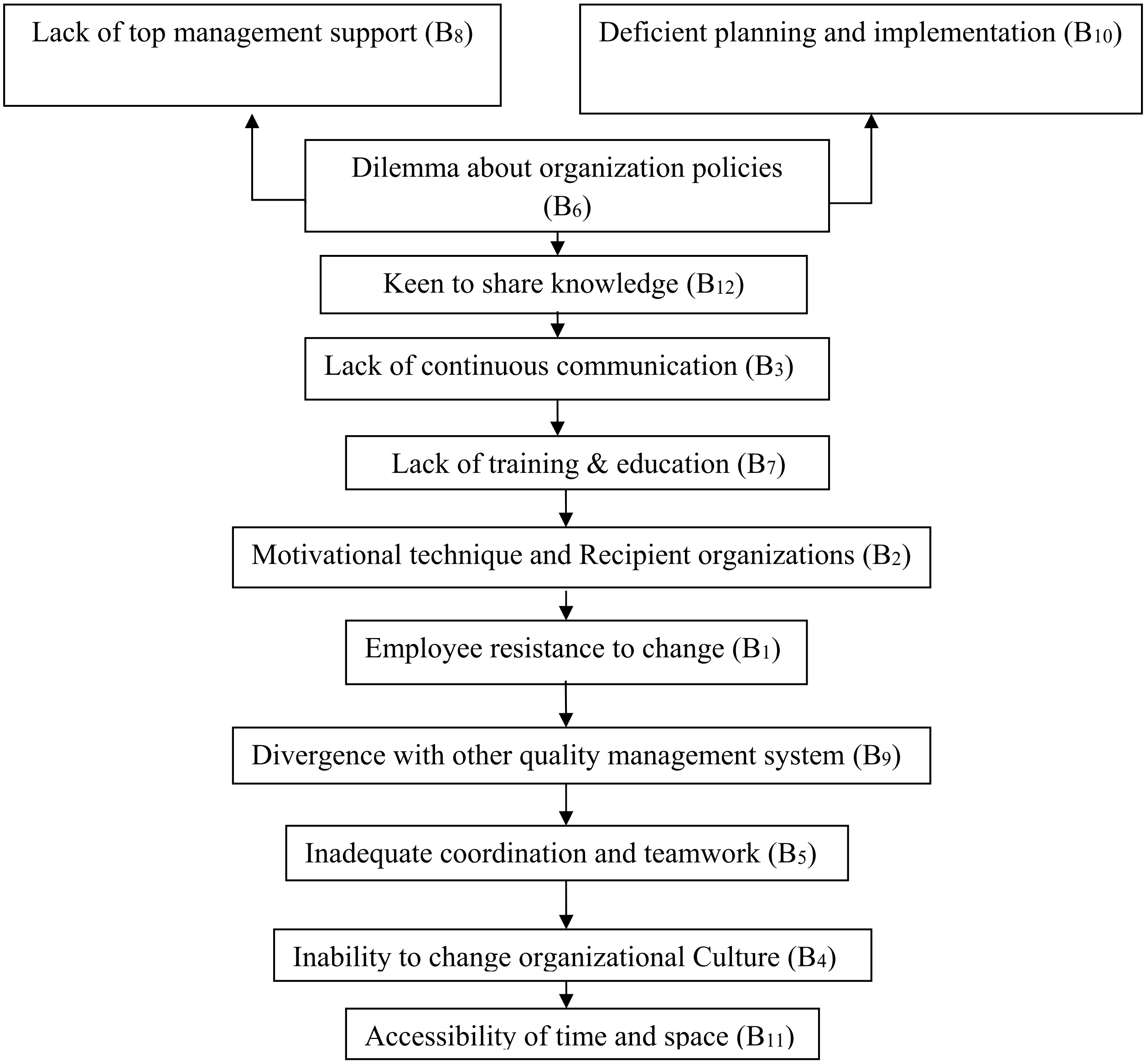


Figure 5.5: Integrated model of barriers affecting manufacturing organization

After going through the integrated model, it is found that barrier (B_{11}) Accessibility of time and space, (B_4) Inability to change organizational Culture and (B_5) Inadequate coordination and teamwork are placed at the same bottom level of hierarchy and indicate independent barriers which drive the barriers situated at in higher level of the model. On the other hand, barriers specifically (B_6) Dilemma about organization policies, (B_8) lack of top management support and (B_{10}) Deficient planning and implementation have propensity to affect the manufacturing organization and appears at the top most position of the model and indicate dependent barriers which are driven by other barriers in the model.

5.7 CONCLUDING REMARKS

This chapter endeavors to evaluate the effectiveness of different barriers inhibiting the proper execution of QT&T in manufacturing organizations. In the present excretion, an integrated ISM model based on contextual relationships has been developed which identified barriers through methodical framework that evocates the picture and helps managers to productively employ the QT&T in manufacturing organizations.

- The basic ISM model allocates the known barriers into nine different levels which show the prolongation of inter-relationships among these measured barriers. With the help of ISM methodology, the model was developed. It has been observed that accessibility of time and space (B_{11}), lack of top management support (B_8) and deficient planning and implementation (B_{10}) situated at (IX, VIII&VII) level of the ISM model. These are necessary inputs for any manufacturing organization to implement QT&T with proper planning with the help of top management support incorporates with the accessibility of appropriate time and space. The level VI constitutes dilemma about organization policies (B_6) which brings inappropriate knowledge about manufacturing organization. Similarly, Lack of training & education (B_7) and keen to share knowledge (B_{12}) both attains at same level of the hierarchy which substitute to integration of information with the aid of the incentive source. These barriers would lead to personalization of knowledge and further endorse integration of knowledge. Motivational technique and recipient organizations (B_2) with lack of continuous communication (B_3) together comprise at level IV which improves the mutual alliance and motivates well organizational culture. On the other hand, employee resistance to change (B_1) becomes dominant barrier while considering the efficient utilization of QT&T in any manufacturing organizations and finally top level of ISM model contributes level II for Inadequate coordination and teamwork (B_5) which combines with inability to change organizational Culture (B_4) and divergence with other quality management system (B_9) together influence same level I and willing to deals with the effectiveness of manufacturing organization. All the nine levels will facilitate to enhanced effective coordination, effective utilization and proper utilization of QT&T in manufacturing organization. The confirmation of ISM development with MICMAC analysis has been carried out with eleven experts (manufacturing organization practitioners – eight and academics – three). The concluded ISM model was developed and MICMAC analysis is carried out which gives an evidence to show resemblance in interrelationships with different barriers associated to their driving power and dependence power.

- The second purpose of present study is to carry out MICMAC analysis which defines barriers into four main quadrants (autonomous, linkage, dependent and independent) with their respective driver power and dependence power. They are:

  1. *Autonomous barriers:* The driving–dependence power diagram as shown in figure 5.4 indicates that there are no autonomous barriers existing in this quadrant these barriers have weak driver and dependence power and thus donated by only few links which directly influence the system. None of the barriers exist in this quadrant.

  2. *Dependent barriers:* Dependent barriers are strongly dependent on other barriers. Motivational technique and recipient organizations (B_2), employee resistance to change (B_1), inadequate coordination and teamwork (B_5), inability to change organizational culture (B_4) and divergence with other quality management system (B_9) have weak driving but have strong dependence power, and described as performance orientated. These barriers will appear at the top level of the ISM hierarchy and are therefore considered important barriers shown in Figure 5.3.

  3. *Linkages barriers:* Linkage barriers are influenced by lower level barriers and in turn impact other barriers in the model, which may affect the successful knowledge flow in manufacturing organizations either in an optimistic or pessimistic way. Two barriers namely keen to share knowledge (B_{12}) and lack of continuous communication (B_3) fall under this quadrant. Managers have to take special care while handling such barriers.

  4. *Independent barriers:* Barriers like accessibility of time and space (B_{11}), lack of top management support (B_8), deficient planning and implementation (B_{10}), inadequate coordination and teamwork (B_5), lack of training & education (B_7) are fall under this quadrant and are called independent barriers which drive other barriers and are subjected to be the most important barrier with high driver power than dependence power.

Afterwards, the developed Integrated ISM-MICMAC model has been presented in Figure 5.5. The analysis of Integrated ISM-MICMAC is as follows:

- Barriers like accessibility of time and space (B_{11}), Inability to change organizational Culture (B_4) and Inadequate coordination and teamwork (B_5) they all appear in the same level, i.e. at the bottom most level which means they drive the barriers present in top level of the model.

- Barriers namely keen to share knowledge (B_{12}), Lack of continuous communication (B_3), Lack of training & education (B_7), Motivational technique and Recipient organizations (B_2), Employee resistance to change (B_1) and Divergence with other quality management system (B_9) fall under middle level which supports both top level and bottom most level of the hierarchy.

- Barriers specifically lack of top management support (B_8), deficient planning and implementation (B_{10}) and dilemma about organization policies (B_6) will retain at top most level and have propensity to refer decisions to higher levels in manufacturing organizations which implies that these are the dependent barriers and are driven by other barriers in the model.

CHAPTER VI

APPLICABILITY OF QT&T IN MANUFACTURING AND SERVICE ORGANIZATIONS: A COMPREHENSIVE SURVEY

6.1 INTRODUCTION

Manufacturing and service organizations identifies the way towards the expansion and modernization of accelerating products in worldwide competition for their quality. Organizations that are continuously strived to attain quality must adopt certain quality tools and techniques (QT&T) for satisfying customer needs. Manufacturing organizations are identified to give solid products while service organizations change input plan into an output one in form of service. In particular, organizations must possess innovative strategies for improving performance (Monteiro et al., 2017). Thus different diagnosis, paradigms or techniques are employed to diminish the gap between organizations. Therefore, it is obligatory to distinguish between planned and operational outcome of the manufacturer in an organization (Suphunnika and Kayis, 2014).

6.2 APPLICABILITY OF QT&T IN VARIED ORGANIZATIONS

Applicability of different quality tools and techniques (QT&T) for creation and inevitability of products and services has sustained many changes to cope up with recent future trends. Several QT&T were suggested and classified into different groups to standardized organizations (manufacturing and service) for improving their efficiency and quality. Formerly exist seven basic (cause and effect diagram, scatter diagram, pareto diagram, flow chart, control charts, histogram and Check sheet) and seven management tools (affinity diagram, arrow diagram, matrix diagram, matrix data analysis, process decision program chart (PDPC), relation diagram and tree diagram) does not ensure organizations to overcome problems but also helps to identify the gap encountered while implementing distinctive QT&T categories. Hence selective usage of QT&T in different areas depends upon the level of applicability in an organization (Toremen et al., 2009; Lau and Tang, 2009; Bugdol, 2005).

Furthermore, during the usage of selective QT&T can help organizations to classify into different groups (Nave, 2002; Revere et al., 2004). It is discovered that only limited number of authors like Hellsten & Klefsjo, (2000); Mehra et al., (2001); Chin et al., (2002); Grover et al., (2004); Thia et al., (2005); Grover et al., (2007); Bamford et al., (2005); Kovach et al., (2011) have categorized these QT&T into diversified groups. Hence this research insists an optimistic approach about the level of implementation and adaptability of various QT&T among different organizations.

In this chapter, all sixteen categories namely: seven basic tools (7BT), management tools (7MT), problem solving tools (PST), software tools (SWT), statistical tools (ST), graphical tools (GT), new product development tools (NPDT), decision making tools (DMT), productivity tools (PT), assessment/analysis tools (AT), combinational tools (CT), relationship tools (RT), lean tools (LT), communicational tools (CMT), motivational tools (MOT), performance measurement tools (PMT) are analyzed by using survey based questionnaire. These categorizations provide valuable insight for adopting distinctive QT&T in an organization. To conquer this gap, a survey regarding the applicability of QT&T was done in NCR region and industrial town Bhiwadi in Rajasthan, India. The foremost objectives of deploying questionnaire based survey are as follows:

- To finds out the level of adoption and applicability of various QT&T in an organization;
- To assess the effect of QT&T categories in different organizations;
- To discover why some organizations, have not implemented QT&T;
- To recognize the benefits and challenges of implementing QT&T in an organization;

Such survey reports provide vital understanding on the execution rate, similarities and divergence for adapting selective QT&T category in particular organization. The next section describes the extent of QT&T categories in various organizations. (Sharma et al. 2020)

6.3 FEASIBILITY OF QT&T CATEGORIZATIONS IN DIFFERENT SECTORS

Innumerable surveys studies (Jin et al., 2008; Salah et al., 2011) have been reported to assemble selective (QT&T) in manufacturing and service organizations. This uncertainty in execution of various (QT&T) in different organizations gives clear perception not only in implementation status but also in the area of realistic research.

6.3.1 QT&T -an extent of applicability in manufacturing organizations

The accomplishment of QT&T in productivity brings significant changes in manufacturing organizations. In early 1990s and late 1980s many researchers contributed their relevancy towards successful development and implementation of QT&T in their organizations while McQuater et al. (1995) identified limited approach and focus for a single tool instead of techniques which has wider applications and related with set of tools. However, Kwok and Tummala, (1998) argued that QT&T are ineffective and do not work correctly for getting preferred outcomes in manufacturing organizations. Despite the fact that no of researchers gave their contributions to implicit quality for providing variety of products in global market.

6.3.2 QT&T -an extent of applicability in service organizations

Garg et al., (2002) and Antony et al., (2004) suggested the increase in product and service quality by productivity enhancement. In other words, adaptability of QT&T in service organizations brings higher quality with lower price independently to bring changes in product or service. As illustrated by various authors about the realistic applicability of QT&T in service organizations: Heizer and Render, (2006) discovered effectual perception of TQM together with service organizations. Hence QT&T applied for both profitable and non-profitable organizations in the service sectors.

On this contradiction, it is revealed that some QT&T categorizations related to manufacturing and other corresponds to service organizations. Bertha et al. (2019) concludes contemporary relationship between quality management and productivity as performance indicator. Likewise, Fay Abdulla Al khalifa (2019); Nimmy J.S (2019); Amit agrahiri et al. (2019) presented different outcomes in various fields about the adoption and assimilation of QT&T in particular organizations. Figure 6.1 shows the applicability of several QT&T in diversified areas and identifies the common region which illustrates the applicability of QT&T in both organizations.

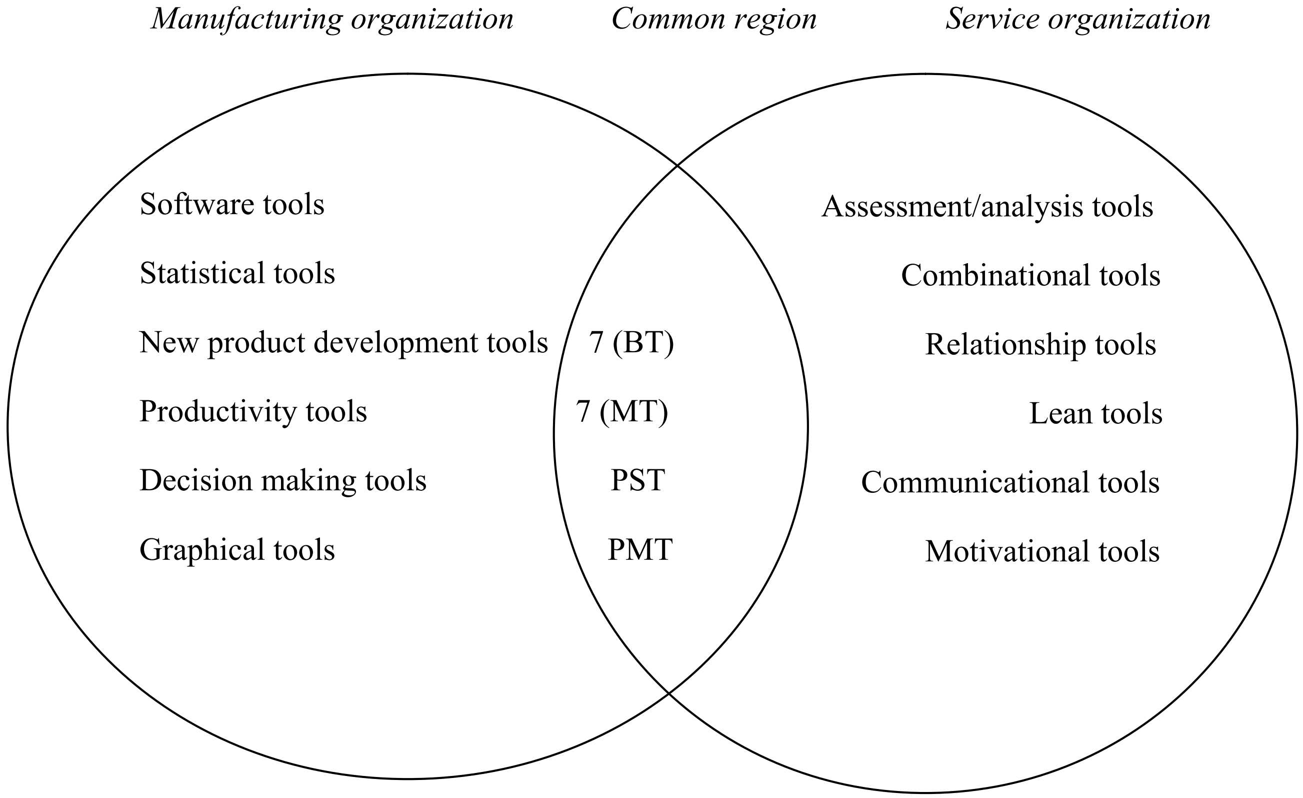


Figure 6.1: Applicability of QT&T in different organizations

6.4 QUESTIONNAIRE DEVELOPMENT

The exploratory research methodology was intended to assist the applicability of different QT&T techniques among various manufacturing and service organizations. To accomplish the objectives of this research, two approaches were intended – development of survey questionnaire and meeting with organizational experts.

