

A NEW MULTIDIMENSIONAL SCALING FRAMEWORK FOR DISCOVERING
CUSTOMER REQUIREMENTS

A Dissertation by

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DEDICATION

To the spirit of my father and mother who inspired me, dear and precious for their prayers and encouragement—may Allah prolong their life; all my brothers and sisters; all members of my family; all of my friends; and, most of all, to my wife Amani, my son Talal, and my daughter Tolai—my greatest appreciation for their encouragement, patience, and support

Allah will raise up in ranks those who believed among you and those who have been given knowledge. Allah is aware of what you do.

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ABSTRACT

Customer feedback analysis provides insights into customer satisfaction and helps improve the quality of services and products. The major issue of concern in analyzing customer feedback is the ability to identify their implicit requirements. While the literature revealed that multidimensional scaling (MDS) has been extensively utilized to summarize qualitative data in order to help identify general structures of dataset, researchers are often tempted to represent scatters in two dimensions. Such reduction in dimensionality may hide new requirements or cause them to falsely merge with others. This research proposes a new framework for performing MDS with the objective of discovering new requirements. The framework builds on the advantages of the MDS procedures and can be utilized to validate known requirements.

Research efforts resulted in the development of a special algorithm, using MATLAB, to support applications of the new framework. An illustrative application is used to demonstrate the steps involved and highlights the ability of the framework to discover emerging requirements.

It is hoped that the new framework would help product and process designers as well as quality practitioners gain a better understanding of customer requirements and attend to their needs.

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LIST OF ABBREVIATIONS

ACSI	American Customer Satisfaction Index
ANOVA	Analysis of Variance
CATA	Computer-Assisted Text Analysis
CI	Critical Incident
CM	Concept Mapping
CVR	Content Validity Ratio
ECSI	European Customer Satisfaction Index
HOQ	House of Quality
ISO	International Standards Organization
ISOMAP	Isometric Feature Mapping
KWIC	Keywords-in-Context
LLE	Locally Linear Embedding
MDS	Multidimensional Scaling
PCA	Principal Component Analysis
PLS	Partial Least Squares
QFD	Quality Function Deployment
SCSB	Swedish Customer Satisfaction Barometer
SD	Semantic Differential
SERVPERF	Service Performance
SERVQUAL	Service Quality
SPSS	Statistical Package for the Social Sciences
VOC	Voice of the Customer

CHAPTER 1

INTRODUCTION

Customer satisfaction is considered a standard of performance and excellence for all companies and industries (Grigoroudis & Siskos, 2010). Indeed, the effective implementation of quality concepts, tools, and techniques leads to increased customer satisfaction and improves the quality of services and products. A survey or questionnaire is a research method that can be used to obtain information about customer needs and identify customer requirements. Drew and Healy (2006) outlined different quality management approaches and concluded that customer surveys are widely used and the most useful tool compared to other quality tools.

Several approaches to customer feedback analysis have been introduced with different features and limitations. These approaches include statistical data analysis methods, quantitative data analysis techniques, and customer satisfaction models. The majority of these approaches focus mainly on analyzing customer responses to closed-ended questions and measuring the overall customer satisfaction. However, assessing the existing approaches has revealed a lack of comprehensive evaluation of customer feedback and limited analysis of customer responses to open-ended questions, which resulted in obtaining an insufficient perception of customer needs and not fully understanding customer requirements.

Requirements captured from the customer are known as voice of the customer (VOC) and should be determined to measure the quality of a product or service and improve customer satisfaction based on customer views. Therefore, obtaining valuable information about customer requirements requires in-depth analysis of customer feedback.

Customer feedback assessment helps mainly with knowing the strengths and weaknesses of services provided or products used by the customers in a practical way through the utilization

of customer feedback techniques. In addition, customer feedback is a key input for improving existing designs or offering new products or services. Valuable information about customer opinions can be elicited in an unstructured fashion (Erickson & Kaplan, 2000). According to Sproull (2002), qualitative text analysis can be used to determine dimensions that derive customer expectations.