6.4.1 Survey questionnaire

To accumulate the complete information of the research, a survey questionnaire was developed. The outline of required questionnaire was taken from Tansey et al. (2001), and Lin and Johnson (2004) and survey questions were derived from Albliwi et al. (2014) and Albliwi et al. (2015). This developed questionnaire was analyzed by number of professional academicians and industrial experts to validate the survey report and obtain best possible results. Minor alterations were suggested for better understanding of QT&T in particular organization. The modified questionnaire consists of three major sections.

- First section consists of background details of the contributing organizations (manufacturing and service) such as name of organization, years of establishment, number of employees, company size and quality certification.
- Second section concerns with implementation status, level of awareness and impact on organization.
- Last section contributes with respondent information (position in organization, department and year of serving). (Appendix-I)

A Likert five-point scale was used to determine the applicability of distinctive QT&T in particular organization. The scale was rating from 1 to 5, 1 stands for exceptionally applicable QT&T, 2 stands for less applicable QT&T, 3 stands for moderate applicable QT&T, 4 stands for more applicable QT&T and 5 signifies strongly applicable QT&T. This valuable insight helps the organizations to assign score for various QT&T according to the extent of applicability.

6.4.2 Meeting organizational experts

Planned meetings were held with distinguish industrial professionals and experts already employed QT&T in different areas of their organizations. The main aim for arranging this meeting was to merge the views of industrial professionals and experts that were look forward in the area of quality improvement. Detailed observations and comments were also taken from senior executives/managers /directors to improve the extent of research and investigate the survey data.

6.4.3 Survey distribution

The survey was conducted in nearby NCR region and industrial town Bhiwadi involving manufacturing and service organizations. These organizations were selected according to their annual turnover (above 200 million). The questionnaires were administered to 398 general managers including director, managing director, executive managing directors and quality managers to facilitate survey response. Both postal and online modes of communication were used for distributing questionnaires. Requesting e-mails were also sent to chief operating executives (COEs) to contribute in filling questionnaires.

However, from 398 distributed survey 190 filled questionnaires were received (88 for service organizations and 102 manufacturing organizations). Thus the combined response rate is 47.73 percent. After reviewing 190 questionnaires only 106 successfully filled questionnaires were selected, 84 become excluded from the analysis on account of financial background (47) and quality certification (32), rest of the 5 respondents were neglected based on unidentified job condition. Hence the concluded response rate for 106 organizations is 26.63 percent which is measured as high according to (Forza, 2009). The below mention tables from 6.1 to 6.4 represents all relevant information required to gather data through survey questionnaire.

Table 6.1: Organizational profile of survey respondents

Organization sector	Frequency of organizations (total 106)	Percentage of organizations
Government	15	14.15
Semi government	18	16.98
Multinational	20	18.86
Non-government organization	22	20.75
Private	31	29.24
Total	106	100

Table 6.2: Survey data based on sub-groups of participated organizations

Type of organization	Frequency of organizations (total 106)	Percentage of organizations
Construction	5	4.71
Consultancy	6	5.66
Financial	4	3.77
Telecom	5	4.71
Shipping	6	5.66
Airline	7	6.60
Retail	5	4.71
Logistics	6	5.66
Metallurgy	5	4.71
Healthcare	4	3.77
Automotive parts	6	5.66
Electrical manufacturing	4	3.77
Beverage	4	3.77
Printing	8	7.54
Insurance	4	3.77
Petroleum	7	6.60
Chemical	5	4.71
Sheet metal	5	4.71
Mining	4	3.77
Warehouse	6	5.66
Total	106	100

Table 6.3: Survey data based on company size

Company size	Frequency of organizations (total 106)	Percentage of organizations
Below 100 employees	22	20.75
Between 101 and 200 employees	28	26.41
Between 201 and 300 employees	31	29.24
Between 301 and 400 employees	12	11.32
Above 400 employees	13	12.26

Table 6.4: Survey data on organizations establishment year

Year of establishment	Frequency of organizations (total 106)	Percentage of organizations
<5 years	20	18.86
>5 years but <10 years	18	16.98
>10 years but <15 years	34	32.07
>15 years but <20 years	24	22.64
20 years and above	10	9.43

Once the necessary information in terms of types of organizations, sub group contribution, company size and year of establishment were composed, they were analyzed by MS Excel software. Percentages were calculated on account of frequency participation at primary stage and then after demographic information have been discussed to show the current extent of applicability of different QT&T in various organizations.

Table 6.1 illustrates the type of organizational sectors participated in survey research. It is found that private sector contributed to be main (29.24 percent) of the total research followed by non-government organization (20.75 percent), multinational (18.86 percent), semi-government (16.98 percent) and government organization (14.15 percent). The next section of this chapter represents the individual sequence of sub organizations participated in survey results. Table 6.2 shows the relevance of participated organizations in individual format.

About (18.86 percent) of the workers have been established in particular organization for less than 5 years, whereas (16.98 percent) contributed with more than 5 years but less than 10 years, (32.07 percent) served more than 10 years but less than 15 years, (22.64 percent) indicated more than 15 years but less than 20 years and only (9.43 percent) of workers employed in an organization for more than 20 years as represented in table 6.4 mean while to the percentage (20.75 percent) for no of employees below 100, (26.41 percent) in between 101 to 200 employees, (29.24 percent) in between 201 to 300 employees, (11.32 percent) in between 301 to 400 employees and finally (12.26 percent) for employees more than 400 as illustrated in table 6.3.

Thus, distinctive observation and data collection has compiled to attain following objectives:

- To find out the level for adoption and applicability of various QT&T in an organization.

Table 6.5 shows the percentage wise categorizations of 152 QT&T into16 groups (Sharma et al., 2017). Each category has different perceived effect on different organizations to assess the level of adoption.

Table 6.5: Survey data on category wise adoption QT&T in an organization

Categorizations	**Percentage of organization**				
	Not adopted	**Less adopted**	**Consider to be adopted**	**Adopted**	**Highly adopted**
Basic quality tools (7BT)	02	19	17	40	28
Management tools (7MT)	04	18	26	44	14
Problem solving tools (PST)	01	08	05	59	33
Software tools (SWT)	03	25	27	39	12
Statistical tools (ST)	05	28	18	44	11
Graphical tools (GT)	06	17	19	48	16
New product development tools (NPDT)	03	22	24	52	5
Decision making tools (DMT)	07	19	21	44	15
Productivity tools (PT)	01	05	04	56	40
Assessment/analysis tools (AT)	03	17	28	51	7
Combinational tools (CT)	04	21	23	40	18
Relationship tools (RT)	08	27	29	36	6
Lean tools (LT)	02	22	22	54	6
Communicational tools (CMT)	04	18	24	50	10
Motivational tools (MOT)	09	21	17	43	16
Performance measurement tools (PMT)	01	06	08	57	34

Out of 106 survey reports the implementation of particular category into different organizations prevail a valuable insight to discriminate between manufacturing and service organizations. The demographic illustrations of QT&T categories have been taken by evaluating the average mean for individual category. Figure 6.2 depicts the implementation rate of different categories according to the adaptability of usage.

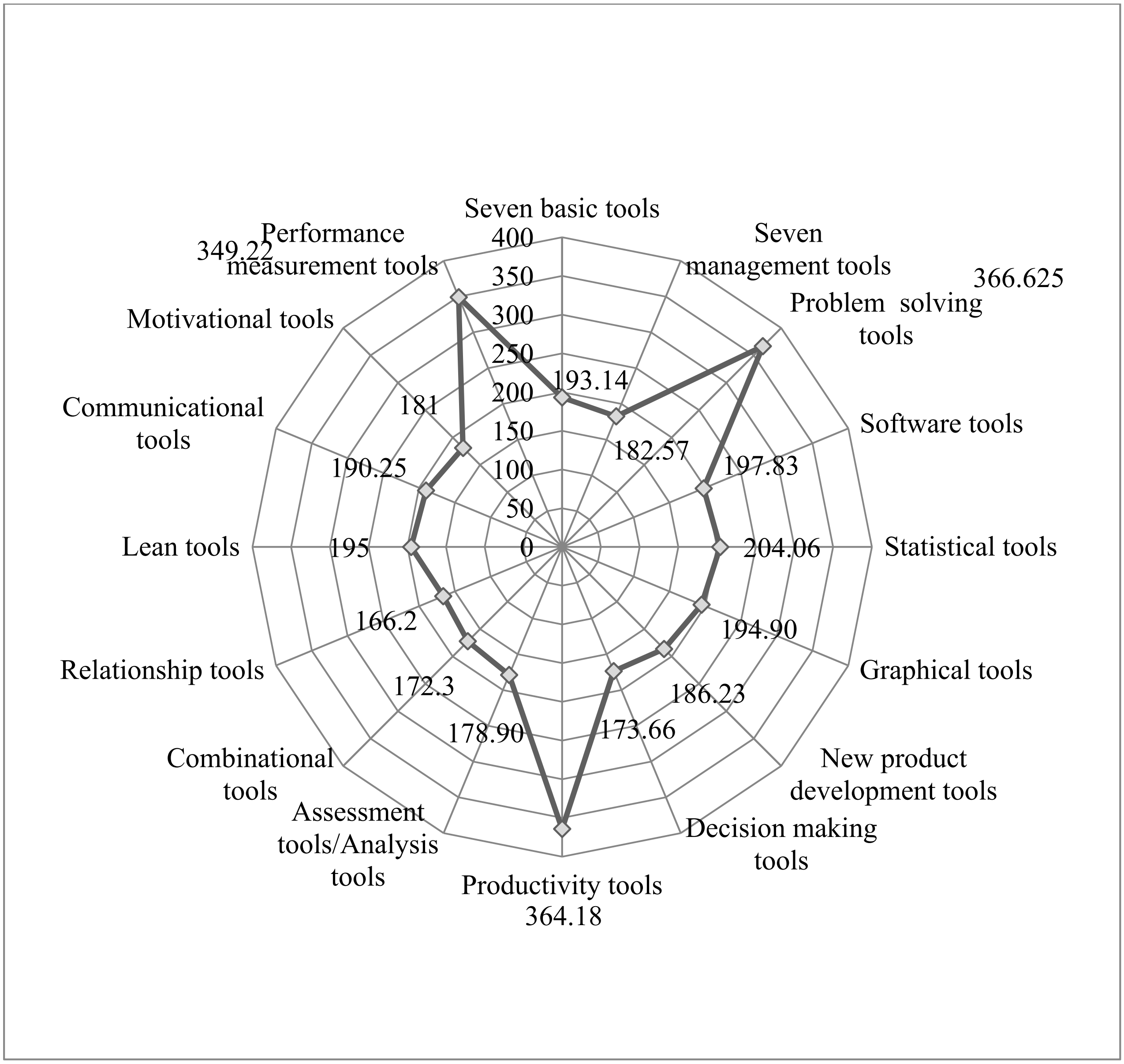


Figure 6.2: Implementation of QT&T in different organizations

From the above analysis, it is obvious that problem solving tools, productivity tools and performance measurement tools contributed to be the most widely used QT&T among manufacturing and service organizations. However, it is significant to mention that 63 organizations out of 106 have not adopted any kind of QT&T in their organizations.

- To assess the effect of QT&T categories in different organizations

The present section describes the assessment of different QT&T categories by questionnaire method. This survey questionnaire was assessed by TOPSIS approach to determine the order preference of QT&T categories in different areas of manufacturing and service organizations. The concept of TOPSIS initially developed by Hwang and Yoon (1981) and first presented by Chen and Hwang (1992). This approach has been used to identify solutions from a finite set of alternatives. The main fundamental aspects of this approach have not only determined the shortest distance from the optimistic ideal solution, but also have the longest distance from the pessimistic ideal solution. Optimistic and pessimistic ideal solutions are also called the ideal and anti-ideal solutions (Zeleny, 1982).

The main steps involved in TOPSIS are as follows (Rao, 2007):

1. The first step is to nomenclature these 16 categorizations into different abbreviations.

2. All unique abbreviations are expressed in matrix form. Each row of the matrix defines one categorization and each column to one criterion. So recital data for *n* alternatives over *k* criteria is obtained. Element X_{ij} of the matrix provides the value of jth criteria in original real values, for the ith categorization. After standardized raw measurements convert raw X_{ij} into standardized measures S_{ij} by using equation given below:

$$S_{ij} = X_{ij} / \left(\left(\sum_{i=1,j=1}^{n,k} \left(X_{ij}{}^{2} \right) \right)^{1/2} \right) \quad \ldots \qquad (6.1)$$

3. Set of importance weights w_k are obtained for each criteria. These weights are determined in such a way that set of weights W_k (k=1, 2,..., n) represent $\sum \mathrm{Wk} = 1$ represented by equation (3.2)

$$\text{Normalised weight of each importamce} = \frac{\text{Total of each importance}}{\text{Grand total of all importances}} \quad \ldots (6.2)$$

4. Multiply each element of column S_{ij} with its linked weight W_{ij} expressed by equation stated below:

$$W_{ij} = wkSij \qquad (6.3)$$

5. Identify the ideal categorization i.e optimistic ideal solution (The ideal categorization is the maximum value of each rating column of weighted matrix donated on each criterion by S+).
6. Identify anti-ideal categorization i.e pessimistic ideal solution (The anti-ideal categorization is the minimum value of each rating column of weighted matrix donated on each criterion by S-).
7. Develop a distance measure over each criterion to both ideal (D+) and anti-ideal (D-). The distance from ideal can be calculated using equation (3.4).

$$D_t^+ = \left\{\sum_{j=1}^{k}(W_{ij}^- \; S_j^+)^2\right\}^{1/2} \qquad i = 1,2,3 \ldots\ldots n \qquad \ldots\ldots\ldots\ldots\ldots \; (6.4)$$

and the distance from anti-ideal can be calculated using equation (6.5).

$$D_t^- = \left\{\sum_{j=1}^{k}(W_{ij}^- \; S_j^-)^2\right\}^{1/2} \qquad i = 1,2,3 \ldots\ldots n \qquad \ldots\ldots\ldots\ldots\ldots \; (6.5)$$

8. Fractional ratio FR is calculated by dividing distance to anti-ideal by the sum of the distance to the anti-ideal and the distance to the ideal, as shown in equation (3.6).

$$FR_i = \frac{D_i^-}{D_i^- + D_i^+} \qquad i = 1,2,3 \ldots..n \qquad \ldots\ldots\ldots\ldots\ldots \; (6.6)$$

9. Finally rank order categorizations by maximizing the ratio describe in step 8.

After analysis, the required results have been validated by TOPSIS approach to know the order of accessibility of various QT&T categorizations in manufacturing and service organizations. Table 6.6 donates the normalized data of sixteen QT&T categories.