Numerous studies have demonstrated the benefits of analyzing customer comments and exploring their perceptions. Several concepts and requirements can be captured from their responses and comments (Miles & Huberman, 1994; Pothas, De Wet & De Wet, 2001). According to Cohen, Manion, and Morrison (2007), a questionnaire survey includes closed-ended and open-ended questions. Customers respond to closed-ended questions, which include multiple choice questions on a scale format, and rate the answer to a given question. The main advantage of closed-ended questions is that they provide simple answers, which are faster to code and easy to analyze. However, the customers are not able to add further explanations or reflect the actual requirements. In contrast, open-ended questions are statements with specific information, and customers can express opinions in their own words. Including open-ended questions in the survey provides an opportunity to discover new customer requirements and update the survey design. Sproull (2002) and Cohen et al. (2007) stated that open-ended questions help to capture customer satisfaction but require more time for respondents to answer them.

Customer responses to open-ended questions are not easy to analyze due to difficulty in measuring the meaning of the responses. Numerous studies have been conducted in the area of customer satisfaction, and several techniques are useful in analyzing open-ended questions. Computer-aided text analysis (CATA) and the identification of hidden requirements of the

customer are not effectively utilized when analyzing customer feedback. Therefore, multidimensional scaling (MDS) is typically utilized to summarize and simplify customer comments.

A comprehensive literature review showed that the methods of identifying customer requirements are still a widely discussed issue among researchers. This research is aimed at discovering customer requirements by utilizing MDS to obtain complete insight into customer perceptions and to discover implicit customer requirements based on their perspective.

Chapter 2 is a review of the literature pertaining to customer satisfaction, quantitative and qualitative techniques for identifying customer requirements, customer satisfaction indices, and dimensionality reduction techniques. Chapter 3 represents a detailed discussion highlighting customer feedback analysis, customer requirements identification, the MDS technique, and shows efforts demonstrating the research gap in the area of customer feedback analysis techniques, research objectives as well as describes the research procedure. An explanation of research steps followed in developing the MDS framework for emerging customer requirements is presented in Chapter 4. Conclusions and recommendations for future research are highlight in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

This chapter is a review of the literature in the area of quality and customer satisfaction questionnaire development. The review is divided into six sections. The first section introduces the concept of quality, customer satisfaction, and loyalty. The second section presents the economic significance of measuring customer satisfaction and loyalty. The third section reviews techniques used to identify customer requirements. Methods for collecting customer feedback and determining their satisfaction and dissatisfaction are discussed in the fourth section. Both qualitative and quantitative techniques that can be used to analyze customer feedback are illustrated in section five. The last section discusses national and international models as well as indices used to measure customer satisfaction.

2.1 Quality, Customer Satisfaction, and Loyalty

Quality has been given a great deal of attention in the past decades since customer satisfaction plays a major role in an organization's success. Many quality experts and researchers have different opinions on the definition of quality; however, there is agreement that only the customer has the right to judge the quality of products or services. Moreover, quality concepts, tools, and techniques have been utilized by industries to face new challenges and competitions.

According to Hayes (1997), quality needs to be defined in order to improve the value of products and services. Several definitions of quality found in the literature. Juran (1979) defined quality as "fitness of purpose." Another definition of quality by Crosby (1979) is "conformance to specifications," whereas Deming and Edwards (1982) described quality as "predictable degree of uniformity."

According to the International Standards Organization (ISO) (1994), quality is the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs. Table 2.1 shows a summary of quality theories and definitions conducted by quality experts compared to ISO 9000 elements.