Table 6.6: Data in normalized form

Rating	5	4	3	2	1
Categorizations	**Highly adopted**	**Adopted**	**Consider to be adopted**	**Less Adopted**	**Not adopted**
7BT	9.8023	8.3673	3.4532	4.6370	0.2166
7MT	2.4506	10.1245	8.0774	4.1617	0.8664
PST	13.6157	18.2042	0.2987	0.8221	0.0542
SWT	1.8004	7.9542	8.7107	8.0280	0.4874
ST	1.5129	10.1245	3.8714	10.0703	1.3538
GT	3.2008	12.0490	4.3135	3.7122	1.9495
NPDT	0.3126	14.1408	6.8826	6.2169	0.4874
DMT	2.8132	10.1245	5.2695	4.6370	2.6535
PT	20.0047	16.4000	0.1912	0.3211	0.0542
AT	0.6126	13.6022	9.3679	3.7122	0.4874
CT	4.0509	8.3673	6.3210	5.6646	0.8664
RT	0.4501	6.7775	10.0490	9.3639	3.4658
LT	0.4501	15.2495	5.7833	6.2169	0.2166
CMT	1.2503	13.0740	6.8826	4.1617	0.8664
MOT	3.2008	9.6695	3.4532	5.6646	4.3864
PMT	14.4534	16.9909	0.7647	0.4624	0.0542

Table 6.7: Weightage of rating

Rating	5	4	3	2	1
	Most important	**Very important**	**Important**	**Somewhat important**	**Least important**
Instance of each importance	271	757	312	293	63
Total of each importance	1355	3028	936	586	63
Normalized weight of each importance	0.2270	0.5074	0.1568	0.0982	0.0106

Table 6.8: Weighted matrix of normalized data

Rating	**5**	**4**	**3**	**2**	**1**
Categorizations	**Most important**	**Very important**	**Important**	**Somewhat important**	**Least important**
7BT	0.1326	0.2809	0.434	0.1423	0.0102
7MT	1.2998	2.3504	1.4987	0.6598	0.0022
PST	0.3249	2.8440	3.5056	0.5922	0.0088
SWT	1.8054	5.1136	0.1296	0.1170	0.0006
ST	0.2387	2.2343	3.7805	1.1424	0.0050
GT	0.2006	2.8440	1.6802	1.4330	0.0138
NPDT	0.4244	3.3846	1.8721	0.5282	0.0199
DMT	0.0414	3.9721	2.9870	0.8847	0.0050
PT	0.3730	2.8440	2.2869	0.6598	0.0271
AT	2.6526	4.6068	0.0830	0.0457	0.0006
CT	0.0812	3.8208	4.0657	0.5282	0.0050
RT	0.5372	2.3504	2.7433	0.8061	0.0088
LT	0.0597	1.9038	4.3613	1.3325	0.0354
CMT	0.0597	4.2836	2.5099	0.8847	0.0022
MOT	0.1658	3.6725	2.9870	0.5922	0.0088
PMT	0.4244	2.7162	1.4987	0.8061	0.0447

Table 6.9: Table of ideal categorization

S+	W_{i1}	W_{i2}	W_{i3}	W_{i4}	W_{i5}
	2.6526	5.1136	4.3613	1.4330	0.0447

Table 6.10: Table of anti-ideal categorization

S-	W_{i1}	W_{i2}	W_{i3}	W_{i4}	W_{i5}
	0.0414	1.9038	0.0830	0.0457	0.0006

Table 6.11: Distance of ideal and anti-ideal alternative from weighted data

Rating	**1**	**2**
Categorizations	**D_i^+**	**D_i^-**
7BT	9.4072	3.1435
7MT	8.4189	4.5609
PST	9.4734	5.4256
SWT	8.3765	4.5400
ST	8.9936	3.6041
GT	9.0039	3.9246
NPDT	8.0765	5.0455
DMT	8.9647	3.7246
PT	9.5648	5.3167
AT	7.8426	5.6015
CT	8.8534	3.7367
RT	8.3353	4.9382
LT	8.2082	5.0410
CMT	8.3240	4.7708
MOT	9.3876	3.2314
PMT	9.4201	5.1540

Table 6.12: Ratio of distance to anti-ideal from total

Sr no	**Categorizations**	R_i
1	**7BT**	0.2505
2	**7MT**	0.3514
3	**PST**	0.3642
4	**SWT**	0.3515
5	**ST**	0.2861
6	**GT**	0.3036
7	**NPDT**	0.3845
8	**DMT**	0.2935
9	**PT**	0.3573
10	**AT**	0.4167
11	**CT**	0.2968
12	**RT**	0.3720
13	**LT**	0.3805
14	**CMT**	0.3643
15	**MOT**	0.2561
16	**PMT**	0.3536

Table 6.13: Ranking the categorizations from largest to smallest value

Sr no	Categorizations	R_i
1	**AT**	0.4167
2	**NPDT**	0.3845
3	**LT**	0.3805
4	**RT**	0.3720
5	**CMT**	0.3643
6	**PST**	0.3642
7	**PT**	0.3573
8	**PMT**	0.3536
9	**SWT**	0.3515
10	**7MT**	0.3514
11	**GT**	0.3036
12	**CT**	0.2968
13	**DMT**	0.2935
14	**ST**	0.2861
15	**MOT**	0.2561
16	**7BT**	0.2505

From the above discussion, it has been evident that categories like assessment/analysis tools (AT), new product development tools (NPDT) and lean tools (LT) prevails the characteristic feature of rank after analyzed by TOPSIS approach. Yet categories like problem solving tools, productivity tools and performance measurement tools noticed narrow down fall in rank order which results in the formation of obstacles/challenges occurred during the successful implementation of QT&T categories in different organizations. The next section of this chapter deals with the challenges and benefits faced by distinctive QT&T categories in various organizations.

- To discover why some organizations, have not implemented QT&T

To respond second objective, list of non-implementers has been calculated from table 6.5, it is found that out of 106 successfully surveying reports, 63 organizations neither implemented nor adopted any kind of QT&T category. The prime challenging factors driven out from survey analysis is lack of knowledge (49 per cent) followed by communication gap (17 per cent) which contributed about more than half percent of the total non-implementers. In fact, these two confronts are key factors while successful implementation and adaptability of QT&T in any organization. Although, rest of the challenges were accountable to investigate the crisis in any organization like lack of training (14 percent), financial constraints (11 percent) and lack of resources about (8 percent). However, categorizations like problem solving tools, productivity tools and performance measurement tools have shown their supremacy towards other categories and exaggerated the most to find out the level of adoption and implementation of QT&T. Figure 6.3 describes the frequency of non-implementers for the of adoption of QT&T in an organization.

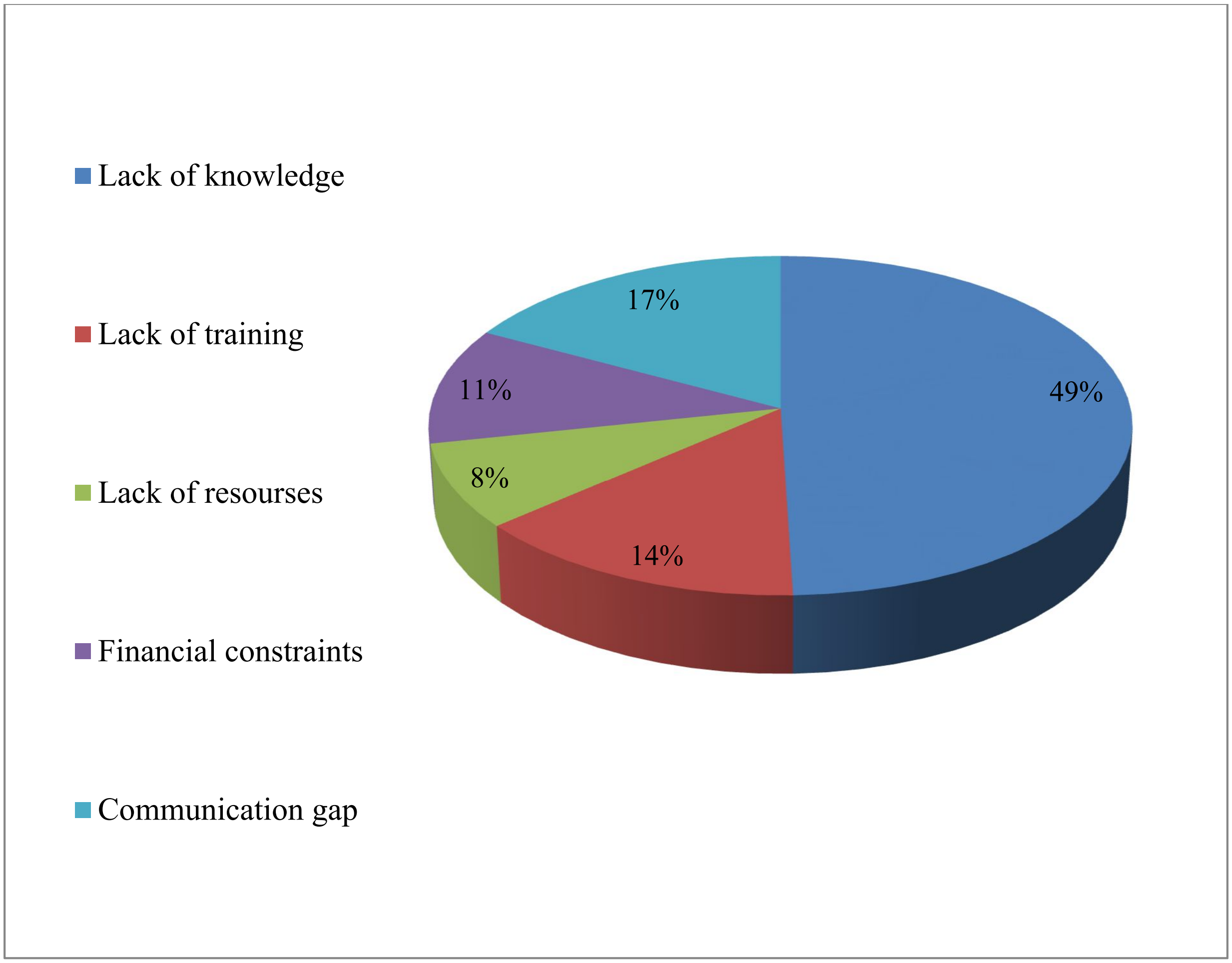


Figure 6.3: Percentage for non-implementers

- To recognize the benefits of implementing QT&T in an organization

Analyses so far demonstrated fine depiction about adoption and implementation of QT&T in manufacturing as well in service organizations. It was found that a total of 43 out of 106 organizations (40.56 percent) successfully implemented QT&T and remaining (59.43 percent) were non implementers. On this contradiction survey respondent were asked whether QT&T helped to raise the efficiency of the firm without overcome any proceeding gaps. Therefore, respondents from different areas of manufacturing and service sectors were invited to give detailed observations about benefits and implementation status of various QT&T.

To eliminate this gap, five benefits have been incorporated after concluded optimum 32 manufacturing and 11 service organizations out of 43. These were increased customer satisfaction (21 percent), improved key performance metrics (25 percent), Improve inventory turnover (32 percent), reduce waste (11 percent) in the process and cost saving (9 percent). Figure 6.4 shows the proportion wise breakup of benefits for various organizations.

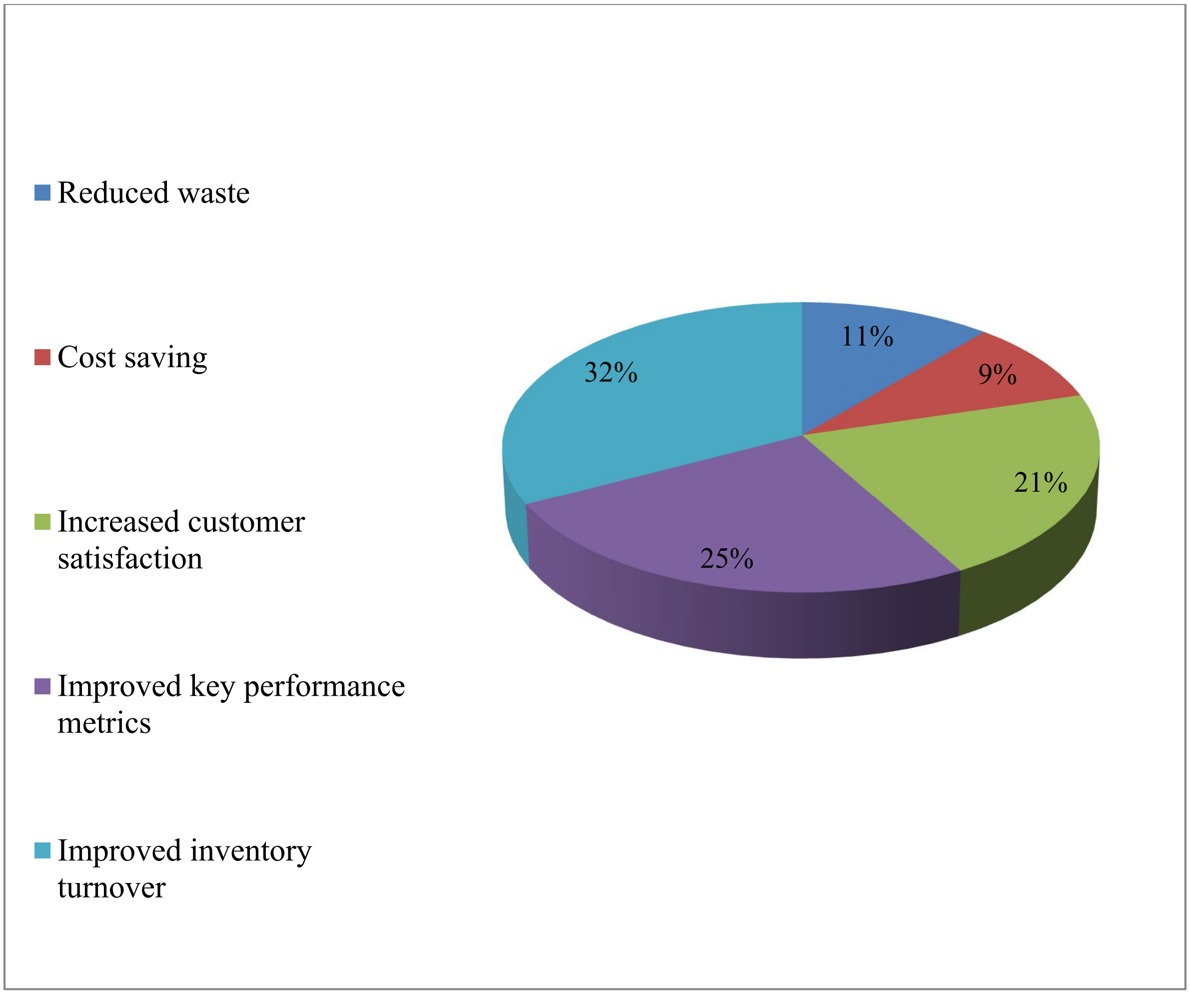


Figure 6.4: Benefits of QT&T in manufacturing and service organizations

By analyzing 106 surveying reports, it was originated that about (40.56 percent) of organizations definitely employed QT&T for improving their efficiency and provides sensible amount of eagerness concerning the usage of QT&T categories in diversified fields. The distinctive tools which fall beneath categories: problem solving tools, productivity tools and performance measurement tools have shown their ascendancy both in individual as well in sub-group classifications.

These results have been validated by performing multidimensional unfolding analysis to find general quantitative scale to inspect relationships between two not applicable and highly applicable tools using SPSS 18 software. After analyzed through multidimensional unfolding test, the order of proximities between not applicable and highly applicable tools have transformed their values from original one to proportional one by converging 368 iterations, with a final penalized stress of .0000997.

To describe the adaptability of different QT&T in various organizations, shepard plot was used. Shepard plot is a scatter plot of input proximities against output distances for every pair of items scaled. The variation coefficient and Shepard's index are sufficiently low and DeSarbo's indices are sufficiently large as shown in table 6.16. Iteration tables 6.14 to 6.15 evaluate stress part between not applicable (horizontal axis) and highly applicable (vertical axis) dimensional categories donated by shepard plot as illustrated in figure 6.5.

- Toward the bottom of the vertical axis categorizations plotted by lines (15, 12 and 18) that restrict performance of other intermediate categorizations donated by lines (6, 14 and 10) pulled down the vertical axis results in transitional adaptability of these categorizations.
- Toward the top of the vertical axis categorizations plotted by lines (3, 9 and 16) that restrict performance of other less dominant categorizations donated by lines (1, 2,4,5,7,13 and 11) pulled up the vertical axis results in fewer adaptability of these categorizations.