TABLE 2.1
COMPARISON OF ISO AND QUALITY GURUS KEY ELEMENTS

	Crosby (1979)	Deming & Edwards (1982)	Feigenbaum (1983)	Ishikawa (1968)	Juran (1979)	ISO 9000 (1994)
<i>Quality definition</i>	Conformance to requirements	Three corners quality: product, user, instructions	What the customer says it is	Customer satisfaction	Fitness for use	Conformance to producers and specifications
<i>Philosophy</i>	Defect-free	Constancy of purpose statistical analysis	Full customer satisfaction at economical cost	Company-wide quality control	Project approach in order of importance	Documentation defines and reflects practice
<i>Approach</i>	Motivate the people	Statistical techniques	Systematic approach to total quality control	Talk with data	Quality trilogy: planning, control, and improvement	Self-audit with independent review
<i>Mechanics</i>	Fourteen steps	Fourteen obligations of management	The nine M's	Seven statistical tools	Diagnostic and remedial journey	Three ISO 9000 standards and two guidelines

Source: Adapted from *Total Quality Management* (Richardson, 1997)

According to Hauser and Clausing (1988), quality function deployment (QFD) is a method of transforming customer requirements or needs into engineering characteristics in order to improve the product used or service provided to the customers. QFD prioritizes each characteristic, which helps focus on characteristics of a new or existing product or service from the customer viewpoint. This results in setting up development targets and increasing customer satisfaction. The voice of the customer, a term used to describe customer needs or requirements,

can be obtained in different ways, such as direct face-to-face interviews, focus groups, and surveys. Customer needs are then summarized in a product planning matrix or house of quality (HOQ). The HOQ matrix is used to translate “what” (or needs) into “how” (or product requirements), in order to satisfy customer needs (Hauser & Clausing, 1988).

Service quality and customer satisfaction are different concepts. Cronin and Taylor (1992) and Teas (1993) defined service quality as an overall assessment, whereas they defined customer satisfaction as a transactions assessment. Parasuraman, Zeithaml, and Berry (1985) identified service quality as measuring the service level delivered to customers that matches with customer expectations. Another definition of service quality by Gronroos (1983) is the fulfillment of customer expectations. Parasuraman, Berry, and Zeithaml (1988) stated that service quality is a long-term assessment of the service, expressed as an antecedent of customer satisfaction. In contrast, Lewis (1989), Zeithaml, Bitner, and Gremler (1996) defined service quality as that which is delivered to customers with a high level of expectation.

According to Fornell (1992), service quality must be measured and evaluated before improving quality, which enables organizations to compete in the global market. Hence, it is useless to invest in service quality and work to improve it without involving customer opinions. Legcevic (2008) emphasized the importance of managing and measuring service quality to survive and grow in business. The most effective way to measure quality is by looking at factors that impact customer satisfaction (Fornell, 1992). According to Schlesinger and Heskett (1991), satisfaction has several components, one of them being service quality. Hunt (1977) stated that evaluating service quality and analyzing customer feedback result in obtaining customers’ overall attitude about the service offered or product used.

Service quality and product quality measurements are different due to service characteristics, which include intangible, inseparable, variable, and perishable (Lovelock & Gummesson, 2004). Because service quality has unique characteristics, customer perception is the main focus when measuring the quality of service offered to the customer. Indeed, service quality has become the main concern of all service industries in recent years. According to Hung, Huang, and Chen (2003), service quality is considered a real challenge and important subject facing service industries in recent years. In the same sense, Zahari, Ismail, and Newell (2008) emphasized the importance of service quality in business, public and private sectors, and service industries.

Customer satisfaction has been a widely discussed topic over the past years. Jamal and Naser (2003) stated that customer satisfaction is a customer judgment about the product consumed or service used. Rust and Oliver (1993) demonstrated the definition of satisfaction as a customer belief, emotion, and reflection, which lead to a positive feeling. In contrast, customer dissatisfaction reveals poor performance and not meeting customer expectation. Hellier et al. (2003) defined customer satisfaction as the customer feelings and pleasure toward service offered, which meet customer needs and expectations.