Table 6.14: Iteration values for not applicable and highly applicable tools

Iteration	Penalized stress	Difference	Stress	Penalty
0	.8630457	0	.1994998	3.7335771
386	.0000997	0000019	.0000000	2.7878634

Table 6.15: Row coordinates between two dimensions

Categories	**Dimension 1 (horizontal axis) (Not applicable tools)**	**Dimension 2 (vertical axis) (Highly applicable tools)**
Basic quality tools (7BT)	-.007	-1.538
Management tools (7MT)	.574	.577
Problem solving tools (PST)	.574	.577
Software tools (SWT)	.574	.577
Statistical tools (ST)	.574	.577
Graphical tools (GT)	.574	.577
New product development tools (NPDT)	.574	.577
Decision making tools (DMT)	1.024	-1.38
Productivity tools (PT)	.837	-.261
Assessment/analysis tools (AT)	.574	.577
Combinational tools (CT)	-1.82	-.785
Relationship tools (RT)	-.007	-1.536
Lean tools (LT)	-.007	-1.536
Communicational tools (CMT)	.145	1.323
Motivational tools (MOT)	.837	-.261
Performance measurement tools (PMT)	.574	.577

Table 6.16: Measure values for not applicable and highly applicable tools

Iterations		386
Final Function Value		.0000997
Function Value	**Stress Part**	.0000000
Parts	**Penalty Part**	2.7878634
Badness of Fit	**Normalized Stress**	.0000000
	Kruskal's Stress-I	.0000000
	Kruskal's Stress-II	.0000000
	Young's S-Stress-I	.0000000
	Young's S-Stress-II	.0000000
Goodness of Fit	**Dispersion Accounted For**	1.0000000
	Variance Accounted For	1.0000000
	Recovered Preference Orders	.9625000
	Spearman's Rho	.9889223
	Kendall's Tau-b	.9775489
Variation Coefficients	**Variation Proximities**	.7781195
	Variation Transformed Proximities	.6526165
	Variation Distances	.5929184
Degeneracy Indices	**Sum-of-Squares of DeSarbo's Inter mixedness Indices**	2.4719183
	Shepard's Rough Non degeneracy Index	.8687500

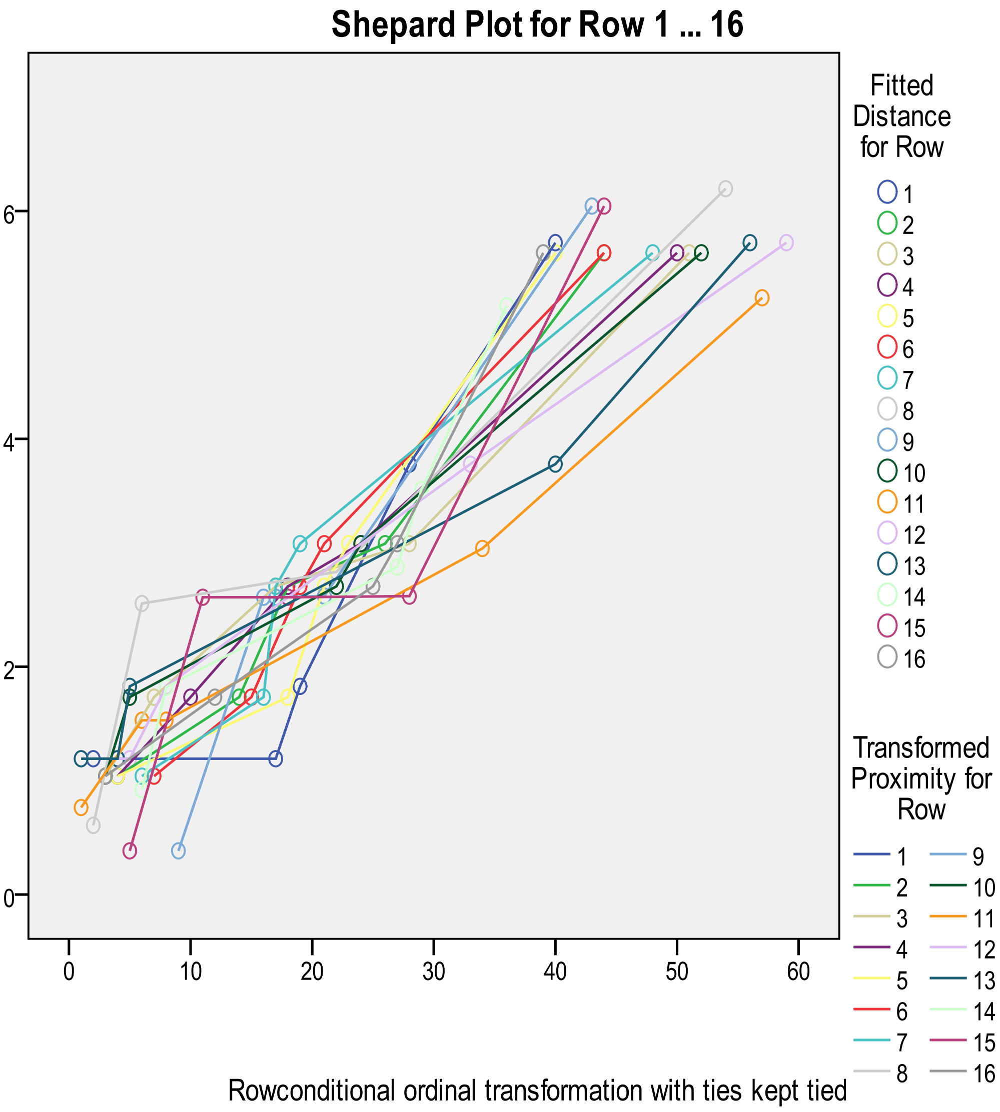


Figure 6.5: (Shepard plot) distinguished applicability of QT&T categories based on the extent of adoption

Thus, it is evident that the categorizations plotted by lines (3, 9, and 16) in proximity row signify more dominant characteristic towards manufacturing and service organizations and hence lead the other categories as illustrated by shepard plot. However large no of organizations (59.43 percent) were non implementers and noticed certain challenges to diminish this gap, these were lack of knowledge (49.20 percent), lack of training (14.28 percent), lack of resources (7.93 percent), financial constraints (11.11 percent) and communication gap about (17.46 percent). The results proved that there were still assorted regions in manufacturing and service organizations that can yield every anticipated QT&T adoption in particular organization.

On the other hand, it is suggested that advance pragmatic investigations should exercise with new categorizations that lead to exemplified larger sample of organizations in order to attain performance and efficiency. This impending research helps to look up the survey data by means of additional methods like case study & longitudinal data to offer further in depth proportional insights to investigate the adaptability of QT&T.

6.5 CONCLUDING REMARKS

- The outcome of the research discloses subsequent insight through the implementation status and adaptability of various QT&T in manufacturing and service organizations.
- The purpose of this survey research is to scrutinize different categories of QT&T and to examine the level of adoption, applicability, benefits and challenges faced by various organizations in NCR region India.
- This chapter acknowledged the applicability of 152 different QT&T into 16 groups to drawn out foremost relationships in terms of implementation status, frequency of non-implementers and benefits of various QT&T categories in both organizations.
- Categories like problem solving tools, productivity tools and performance measurement tools retain to be most dominant for improving efficiency of organizations contributed by transformational shepard plot.

CHAPTER VII

ANALYSIS AND COMPARISON OF DOMINATING CATEGORIES

7.1 INTRODUCTION

Imminent versatility in products and services maintain to develop an intense competition between manufacturing and service organizations for satisfying customer demands in nationwide and worldwide market. The introductory perspective of an organization includes product identification and requirement in terms of design, operation and outcomes. Therefore, organizations (manufacturing and service) needs to improve the quality of their products and services continuously by enfold their policies in more appropriate manner for achieving output. Consequently, all organizations desire to improve the quality of their products and services to meet ever increasing customer demands. In particular, organizations must adopt certain innovative strategies and tasks for improving performance (Monteiro et al., 2017). Thus organizations must employ various development and performance techniques to suppress research activity.

Hence the real characteristics assessment of the products can be evaluated by quality perspective (Vališ et al., 2012; Galar et al., 2012). In current scenario, manufacturing organizations are considered to produce solid products whereas service organizations transform input plan into an output one in form of service. Manufacturing organizations plays a vital role to elevate the values and overall development of the products with absolute accuracy. The primary constraint of any product life cycle is to identify customer demands and addressed them in terms of design to end up with completed product or an afford service (Nobelius and Trygg, 2002; Akroush, 2012; Schöggl et al., 2017). Any product confirmed to be established if it satisfies the manufacturer's technical requirements. To accomplish competitiveness as well as responsiveness manufacturing organizations evolves feasible administration of resources and operations that has been visualized by indispensable module of the organization.

However, service organizations discovered optimum solutions to surmount quality by analyzing their requirements on an incessant manner. In other words, organizations like healthcare, hospitality, banking, insurance and tele-communication etc. contributed to endorse constant improvement in quality that focused on new strategies and outcomes concerned with upcoming demands of future. Therefore, manufacturing and service organizations must adopt assorted techniques to sustain latest technologies and provide best possible outcomes in terms of products and services for satisfying customer demands.

7.2 IMPLEMENTATION STATUS OF QT&T IN MANUFACTURING & SERVICE ORGANIZATIONS

In recent scenario, organizations ought to implement distinctive QT&T (quality tools and techniques) for achieving desired outcomes to ensure quality. Hence QT&T emphasized more on quality by improving performance of products, processes and services of the organizations by identifying gaps between them. Each QT&T have diversified apparent effect on every organization which results increase in productivity by minimal cost investment. Previous surveys on QT&T in manufacturing and service organizations analyzed sixteen different categories based on questionnaire analysis. After going through comprehensive survey study, categories such as problem solving tools, productivity tools and performance measurement tools preserve to be the most leading categorizations for improving efficiency of the organizations *(Sharma et al., 2020)*. Figure 7.1 illustrates the implementation status of various QT&T in manufacturing and service organizations based on adaptability of usage.

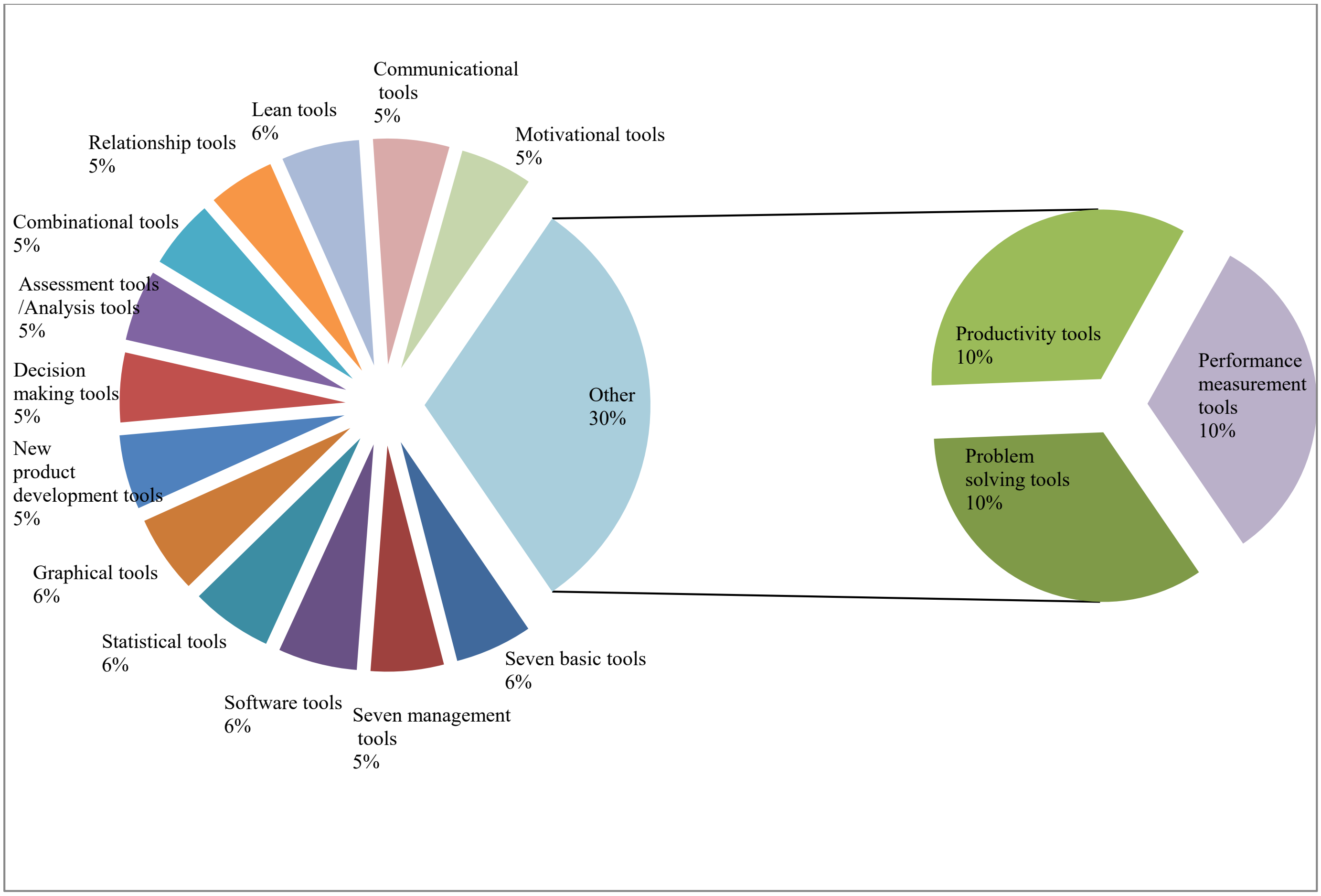


Figure 7.1: Implementation status of various QT&T categories in different organizations

From pie-chart analysis, it was clearly understood that 30% of the total contributors retain to be the problem solving tools (PST), productivity tools (PT) and performance measurement tools (PMT) considered being the most dominating categories irrespective of the other categorizations.

Therefore, to have a deeper perspective for assessing and validating the survey results, an amended questionnaire consist of two parts was developed and sent to various organizations to know the intricacy of relationships and calculate the range for the assessment of QT&T in distinctive organizations. This amended questionnaire concerned with tools and techniques which fall under these dominating categorizations. To achieve this, the questionnaire survey analysis has been done in Indian manufacturing and service organizations located in nearby NCR region and industrial town bhiwadi (India). In order to accomplish the overall research aim, this chapter answers the following research questions:

*RQ1.*To identifies the foremost QT&T among these dominating categories.

*RQ2.*To builds up an assessment model for validating the current status of QT&T in manufacturing and service organizations.

The rest of the chapter has been planned as follows: Next section concerns about the survey framework of QT&T in the current scenario. The former research investigates only about the survey results of distinctive QT&T categorizations but not keen to focus upon the current status of QT&T in manufacturing and service organizations. Thus, the topical layout of QT&T in current scenario has been illustrated in figure 7.2.

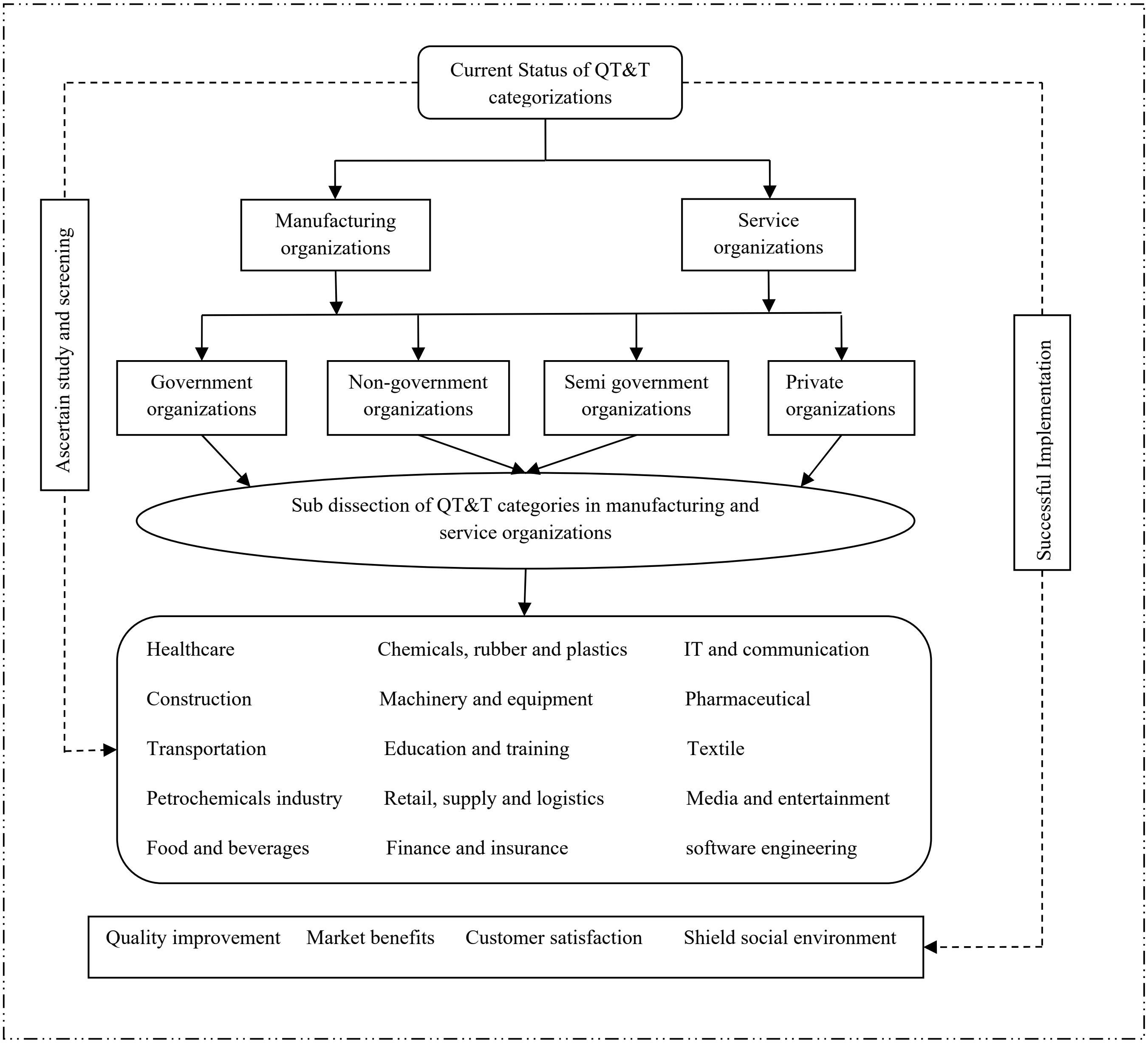


Figure 7.2: Hierarchy status of QT&T in organizations

7.3 ADMINISTRATION OF AMENDED SURVEY QUESTIONNAIRE

To attempt the aforementioned research questions, a survey was carried out in manufacturing and service organizations located in nearby NCR region and industrial town bhiwadi (India) by means of questionnaire method. The motive to prefer that regions is to provide the connectivity with multinational, regional, government and private organizations necessary for survey research. The information gathered from survey results provides in depth understanding of QT&T categorizations crucial for planning and further investigation of the research. For acknowledging the outcomes of the research, design of survey tool (questionnaire) is necessary

(Creswell, 2009; Welman, 2005). Therefore, detailed observation of survey report with respect to response rate and distribution of questionnaire has been discussed in next section of this chapter.

7.3.1 Questionnaire development

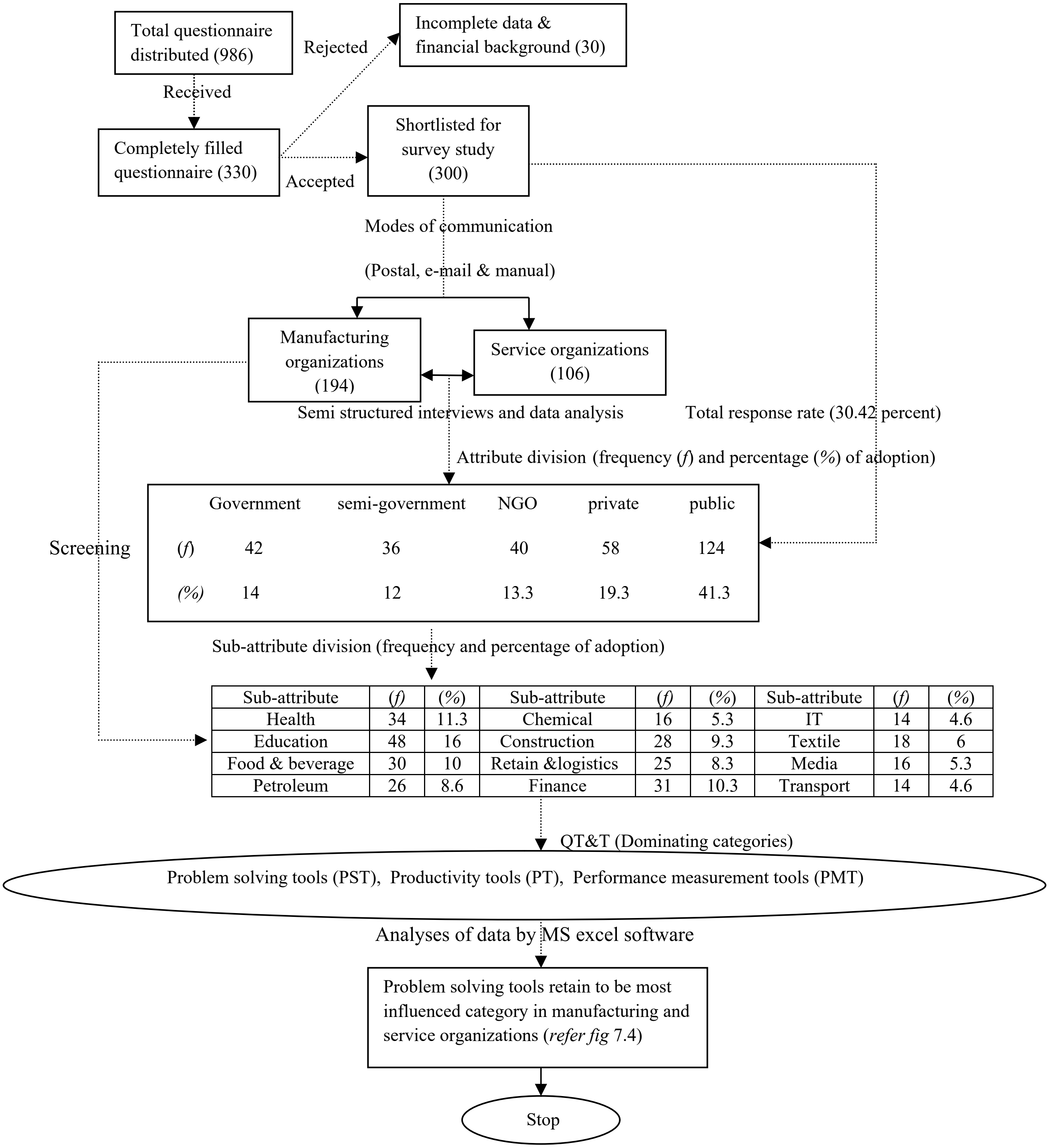
The survey questionnaire was designed to conquer gap in previous survey studies. Based on applications and existing literature outcome, this questionnaire was analyzed by number of professional academician, industrial experts and quality contributors to validate the survey results. After subsequent alterations and brainstorming, the amended questionnaire was obtained which consist of two parts:

- First part deals with demographical details of the organizations like type of organization (product based/service based), year of establishment, quality certification, no of employees and respondent information (name, valid phone number and e-mail address).
- Second part contained questions based on the following criteria:
  1) Extent of usage of QT&T in Organizations (Government, semi-government, private and public, large and SMEs, any industry)
  2) Stages of usage QT&T in organizations (Planning, production, post-production, general).
  3) Years of deploying QT&T (PST, PT, PMT) in organizations.
  4) QT&T training schedule (weekly/monthly/yearly).
  5) Impact on organizations. (Appendix-II)

The replies in the second part of the questionnaire would be analyzed by Likert scale having five-point scale division (1 = not employ, 2 = very little employ, 3 = little employ, 4 = moderate employ, 5 = highly employ).

7.3.2 Survey distribution and data acquisition

A total of 986 amended questionnaires were sent randomly in manufacturing and service organizations. The organizations with annual turnover ranging from than Rs. 500 crores to Rs. 1,200 crores were included to undertake survey outcomes. All possible modes of communications (postal, via-e-mail, fax or manually) have been employed to meet best responses. Out of 986 questionnaires, only 330 completely filled questionnaires were received. A total of 30 questionnaires were neglected based on incomplete data and financial background. Hence the proficient response rate for 300 organizations is 30.42 percent which is considered as high according to (Forza, 2009). The pictographic illustration in terms of distribution, data analysis and response rate for categorizations (PST, PT & PMT) have been discussed in flow chart as shown in figure 7.3.



	Government	semi-government	NGO	private	public
(*f*)	42	36	40	58	124
(*%*)	14	12	13.3	19.3	41.3

Sub-attribute	(*f*)	(*%*)	Sub-attribute	(*f*)	(*%*)	Sub-attribute	(*f*)	(*%*)
Health	34	11.3	Chemical	16	5.3	IT	14	4.6
Education	48	16	Construction	28	9.3	Textile	18	6
Food & beverage	30	10	Retain &logistics	25	8.3	Media	16	5.3
Petroleum	26	8.6	Finance	31	10.3	Transport	14	4.6

Figure 7.3: Flow diagram for survey questionnaire analysis

By going through both parts of questionnaire (I&II) and survey reports, the author has built an obvious perception for the implementation of different quality tools and techniques in manufacturing and service organizations. This section primarily shows the percentage wise break up of every categorization on particular organization. Figure 7.4 describes the survey data comparison of PST, PT & PMT categories based on extent of usage and impact on organizations. From the figure, it was clearly observed that problem solving tools sustained to be the most leading category with (33.04) percent contribution irrespective of productivity tools with (17.69) percent and performance measurement tools (13.61) percent. Figure 7.4 depicts the comparison of PST, PT & PMT in various organizations.

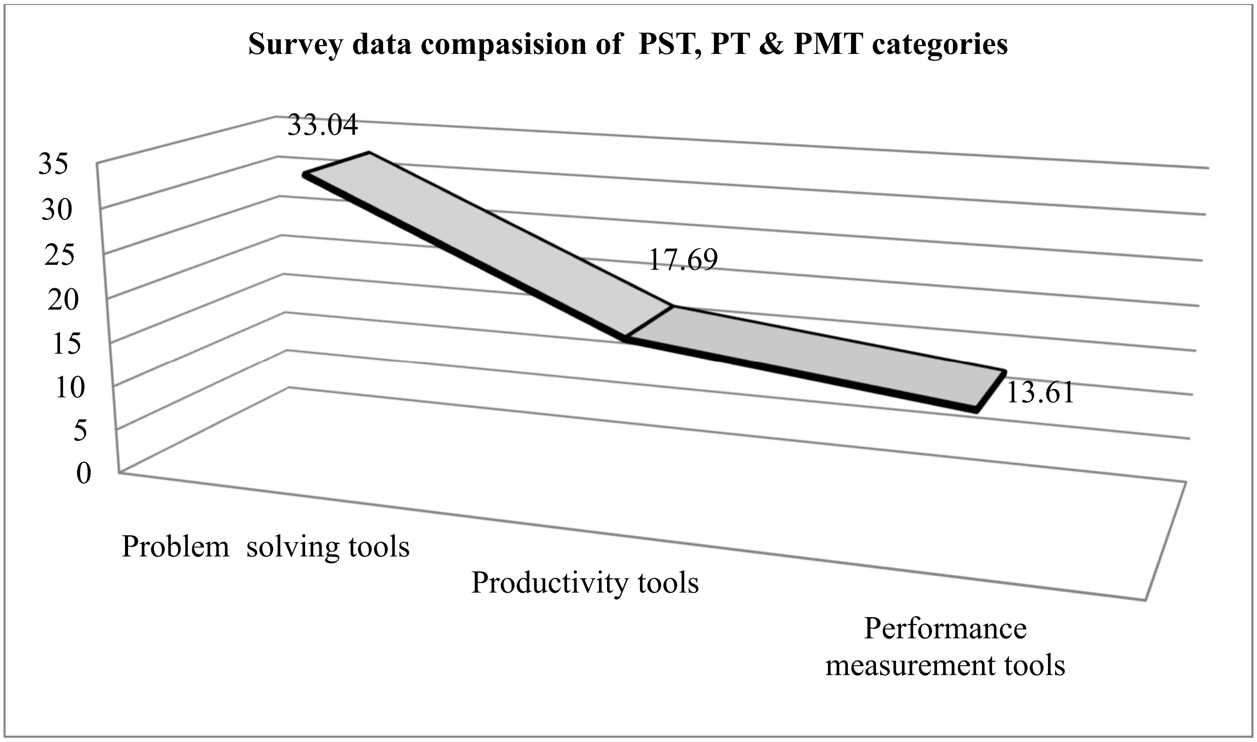


Figure 7.4: Percentage wise comparison of PST, PT, PMT categories

The next section illustrates the first research question of the survey analysis to determine the role of individual QT&T in manufacturing and service organizations.

*RQ1.*To identifies the foremost QT&T among these dominating categories.

The no of organizations examined in study have been classified into manufacturing (194) and service (106) organizations. The total contribution exhibited individually by these organizations were 64.66 percent & 35.33 percent respectively.

Figures 7.5 to 7.7 represent the individual contribution of particular QT&T which fall under these dominating categories (PST, PT & PMT). The next section describes the influence of particular QT&T in manufacturing and service organizations.

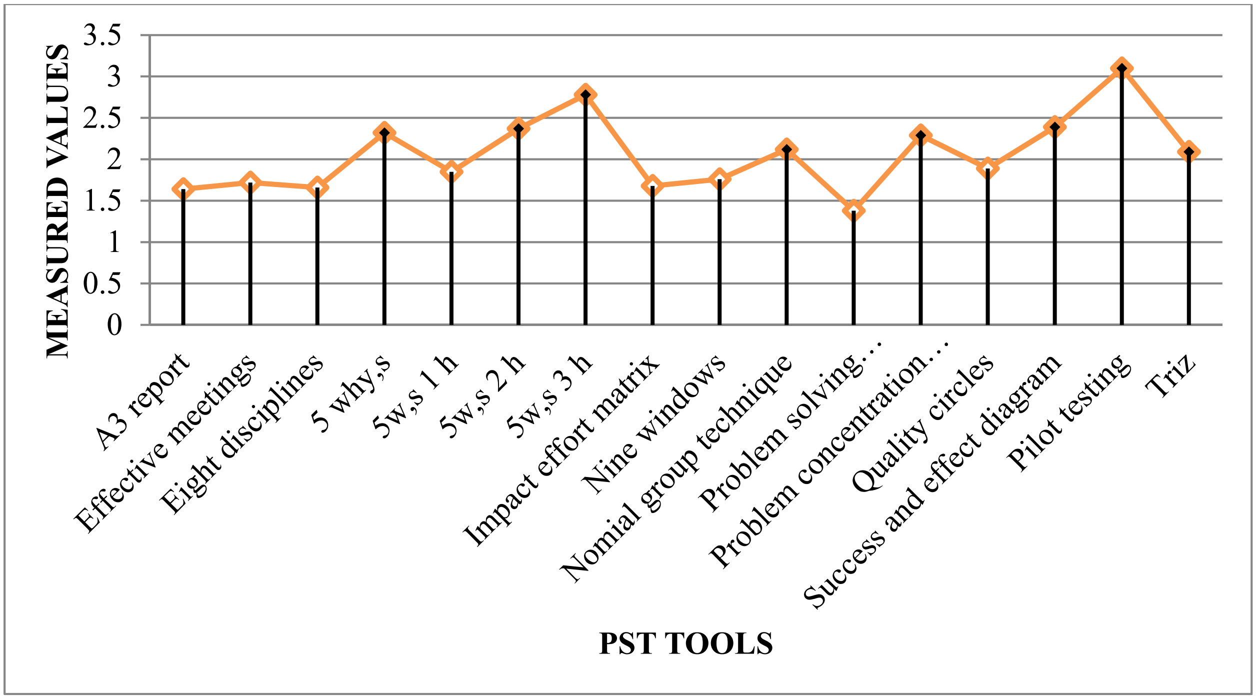


Figure 7.5: Percentage wise comparison of PST category

Figure 7.5 donates the contribution of eight foremost QT&T viz: 5 why's, 5 why's 2h, 5 why's 3h, nominal group technology, problem concentration diagram, success and effect diagram, pilot testing and triz. The average contribution of these QT&T governs the rest of tools which fall under PST category. All leading QT&T donates 2 percent or above contribution of survey response for finding the accessibility of particular QT&T in manufacturing and service organizations.