There is agreement among researchers that a relationship exists between service quality and customer satisfaction (Parasuraman et al., 1985). Baker (2013) concluded that there is a strong relationship between service quality and customer satisfaction. Moreover, customer satisfaction is highly affected by the quality of service

Several instruments developed in the past measure service quality and customer satisfaction. Gronroos (1984) developed a service quality instrument to recognize how customers assess the quality of service delivered. This instrument includes two dimensions: technical

quality and functional quality. Technical quality is the result of service performance and can be evaluated objectively. It includes the following attributes: technical solutions, machines, knowledge, and an employee's technical ability. Functional quality is how the service is delivered to the customer and can be determined subjectively. It includes four attributes: attitude, availability, environment, and customer contact.

Lehtinen and Lehtinen (1982) classified service quality into physical and interactive elements that can be categorized into several attributes. Rust and Oliver (1993) identified three critical dimensions of service quality: service product, service delivery, and service environment. Baker (2013) concluded that service quality dimensions perceptions are multidimensional, and every industry has unique dimensions. Parasuraman et al. (1985) described service quality as a comparison between customer expectation and customer perception. They proposed a total of ten dimensions: responsiveness, tangibles, reliability, competence, courtesy, credibility, security, access, communication, and understanding the customer. In order to avoid overlaps in the scale, these dimensions were reduced to five—reliability, assurance, tangibles, empathy, and responsiveness—and are known as service quality (SERVQUAL) dimensions. From these, the SERVQUAL instrument was developed (Parasuraman et al., 1988).

The SERVQUAL instrument has been widely utilized in service industries to measure service quality and obtain an overall customer satisfaction score. However, several studies proved that SERVQUAL was not applicable to all service industries. For instance, Carman (1990) stated that SERVQUAL cannot be used as a generic instrument to measure service quality for the following reasons: First, the judgment of new consumers is different from loyal consumers. Second, the consumer expectation score needs to be recorded before delivering the service. Third, the importance of dimension was not added to the measurement. According to

Cronin and Taylor (1992), the SERVQUAL instrument provides information about the quality of service through customer perceptions regardless of customer expectations. Because the SERVQUAL instrument received several critiques from different researchers, Parasuraman, Zeithaml, and Berry (1994) revised the SERVQUAL instrument and segregated customer expectations into two kinds—desired quality and adequate quality—and compared them with customer perceptions.

Cronin and Taylor (1992) developed a service quality instrument known as service performance (SERVPERF) to measure the customer perceptions of service quality. It consists of the same five quality dimensions included in SERVQUAL with 22 items. SERVPERF differs from SERVQUAL in terms of measuring customer perceptions only, and improving construct validity and operational efficiency.

Indeed, SERVQUAL and SERVPERF were the main service quality instruments used to measure service quality and customer satisfaction. Both utilize only a quantitative data analysis method to analyze customer feedback without the use of qualitative data analysis.

2.2 Economic Significance of Measuring Customer Satisfaction and Loyalty

A comprehensive literature review showed that measuring customer satisfaction and loyalty are still a widely discussed issue among researchers. In addition, continuous monitoring of customer requirements and evaluating survey items are not considered, as indicated by many researchers.

Measuring customer satisfaction is the main concern of all companies and industries since it provides an indication of the quality of service provided or product used from the viewpoint of the customer. According to Gerson (1993), measuring customer satisfaction is an

efficient way to understand customer expectation. Moreover, customer satisfaction is considered a standard of excellence for all companies and industries.

A review of previous studies revealed that several approaches and techniques have been developed in assessing customer satisfaction: gathering customer judgments, utilizing multivariate analysis, and using qualitative and quantitative approaches.

Grigoroudis and Siskos (2002) demonstrated the most important customer satisfaction measurement approaches: quantitative methods and data analysis techniques, quality procedures, consumer behavioral analysis, and methodological techniques, as summarized in Table 2.2.

TABLE 2.2
CUSTOMER SATISFACTION MEASUREMENT

Quantitative Methods and Data Analysis Techniques	Quality Procedures	Consumer Behavioral Analysis	Methodological Techniques
Descriptive Statistics	Malcolm Baldrige Award	Expectancy Disconfirmation Model	Customer Loyalty Kano Model
Multiple Regression Analysis	European Quality Model	Motivation Theories	Fornell Model
Factor Analysis	Ideal Point	Equity Theory	
Probit-Logit Analysis	SERVQUAL	Regret Theory	
Discriminant Analysis			
Conjoint Analysis			
Statistical Quantitative			
Cluster Analysis, Probability-Plotting Methods			

Source: Adapted from *Preference Disaggregation for Measuring and Analyzing Customer Satisfaction: The MUSA Method* (Grigoroudis & Siskos, 2010).

Cengiz (2010) stated that measuring customer satisfaction yields long-term success in the market by understanding customer needs, improving services and products, and monitoring customer feedback. The purpose of measuring customer satisfaction is to understand the performance of the business process, to make vital changes and improvements if required, and to discover the effects as the result of changes and improvements.

According to Fornell (1992), customer satisfaction leads to increased customer loyalty and money savings in the long term. In addition, the word-of-mouth spread of information by satisfied customers contributes to reducing the cost of obtaining new customers as well as to increasing the reputation of the organization. Several researchers demonstrated that organizations that employ quality and pay attention to customer satisfaction measurements obtain a high return in the economy (Anderson, Fornell, & Rust 1997; Bolton, 1998). A study conducted by Anderson et al. (1997) to measure the effect of customer satisfaction on an organization's success and the study outcomes revealed that there is a positive impact of customer satisfaction on the financial performance of the organization.

Measuring customer satisfaction leads to customer retention, repurchase intention, and loyalty. Moreover, satisfied customers are not willing to move to competitors, and loyal customers are less sensitive to price changes compared to new customers (Nam, Ekinici, & Whyatt, 2011). According to Sun and Kim (2013), customer satisfaction measurement leads to increased incomes and an enhancement of the value of the organization, and can be used as a predictor measure of financial performance.

Fornell, Mithas, Morgeson III, and Krishnan (2006) indicated that customer satisfaction is considered a performance indicator and assists organizations in evaluating current and future plans.

2.3 National and International Customer Satisfaction Indices

The customer satisfaction measurement has a significant importance nationally and internationally, and several customer satisfaction indices and barometers have been developed, including the Swedish Customer Satisfaction Barometer (SCSB), the American Customer Satisfaction Index (ACSI), and the European Customer Satisfaction Index (ECSI).

The SCSB model was launched in 1989 as the first national customer satisfaction index and included two antecedents of customer satisfaction: perceptions and expectations (Fornell, 1992). According to Johnson, Gustafsson, Andreassen, Lervik, and Cha (2001), increased customer satisfaction results in decreased customer complaints and increased customer loyalty.

Figure 2.1 represents the components of the SCSB model.