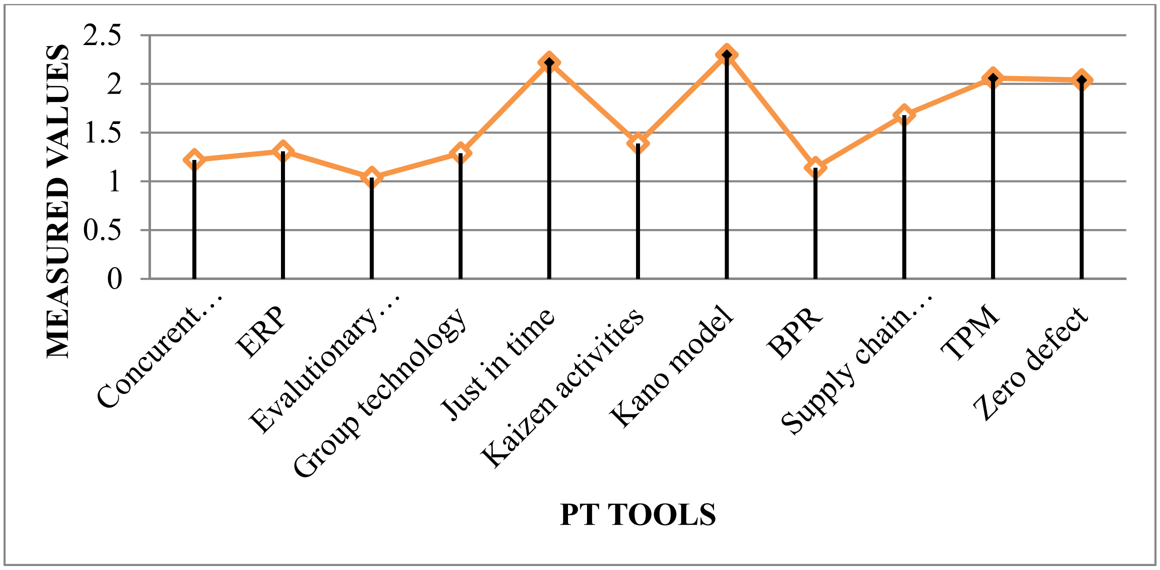


Figure 7.6: Percentage wise comparison of PT category

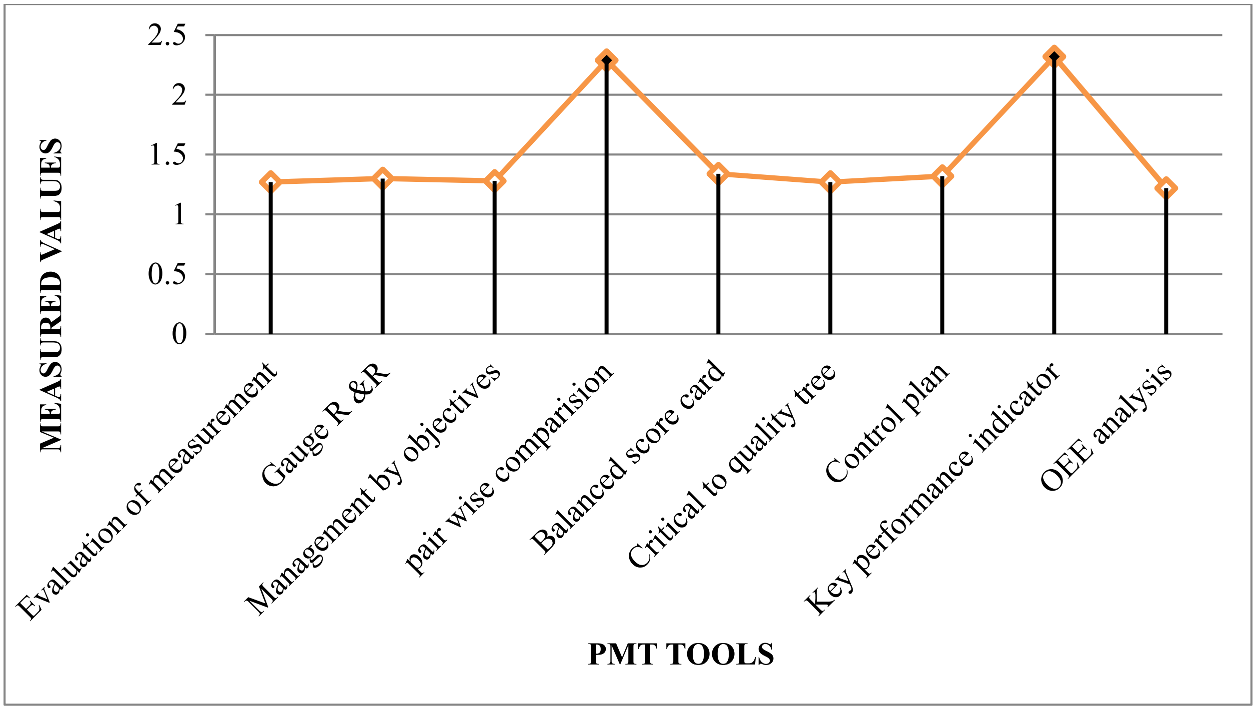
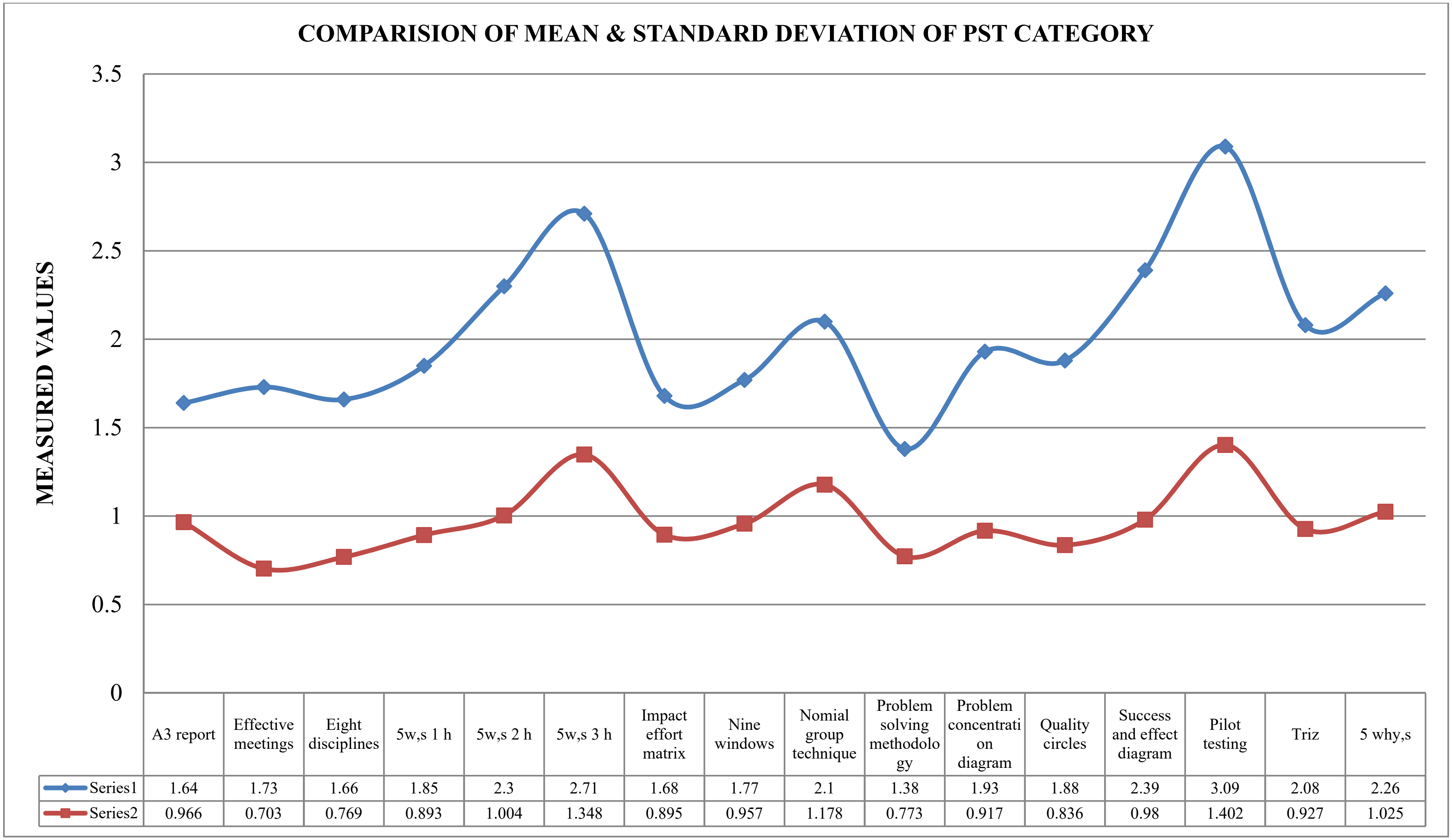


Figure 7.7: Percentage wise comparison of PMT category

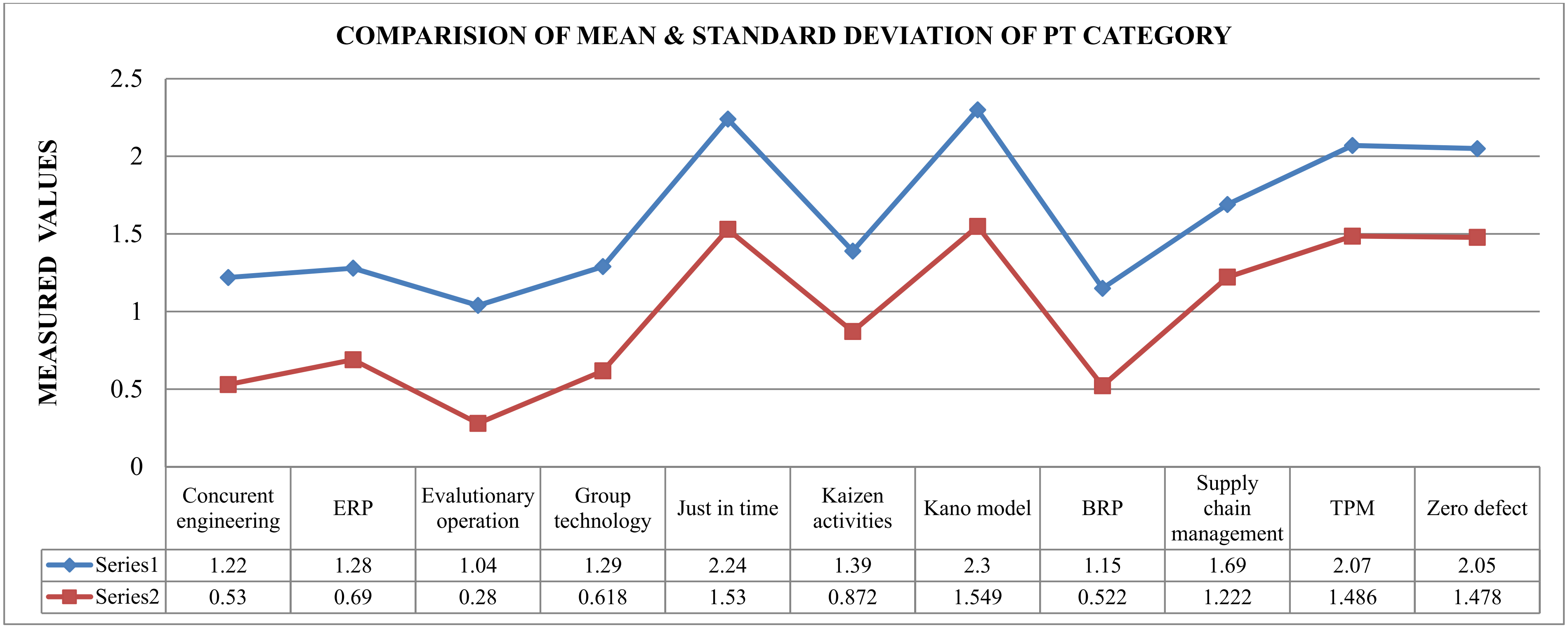
Similarly figures 7.6 & 7.7 represent the contribution of PT and PMT categories. From the above mentioned figures, it has been understood that four prime QT&T like: Just in time, kano model, TPM and zero defect donates the overall contribution of 2 percent or above followed by other QT&T fall under PT category. Moreover, PMT category also contributes two major QT&T i.e key performance indicator and pair wise comparison which further helps to assessed model for validation of QT&T in manufacturing and service organizations.

The statistical package for social sciences (SPSS version 20) has been used for data processing and survey analysis. A summary of total influenced mean (m) along with standard deviation (σ) for principal categories (PST, PT, and PMT) have been evaluated. According to (Sharma et al., 2017), PST category donate 16 tools, PT category offer 11 tools whereas PMT category carried out 9 tools. It was originated that average mean possess by PST category becomes 32.45 and standard deviation 15.57. Likewise PT category contributed (m=17.72; σ =10.77) and PMT category offer (m=13.64; σ =7.651) values for the extent of usage and impact on organization in both manufacturing and service sector. The mean and standard deviation graph for PST, PT and PMT categories has been described in figures from 7. 8 - 7.10.



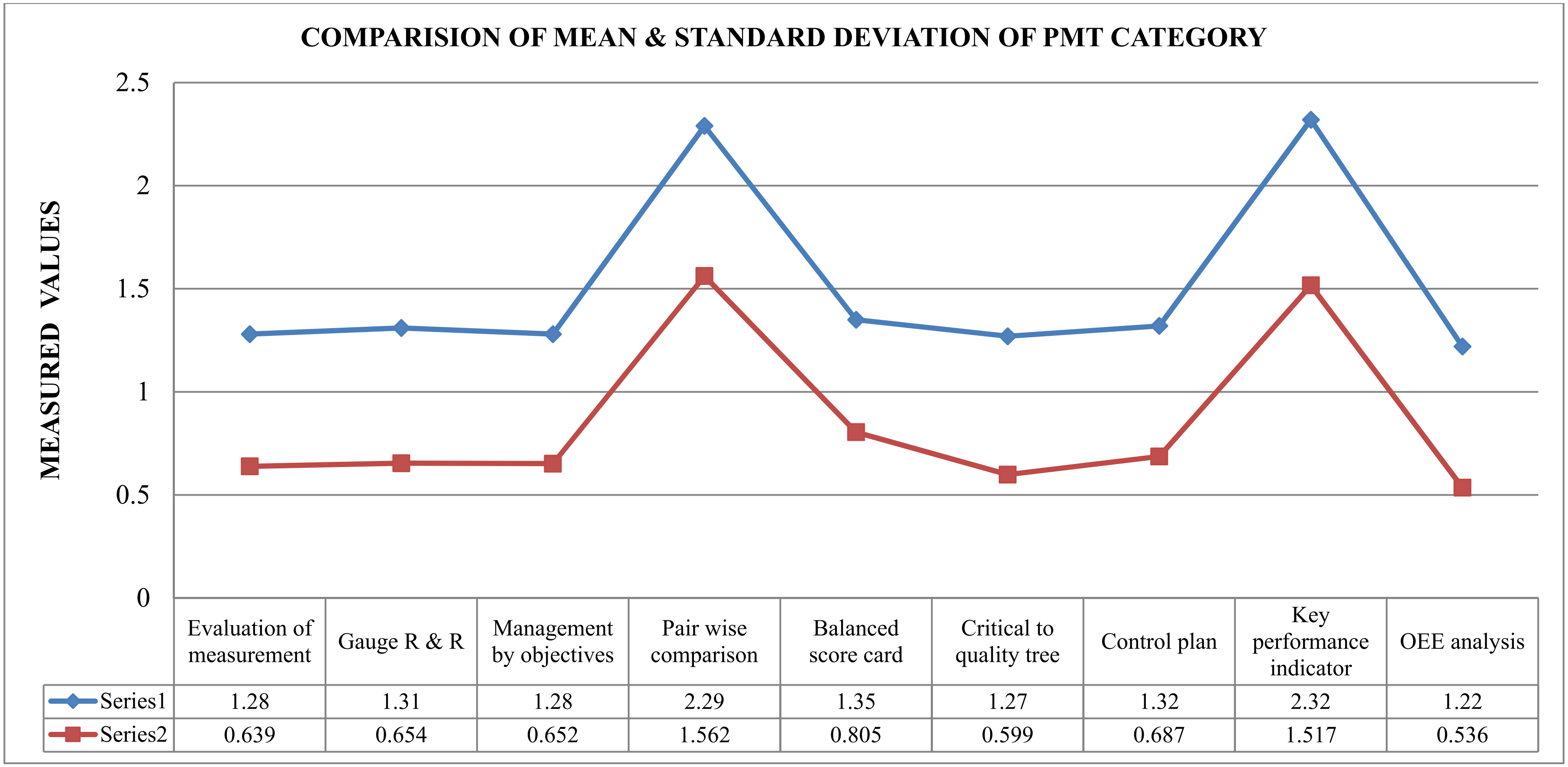
	A3 report	Effective meetings	Eight disciplines	5w,s 1 h	5w,s 2 h	5w,s 3 h	Impact effort matrix	Nine windows	Nomial group technique	Problem solving methodology	Problem concentration diagram	Quality circles	Success and effect diagram	Pilot testing	Triz	5 why,s
Series1	1.64	1.73	1.66	1.85	2.3	2.71	1.68	1.77	2.1	1.38	1.93	1.88	2.39	3.09	2.08	2.26
Series2	0.966	0.703	0.769	0.893	1.004	1.348	0.895	0.957	1.178	0.773	0.917	0.836	0.98	1.402	0.927	1.025

Figure 7.8: Comparison of mean & standard deviation of PST category



	Concurent engineering	ERP	Evalutionary operation	Group technology	Just in time	Kaizen activities	Kano model	BRP	Supply chain management	TPM	Zero defect
Series1	1.22	1.28	1.04	1.29	2.24	1.39	2.3	1.15	1.69	2.07	2.05
Series2	0.53	0.69	0.28	0.618	1.53	0.872	1.549	0.522	1.222	1.486	1.478

Figure 7.9: Comparison of mean & standard deviation of PT category



	Evaluation of measurement	Gauge R & R	Management by objectives	Pair wise comparison	Balanced score card	Critical to quality tree	Control plan	Key performance indicator	OEE analysis
Series1	1.28	1.31	1.28	2.29	1.35	1.27	1.32	2.32	1.22
Series2	0.639	0.654	0.652	1.562	0.805	0.599	0.687	1.517	0.536

Figure 7.10: Comparison of mean & standard deviation of PMT category

The above graphs show the respective values of mean (series 1) and standard deviation (series 2) for three prominent categories. Further, the analysis for determine the two-tailed significance values for all categorizations have been done by Tukney's test for non-additivity. It is also named (two-way Anova), assists to compute regression analysis of variables related to probable values of the responses. The significance values of all categorizations should be less than or equal to 0.05. Tables 7.1-7.3 exemplify the values of non-additivity along with the two-tailed significance no in organizations.