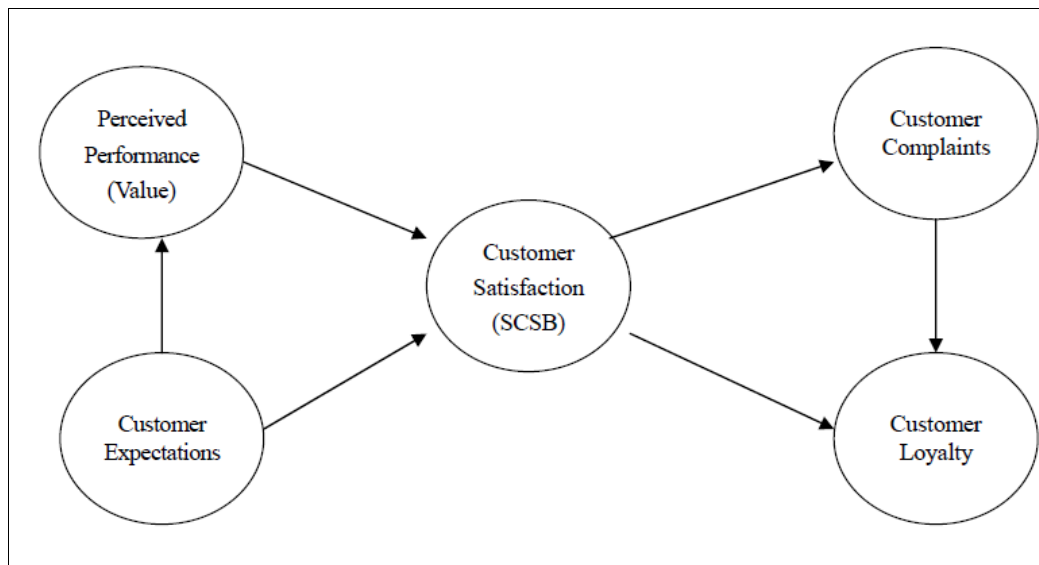


Figure 2.1: Swedish Customer Satisfaction Barometer model
(Source: Fornell, 1992)

The ACSI was developed based on the SCSB model and introduced in 1994. ACSI represents the national index across several sectors over periods of time and is used as a measurement tool for evaluating and improving the quality of products and service as experienced by customers (Fornell, Johnson, Anderson, Cha, & Bryant, 1996). The main

concept of the ACSI model is to measure overall customer satisfaction with multiple indicator approaches, which allows making a comparison among various sectors, industries, and other nations. The ACSI model contains “seven latent variables,” and each variable includes several measurements. A total of three questions on a 1 to 10 scale is included in the ACSI survey and represent determinants of overall customer satisfaction: perceived quality, perceived value, and customer expectations. The evaluated industry is given a score out of 100, which reflects how satisfied the customers are with the product used or service provided. The consequences of overall customer satisfaction are customer complaints and loyalty. Customer complaints decrease as overall customer satisfaction increases, and vice versa. Customer loyalty is considered the ultimate dependent variable (Fornell, 1996). Figure 2.2 shows the main variables of the ACSI model.

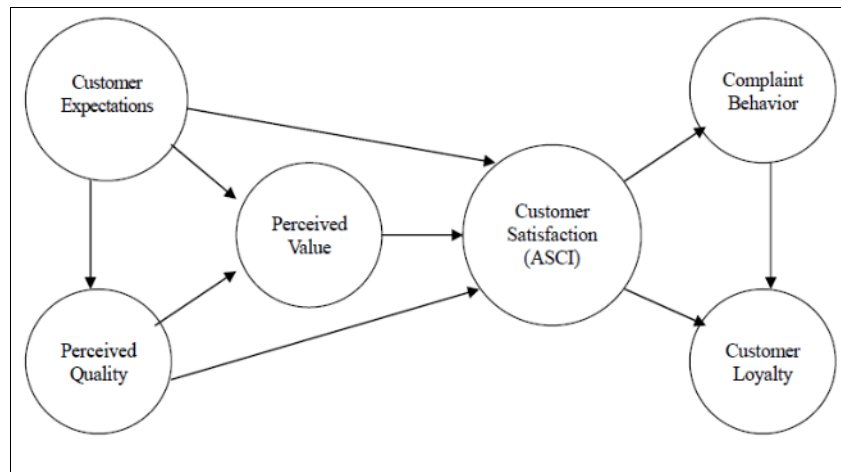


Figure 2.2: American Customer Satisfaction Index (ACSI) model
(Source: Fornell, 1996)

The general formula of ACSI is

$$\left[\frac{X1 - 1}{9} \times W1 + \frac{X2 - 1}{9} \times W2 + \frac{X3 - 1}{9} \times W3 \right] \times 100$$

where X1 is the mean of all items rated by respondents and is included in the customer's expectation variable; X2 is the mean of all items rated by respondents and is included in the

perceived quality variable; X3 is the mean of all items rated by respondents and is included in the overall quality variable; and W1, W2, and W3 are the average weights of each variable and can be calculated by the partial least squares (PLS) regression method (Fornell, 1996).