<table>
<tr><th colspan="8">ANOVA with Friedman's Test and Tukey's Test for Nonadditivity</th></tr>
<tr><th colspan="3"></th><th>Sum of Squares</th><th>df</th><th>Mean Square</th><th>Friedman's Chi-Square</th><th>Sig</th></tr>
<tr><td colspan="3">Between People</td><td>370.792</td><td>299</td><td>1.240</td><td></td><td></td></tr>
<tr><td rowspan="5">Within People</td><td colspan="2">Between Items</td><td>876.277</td><td>15</td><td>58.418</td><td>60.526</td><td>.000</td></tr>
<tr><td rowspan="3">Residual</td><td>Nonadditivity</td><td>62.202^a</td><td>1</td><td>62.202</td><td>65.370</td><td>.000</td></tr>
<tr><td>Balance</td><td>4266.647</td><td>4484</td><td>.952</td><td></td><td></td></tr>
<tr><td>Total</td><td>4328.848</td><td>4485</td><td>.965</td><td></td><td></td></tr>
<tr><td colspan="2">Total</td><td>5205.125</td><td>4500</td><td>1.157</td><td></td><td></td></tr>
<tr><td colspan="3">Total</td><td>5575.917</td><td>4799</td><td>1.162</td><td></td><td></td></tr>
<tr><td colspan="8">Grand Mean = 2.03</td></tr>
<tr><td colspan="8">a. Tukey's estimate of power to which observations must be raised to achieve additivity = -.945.</td></tr>
</table>

Table 7.1: Comparison of mean squares between problem solving tools (PST)

<table>
<tr><th colspan="8">ANOVA with Friedman's Test and Tukey's Test for Nonadditivity</th></tr>
<tr><th colspan="3"></th><th>Sum of Squares</th><th>df</th><th>Mean Square</th><th>Friedman's Chi-Square</th><th>Sig</th></tr>
<tr><td colspan="3">Between People</td><td>711.135</td><td>299</td><td>2.378</td><td></td><td></td></tr>
<tr><td rowspan="5">Within People</td><td colspan="2">Between Items</td><td>669.314</td><td>10</td><td>66.931</td><td>63.735</td><td>.000</td></tr>
<tr><td rowspan="3">Residual</td><td>Nonadditivity</td><td>419.915^a</td><td>1</td><td>419.915</td><td>461.436</td><td>.000</td></tr>
<tr><td>Balance</td><td>2720.043</td><td>2989</td><td>.910</td><td></td><td></td></tr>
<tr><td>Total</td><td>3139.959</td><td>2990</td><td>1.050</td><td></td><td></td></tr>
<tr><td colspan="2">Total</td><td>3809.273</td><td>3000</td><td>1.270</td><td></td><td></td></tr>
<tr><td colspan="3">Total</td><td>4520.407</td><td>3299</td><td>1.370</td><td></td><td></td></tr>
<tr><td colspan="8">Grand Mean = 1.61</td></tr>
<tr><td colspan="8">a. Tukey's estimate of power to which observations must be raised to achieve additivity = -1.749.</td></tr>
</table>

Table 7.2: Comparison of mean squares between problem solving tools (PT)

ANOVA with Friedman's Test and Tukey's Test for Nonadditivity

			Sum of Squares	df	Mean Square	Friedman's Chi-Square	Sig
Between People			778.569	299	2.604		
Within People	Between Items		485.807	8	60.726	94.080	.000
	Residual	Nonadditivity	276.010[a]	1	276.010	520.474	.000
		Balance	1267.961	2391	.530		
		Total	1543.971	2392	.645		
	Total		2029.778	2400	.846		
Total			2808.347	2699	1.041		

Grand Mean = 1.52

a. Tukey's estimate of power to which observations must be raised to achieve additivity = -1.127.

Table 7.3: Comparison of mean squares between problem solving tools (PMT)

The comparative analysis of PST, PT & PMT categories through Tukney's test gives an obvious perception for the implementation and existence of QT&T in manufacturing and service organizations. Tables 7.1-7.3 depict the values of mean squares between and within the organizations stipulated for finding the significance of foremost category. The hypothesis value ($P<0.05$) is considered significant and has been used to analyze data. For values less than or equal to 0.05 becomes accepted otherwise rejected. Descriptive Tukney's test for non-additivity has been employed to accomplish the fundamental objectives of the research. The two-tailed significance no provides a valuable insight for the acceptance of leading category participated in survey research. Investigation so far reveals that the significance level for all three prominent categories (PST, PT & PMT) falls within the normal range. Therefore, further exploration for evaluating QT&T model has been validated by considering the values of Cronbach's α for all dominating categories.

According to Nunnally (1978) the value of Cronbach's α should be greater than 0.7. The extracted values of Cronbach's α for PMT, PST & PT categories are found to be 0.75, 0.22 and 0.58 respectively. Therefore, above analysis revels that PMT category in table 7.4 matches the desired P value and thus allows the researchers to narrow research area around PMT category rather assessing both PST and PT categories. The next section deals with the validation of PMT category by factor analysis method.

*RQ2.*To builds up an assessment model for validating the current status of QT&T in manufacturing and service organizations.

To assess the model for validating PMT category, Exploratory Factor Analysis (EFA) along with Confirmatory factor analysis (CFA) has been done. In EFA the scrutiny of factors has been made by performing two tests in SPSS 20 software; Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of Sphericity. According to Kaiser (1974) the value of KMO lies between 0.5 and 1.0 used to describe the suitability of factors in PMT category.

On the other side, Bartlett's test of Sphericity is employed to measure the significance level between the variables. Significance values less than 0.05 was considered important and values more than 0.10 indicates that data is not suitable for factor analysis (Prasad et al. 2010). In addition, the value of Cronbach's α has been calculated for checking the reliability of QT&T's category (PMT) along with the analysis of communalities. Smaller values of communalities i.e (<0.5) in extraction column describe the inability of variable to not fit well in factor solution and higher value of communalities i.e (>0.5 to 1) donates the extraction of principal variables to fit optimum for factor estimation. To show the relevance of Exploratory Factor Analysis (EFA) following steps have been adopted to conquer the desired results:

- PMT category involves 09 distinctive QT&T. The sample data of total 300 manufacturing and service organizations have been analyzed by using SPSS 20 software to explicit desired outcomes.
- Reliability test has been carried out to check the internal consistency of QT&T category by identifying Cronbach's α. The value of Cronbach's α for PMT category is found to be 0.75 considered appropriate for further analysis of data. Table 7.4 identifies case processing summary of PMT category along with the extracted value of Cronbach's α.
- The observed values obtained from Kaiser-Meyer-Olkin (KMO) and Bartlett's tests of Sphericity (chi square value) were 0.800 and 643.308 respectively. The derived values shown in table 7.5 prove to be suitable for factor analysis after comparing with standard KMO and chi square values.
- Table 7.6-7.7 depicts the extraction of component analysis (communalities) and total variance explained. The values greater than 0.5 have been chosen or else rejected.
- Figure 7.11 provides valuable insight to differentiate 9 communalities into 3 PMT component factors (PMT 1, PMT 2 & PMT 3) with eigen values as shown in scree plot.
- Three component factors have been extracted as described in table 7.8.
- Component matrix with Varimax rotation has been evaluated along with Kaiser Normalization value which restricts matrix values greater than 0.7 as described in table 7.9.
- Finally, three components have been extricated after Varimax rotation and Kaiser Normalization. No further analysis has been needed.

- From the above analysis, it is revealed that foremost category (PMT) becomes splinted into three principal components/factors i.e. PMT 1, PMT 2 and PMT 3.
- The three principal components PMT 1, PMT 2 & PMT 3 and their respective QT&T for further analyzed to validate the model.
- By identifying three extracted factors through EFA, the foremost results have been processed for validation by CFA using AMOS software as shown in figure 7.12. After being analyzed by AMOS 18 software the measured values EFA and CFA to fit the existing model becomes: Model Chi Square ($\chi 2$) =178.732; DF=79 Cmin $/DF(\frac{\chi 2}{DF})$ = 1.8826; p=.000 absolute fit indices (Goodness-of-Fit Statistic (GFI)= 0.936; Adjusted Goodness-of-Fit Statistic (AGFI) =0.907; Root Mean Square Residual (RMR)=0.003; Weighted root mean residual (WRMR)=0.86; Root Mean Square Error of Approximation (RMSEA)=.075 and values for incremental Fit Indices were (Normed-Fit Index (NFI)=0.905; Comparative Fit Index (CFI)=0.926; Incremental Fit Index (IFI)=0.928; Tucker-Lewis index (TLI)=0.907 .

Reliability Statistics and Case Processing Summary		
Cronbach's α.	Cronbach's α. Based on Standardized Items	N of Items
0.752	0.793	9
	N	%
Cases Valid Excluded^a Total	300 0 300	100 0 100

Table 7.4: Reliability Statistics of PMT category

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.800
Bartlett's Test of Sphericity	Approx. Chi-Square	643.308
	df	36
	Sig.	.000

Table 7.5: KMO and Bartlett's Test of PMT category

Communalities		
	Initial	Extraction
Evaluation of measurement	1.000	.505
Gauge R & R	1.000	.524
Management by objectives	1.000	.748
Pair wise comparison	1.000	.639
Balanced score card	1.000	.813
Critical to quality tree	1.000	.527
Control plan	1.000	.774
Key performance indicator	1.000	.531
OEE analysis	1.000	.747
Extraction Method: Principal Component Analysis.		

Table 7.6: Communalities of extraction of PMT category

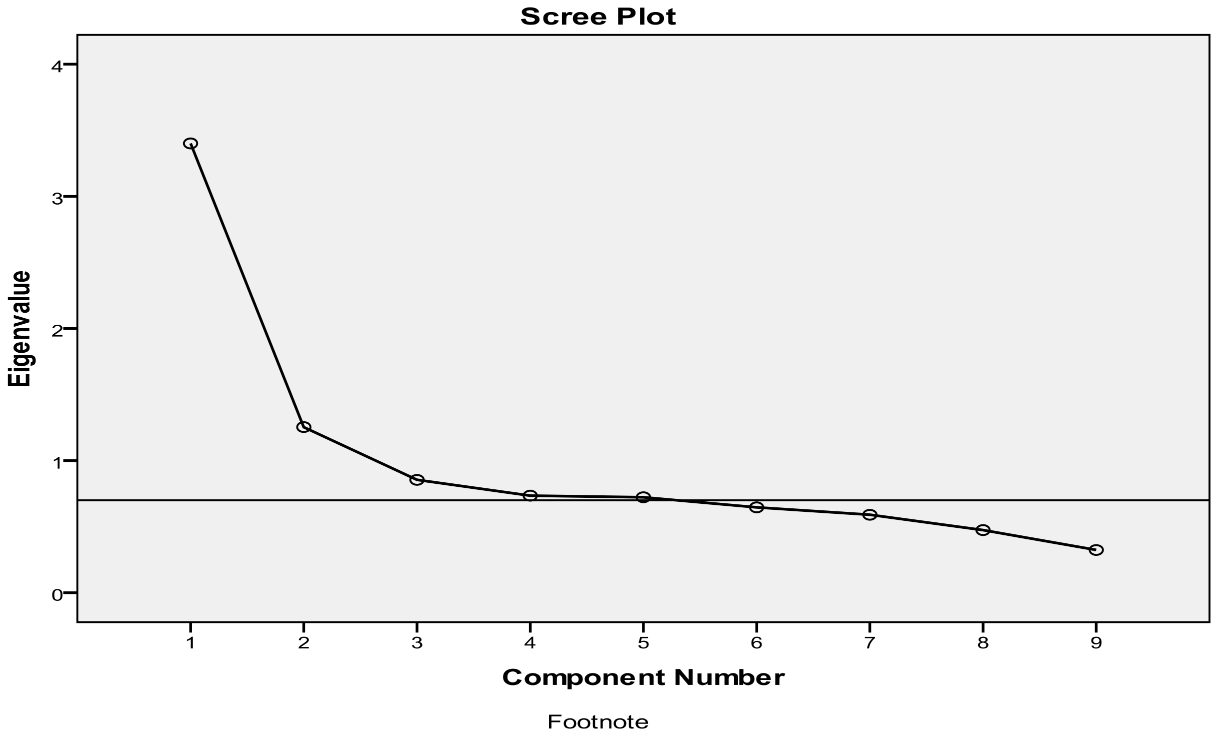


Figure 7.11: Scree plot of 3 principal components

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.401	37.784	37.784	3.401	37.784	37.784	2.220	24.668	24.668
2	1.254	13.933	51.717	1.254	13.933	51.717	1.729	19.212	43.880
3	.854	9.490	61.207	.854	9.490	61.207	1.559	17.327	61.207
4	.735	8.165	69.372						
5	.723	8.032	77.405						
6	.646	7.176	84.581						
7	.590	6.556	91.137						
8	.474	5.269	96.406						
9	.323	3.594	100.000						
Extraction Method: Principal Component Analysis.									

Table 7.7: Total variance of PMT category

Component Matrix[a]			
	Component		
	1	2	3
Pair wise comparison	.681		
Management by objectives	.632		
Balanced score card	.631	-.581	
Control plan	.627	-.578	
Critical to quality tree	.614		
Gauge R &R	.592	.411	
Evaluation of measurement	.592		
Key performance indicator	.577	.418	
OEE analysis	.579		.619
Extraction Method: Principal Component Analysis.			
a. 3 components extracted.			

Table 7.8: Component Matrix of PMT category

Rotated Component Matrix[a]			
	Component		
	1	2	3
Pair wise comparison	.771		
Key performance indicator	.718		
Gauge R & R	.667		
Evaluation of measurement	.641		
Management by objectives		.721	
Balanced score card		.873	
Control plan		.840	
OEE analysis			.732
Critical to quality tree			.644
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.			
a. Rotation converged in 4 iterations			

Table 7.9: Rotated Component Matrix of PMT category

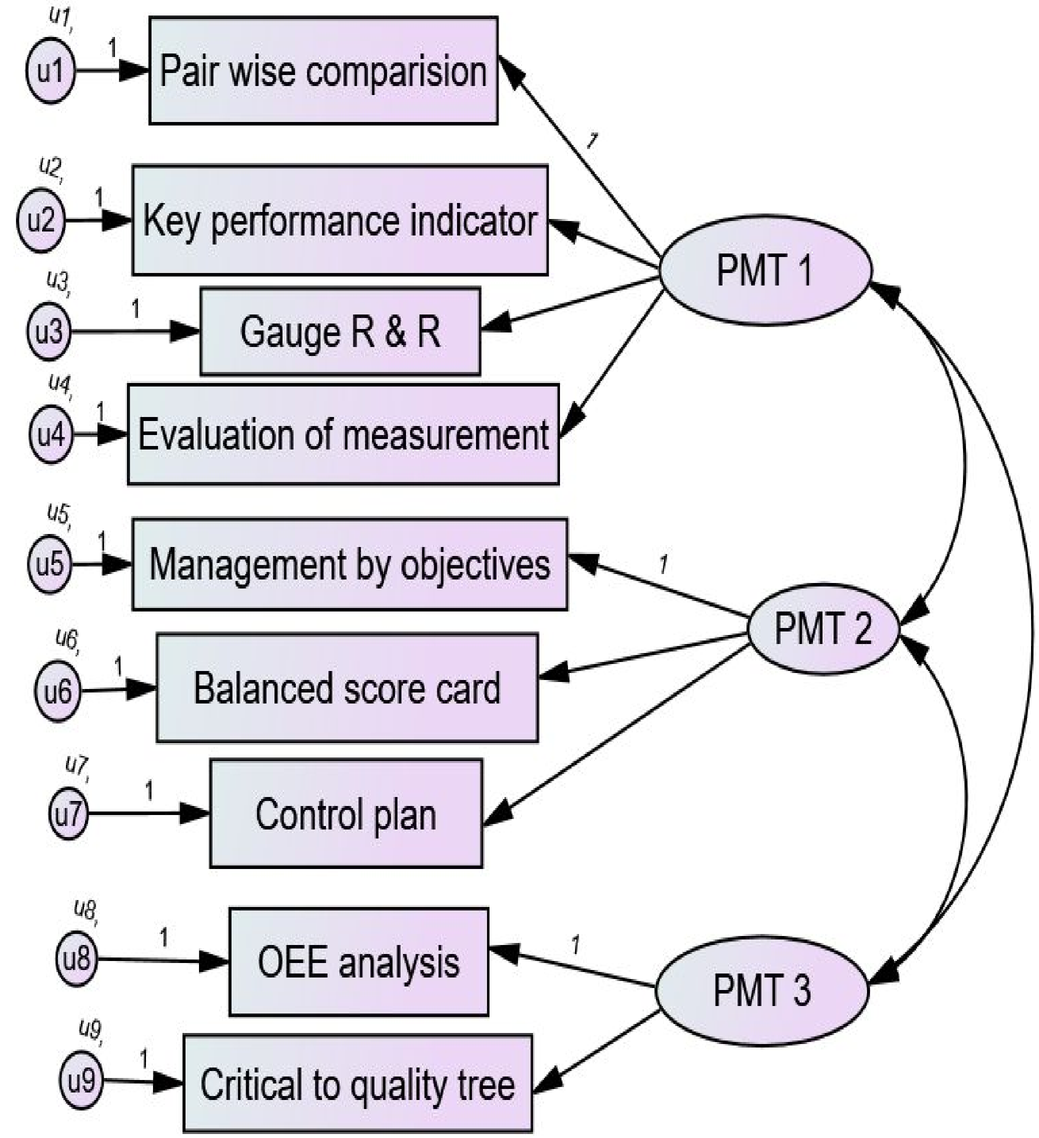


Figure 7.12: EFA model for 3 PMT components.

7.4: CONCLUDING REMARKS

- This chapter provides valuable insight for the contribution of PST, PT and PMT categories in manufacturing and service organizations. Out of 3 foremost categories, Performance measurement tools (PMT) preserves to be most prevailing category to discriminate QT&T in terms of implementation status and impact on the organizations.
- The survey-questionnaire method has been used to instigate the accessibility of PMT category in manufacturing and service organizations. Tukney's test for non-additivity becomes employed to undertake the significant nature of the particular categories.
- The value of Cronbach's α has been used to slender the research around PMT category.
- Exploratory factor analysis (EFA) has been deployed to carry out extracted components of PMT category.
- In the present analysis, usually 3 principal components (PMT 1, PMT 2, & PMT 3) have been extracted from rotated component matrix. Scree plot has been deployed to show the obscurity of PMT components in eigen value graph by Kaiser Normalization with varimax rotation.
- Variables with certain uniqueness have been drawn to know the interrelationships between the components and finally, analyses for the estimates and fit indices have been calculated to validate the proposed model for PMT category.

CHAPTER VIII

SUMMARY, LIMITATIONS AND SCOPE OF FUTURE RESEARCH

The key contribution of this research is to identify & scrutinized variety of QT&T into three foremost categories to develop an instructive quality framework for manufacturing organizations. Specifically, the proposed framework provides an elusive approach for the depiction & accomplishment of significant QT&T categories into five major streams of research : first stream of research involves the categorization of various QT&T into substantial groups; second stream begins with the contribution of MADM methodology for finding the effectiveness of QT&T categories in manufacturing organizations; third stream of research contributes to the identification & determination of assorted barriers liable to affect the utilization of various QT&T in manufacturing organizations; fourth stream deals with analysis of survey respondents by questionnaire method to know the intricacy of QT&T categories in manufacturing organizations and finally concluded stream donates the outcome of survey responses into well-developed structured QT&T model. This study provides a positive framework for the researchers to bridge the gap between organizations adopted distinctive QT&T.

8.1 SUMMARY OF WORK DONE

This section represents the work done in the direction of applications & effectiveness of quality tools and techniques in manufacturing organizations. The main intents of this research are as follows:

- Grounded in the literature and beliefs of various experts (industrial and academia), a total number of 152 distinctive QT&T were identified and categorized into 16 groups based on characteristics of applications.
- A widespread literature investigation was carried out in different manufacturing and service organizations to counteract the gaps/ restrictions incurred by various QT&T categories at successive stages of implementation in manufacturing organizations.
- By concluding the applications of 16 QT&T categories, an integrated methodology (GTA-AHP) has been adopted to measure the effectiveness of particular organization through single numerical index. This numerical index is useful for determining the permanent function of QT&T categories by establishing the comparison between various organizations with significant organization.

- After thorough analysis of literature background, barriers affecting the effective utilization of QT&T have been identified in manufacturing organizations. The present research attempts to scrutinize the identified QT&T barriers into well-developed integrated model.
- The proposed framework uses an integrated (ISM-MICMAC) methodology to rank the identified barriers associated with manufacturing organizations and calculates their effectiveness for the same by means of subtracting dependence power from driver power.
- Questionnaire based survey was adopted to narrow the gap and establish the relationship between different organizations successfully implemented QT&T.
- The administration of survey questionnaire leads to carry out by five different interpretations:
    - First and foremost, pilot survey was conducted to know the response rate and determine the direction of present search participated in survey study.
    - The developed questionnaire was distributed among various manufacturing and service organizations to determine the implementation status, level of awareness and impact on organization.
    - The response obtained from survey analysis reveals that out of 16 distinctive QT&T categories, only three dominating categories has been extracted after being investigated by SPSS statistical software.
    - The three foremost categories i.e. problem solving tools (PST); a productivity tools (PT) and performance measurement tools (PMT) implies the dominance of QT&T in manufacturing organizations.
    - The concluded survey results narrow the research area towards these three significant categories (PMT, PT & PST) to validate into QT&T model by means of amended questionnaire.
- SPSS statistical software incorporated with shepard plot have been utilized to recognize the dominance and assess the effect of QT&T in manufacturing organizations.
- Finally, structural equation modelling has been applied to convert three significant categories into three extracted factors. To validate the results and develop a successful model of QT&T: confirmatory factor analysis along with exploratory factor analysis has been used to validate theoretical model into well-structured framework.

The next section of this chapter deals with the major contribution of the present research fulfills to carry out various objectives of the study.

8.2 MAJOR CONTRIBUTION OF RESEARCH

The major contributions of research associated with present work are as follows:

- Literature emphasized that the present work provides an obvious perception for the utilization & implementation of various QT&T in manufacturing and service organizations. Although, it is obligatory to implicit the limitations and silent features of QT&T categories within the organizations.
- Sixteen categories incorporated with distinctive 152 QT&T have been identified and recommended particularly for manufacturing organizations.
- Classification of QT&T categories in on the basis of applications donated the adaptability of particular organization to encounter problems.
- An additional unique framework of methodology comprises with (GTA-AHP) approach has been utilized to carry out the effectiveness of QT&T categories in particular organization.
- The anticipated integrated methodology has provided an accurate approach to tackle all situations related to decision making in manufacturing organizations rather than using either GTA or AHP in isolation.
- Single numerical index has been developed to compare effectiveness of different manufacturing organizations.
- The key aspects associated with each QT&T have been recognized to distinguish the gaps and identify the barriers incurred in literature outcome.
- A brief overview of identified QT&T barriers associated with different stages of manufacturing organizations has been analyzed to developed ISM based quality model.
- Another integrated methodology consists of ISM-MICMAC approach have been adopted to counter effectiveness sustained by manufacturing organizations.
- Implementation status, frequency of non-implementers and benefits of various QT&T categories have been determined in manufacturing and service organizations.
- Categories such as: PMT, PT & PST for improving the efficiency of manufacturing organizations have been evaluated by transformational shepard plot.
- The accessibility of PMT category in manufacturing and service organizations incorporated with Tukney's test for non-additivity have been employed to undertake the significant nature of the particular categories.
- A unique comprehensive model consists of three prominent categories have been validated in manufacturing organizations by means of structural equation modelling.
- Variables with certain uniqueness have been extracted to know the interrelationships between significant QT&T categories and lastly, fit indices have been calculated to validate the proposed model for PMT category in manufacturing organizations.

8.3 IMPLICATIONS OF THE RESEARCH

The present research also offers some managerial implications that have been divided into two important aspects:

- Implications associated with academicians
- Implications associated with manager's/decision makers

The brief deliberation of implications associated with various academicians & managers are as follows:

8.3.1 Implications associated with academicians

- With the help of this study, academicians may know the intricacy of various gaps encountered with different areas of manufacturing organizations.
- The present study manages the academicians to differentiate various organizations that are not familiar with some tools and their associated values.
- Pilot survey together with development of amended questionnaire facilitates the academicians to deal with complex situations and tackle crisis associated with implementation of QT&T.
- Integrated (GTA-AHP) methodology assists the academicians to develop framework for understanding effectiveness of manufacturing organizations.
- ISM approach together with MICMAC analysis allows different academicians to visualize context relationships among various QT&T at different stages of production system.

8.3.2 Implications associated with manager's/decision makers

- Managers and decision makers from various areas of manufacturing insist serious efforts towards successful adoption and integration of developed methodologies for determining the impact of QT&T categories in varied organizations.
- Apart from identification of various barriers influencing QT&T categories corroborates various issues, concerns and roadblocks that need to be taken care of during implementation of QT&T.
- Validation of QT&T model by extracting foremost categories helps managers and decision makers to develop a structured model that fit in the standard values of CFA and EFA modelling analysis.

The next section describes the overall limitations of the present work along with scope of future research.

8.4 LIMITATIONS OF PROPOSED WORK

Although the present research offers the valuable insights for the use and adoption of distinctive QT&T categories in manufacturing organizations, it offers certain limitations that need to be interpreted with caution. The limitations of the present work are as follows:

- Exploratory survey of QT&T categories in different manufacturing organizations has been limited to NCR region (India). Hence vast survey brings some changes in usability status and adaptability of particular QT&T in varied organizations.
- The proposed integrated GTA-AHP methodology for evaluating the effectiveness of QT&T in manufacturing organization is new one and no work can be impeccable in this direction. Therefore, it represents some biasness to be offered by some researchers who applied distinctive new methodologies like VIKOR, PROMETHEE, DEMATEL and ELECTRE etc to formulate new outcomes.
- It insists relative importance and interconnection of different QT&T in broad manufacturing areas which requires the development of equation, pair wise comparison matrix and permanent function equation which becomes more difficult especially when categorization of QT&T are more and for this software need to be developed.
- More categorizations can be made with different tools and techniques to restrain this approach.
- Validation of barriers by Integrated ISM-MICMAC model has been limited to manufacturing only. Consequently, more barriers have been identified by considering service organizations for getting more informative results.
- The administration of survey questionnaire has been developed to narrow the research gap towards three prominent categories i.e PMT, PST and PT categories. For this reason, new statistical software (like STATA and Amos) has been used to validate the survey outcomes.
- The categories adopted for present study have been taken from past results and extensive literature survey. Thus it is difficult to compare QT&T constraints with earlier outcomes of the research.

8.5 SCOPE FOR FUTURE WORK

Following work may be carried out in future to extend the succession of present work. These are:

- It allows self-analysis, evaluation, implementation and comparison of manufacturing and service organizations.
- Mathematical analysis allows conversion of qualitative factors to quantitative values through systematic integrated approach which is relatively more ambient technique over conventional methods.
- This impending research helps to look up the survey data by means of additional methods like case study & longitudinal data to offer further in depth proportional insights to investigate the adaptability of QT&T.
- The current research has been limited to Indian manufacturing and service organizations, future research may be carried out on global platform.
- This research work developed an integrated ISM model that has not been statistically validated. So, in future, the developed model can be tested by LISREL software to validate and development of model.
- Advanced statistical software (like STATA and Amos) has been used to validate the survey results.
- Exploratory research should be conducted in other country for the validation of model in particular organization.

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[Appendix –I]

Questionnaire

Section A

1. Name of organization ……………………………
2. Year of Establishment: (tick appropriate column)

<5 years		>10 years but <15 years	
>5 years but <10 years		>15 years but <20 years	
20 years and above			

3. No of Employees and company size: (tick appropriate column)

Below 100 employees		Between 201 and 300 employees	
Between 101 and 200 employees		Between 301 and 400 employees	
Above 400 employees			

4. Quality certification: Does your organization have quality Certification:

YES	
NO	

Section B

Implementation status of the following QT&T in your organization

Please give response on the scale of 1 to 5 in the adjoining columns. (From very low to very high)

Scale:

1	Very Low
2	Low
3	Average
4	High
5	Very High

Sr no	QT&T Categories	Usage yes/ no	Level of awareness (1-5)	Impact on organization (1-5)	Effectiveness (1-5)	Remarks, if any
1	Basic quality tools (7BT)					
2	Management tools (7MT)					
3	Problem solving tools (PST)					
4	Software tools (SWT)					
5	Statistical tools (ST)					
6	Graphical tools (GT)					
7	New product development tools (NPDT)					
8	Decision making tools (DMT)					
9	Productivity tools (PT)					
10	Assessment/analysis tools (AT)					
11	Combinational tools (CT)					
12	Relationship tools (RT)					
13	Lean tools (LT)					
14	Communicational tools (CMT)					
15	Motivational tools (MOT)					
16	Performance measurement tools (PMT)					

Section C

Respondent information

- Name ……………
- Position in organization ………….
- Department ………………
- Year of serving ……………

[Appendix –II]

Questionnaire

Section A

3. Name of organization ……………………………
4. Type of organization: Product based/Service based. (Tick appropriate column)
5. Year of Establishment: (Tick appropriate column)

<5 years		>10 years but <15 years	
>5 years but <10 years		>15 years but <20 years	
21 years and above			

6. Quality certification: Does your organization have quality Certification:

YES	
NO	

7. No of Employees and company size: (tick appropriate column)

Below 100 employees		Between 201 and 300 employees	
Between 101 and 200 employees		Between 301 and 400 employees	
Above 400 employees			

8. Respondent information

- Name ……………
- Position in organization ………….
- Department ………………
- Year of serving ……………

***Section** B*

Implementation status of the following QT&T in your organization

Please give response on the scale of 1 to 5 in the adjoining columns.(From very low to very high)

Scale:

6	Very Low
7	Low
8	Average
9	High
10	Very High

Sr no	QT&T Category	Extent of Usage (1-5)	Stages of usage QT&T (Tick column)				Training Schedule (Tick column)			Impact on organizations (Y/N)
	Problem solving tools (PST)		Planning	Production	Post production	General	Week	Month	Year	
1	A3 report									
2	Effective meetings									
3	Eight disciplines									
4	Five why's (5w's)									
5	Five why's and one how's (5w1h)									
6	Five why's and two how's (5w2h)									
7	Five why's and five how's (5w5h)									
8	Impact effort matrix									
9	Nine windows									
10	Nomial group Technique(NGT)									
11	Problem solving methodology									
12	Problem concentration diagram									
13	Quality circles									
14	Sucess and effect diagram									
15	Pilot testing									
16	Triz									

Sr no	QT&T Category	Extent of Usage (1-5)	Stages of usage QT&T (Tick column)				Training Schedule (Tick column)			Impact on organizations (Y/N)
	Productivity tools (PT)		Planning	Production	Post production	General	Week	Month	Year	
1	Concurent engineering									
2	Enterprise resource planning (ERP)									
3	Evalutionary operation (EVOP)									
4	Group technology (GT)									
5	Just in time (JIT)									
6	Kaizen activities									
7	Kano model									
8	Business process re- engineering (BPR)									
9	Supply chain management									
10	Total productive maintenance (TPM)									
11	Zero defect (ZD)									

Sr no	QT&T Category	Extent of Usage (1-5)	Stages of usage QT&T (Tick column)				Training Schedule (Tick column)			Impact on organizations (Y/N)
	Performance measurement tools (PMT)		Planning	Production	Post production	General	Week	Month	Year	
1	Evaluation of measurement/ inspection system									
2	Gauge repeatability and Reproducibility/ Gauge (R&R)									
3	Management by objectives (MBO)									
4	Pair wise comparison									
5	Balanced scorecard									
6	Critical to quality (CTQ) Tree									
7	Control plan									
8	Key performance indicator (KPI)									
9	OEE analysis (overall equipment effectiveness)									

BRIEF PROFILE OF THE RESEARCH SCHOLAR

Vivek Sharma is pursuing his PhD from the J.C. Bose University of Science and Technology, YMCA, Faridabad, Haryana, India. He received his B. E in Mechanical Engineering from MD University, Rohtak, India in 2007 with honours and M.Tech in Mechanical Engineering (Manufacturing and Automation) from the YMCA Institute of Engineering, Faridabad (Haryana), India in 2009. He had published papers in various reputed journals and attending many international and national conferences. His area of research is quality management system and applications of MADM techniques in manufacturing and service organizations.

LIST OF PUBLICATIONS OUT OF THESIS

List of published papers

Sr no.	**Title of paper along with volume, issue no and year of publication.**	**Publisher**	**Indexing**	**Refereed or non-refereed**	**Whether you paid any money for publication**	**Remarks**
1.	Quality tools and techniques: an introspection and detailed classification, **International journal of quality and innovation,** Vol. 3(2-4), 107-142, 2017.	Inderscience	Goggle scholar & J-gate	Refereed	No	Published
2.	Analyzing the barriers affecting the effective utilization of quality tools and techniques using integrated ISM approach. Vol. 7, No. 11, pp. 525-540, **Management Science Letters, 2017.**	Growing Science	Scopus	Refereed	No	Published
3.	Applicability of quality tools and techniques in manufacturing and service organizations: A comprehensive survey. Vol. 12, No.1, pp.37–58, **International journal of six sigma and competitive advantage, 2020.**	Inderscience	Scopus	Refereed	No	Published
4.	An integrated AHP-GTA approach for measuring effectiveness of quality tools & techniques. 11(1), 54-63, **International journal of system assurance engineering and management, 2020.**	Springer	ESCI	Refereed	No	Published

List of communicated papers

1.	Analysis and validation of Quality tools and techniques by application of Factor Analysis. **International journal of quality research.**	Center for Quality, University of Montenegro.	ESCI	Refereed	No	Communicated

List of Papers in Conferences/ Seminars

Sr no	**Topic**	Year
1.	A novel classification of Quality tool & techniques for manufacturing organizations. 2nd International conference at G.B.U Noida on 16th and 17th July 2016.	2016
2.	Survey on the usage of quality tools and techniques in Indian manufacturing organizations. 1st international conference at N.I.T Hamirpur on 14th and 15th July 2016.	2016
3.	Accessibility of QT&T in manufacturing and service organizations by TOPSIS approach. National conference of trends and advances in mechanical engineering. TAME YMCA. Feb 2019	2019