ACSI has several advantages in that it is a reliable satisfaction index providing cumulative satisfaction indications over time and valuable benchmarks for customer satisfaction constructs including quality, value, and loyalty. However, ACSI has some limitations, as reported by Fornell (1996), in terms of a significant relationship among ACSI variables in some of the public and private sectors.

The ECSI model is similar to the ACSI model but includes five main variables—perceived quality, customer expectations, perceived value, customer satisfaction index, and customer loyalty—as well as two latent variables: customer image and customer complaint. According to Johnson et al. (2001), the ECSI differs from the ACSI in terms of not including a customer behavior incidence as a customer satisfaction consequence. Moreover, ECSI includes a customer image as a latent variable in the model. Figure 2.3 illustrates the ECSI model.

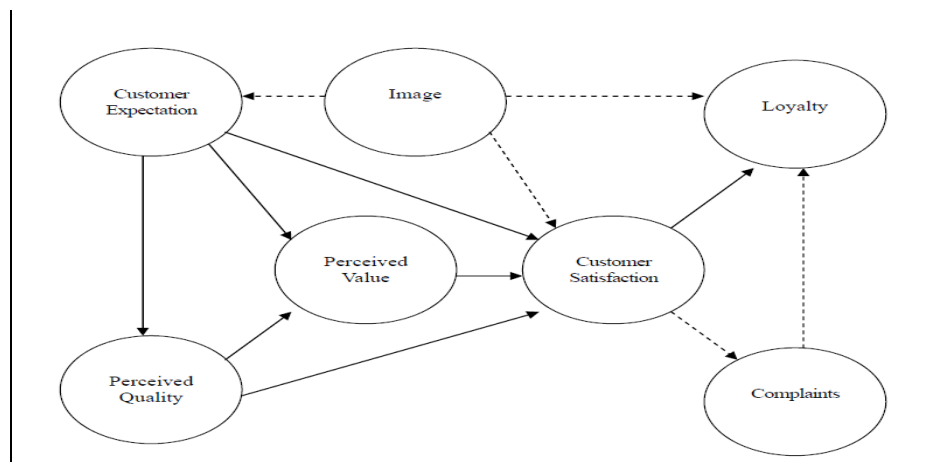


Figure 2.3: European Customer Satisfaction Index (ECSI) model
(Source: Fornell, 1996)

Previous studies have shown that many countries, such as New Zealand, Taiwan, Austria, Korea, and Turkey, have introduced their own national satisfaction indices. National customer

satisfaction indices and barometers are used as cumulative indicators of customer satisfaction over time and across several industrial sectors.

2.4 Methods for Collecting Customer Feedback

Several ways of collecting customer feedback, as indicated by Juran and Godfrey (1999), include focus groups, interviews, and surveys. According to Willig (2008), focus groups provide an explanation of the nature of the phenomenon and enable researchers to understand human perceptions. Moreover, focus groups allow participants to interact and share views, opinions, experiences, and ideas. The main advantage of the focus group method is gathering rich comments from participants and obtaining information about how attitudes are formed and change as well as how participants construct meaning. However, the focus group has several limitations. Given (2008) stated that the focus group cannot be used if the objective of the study is to obtain detailed information about respondents. Also, the focus group is not useful if the number of participants is not sufficient.

The interview is the most popular method of data collection due to the ability to analyze data by using various research methods, and it is easy to arrange and organize compared to other data collection methods (Willig, 2008). However, qualitative data obtained and contextual characteristics of the interviewers such as respondents' word meanings, thoughts, and feelings cannot be captured (Potter and Hepburn, 2005). According to Yin (2003), research methods include a survey, experimentation, archival analysis, history, and the case study, depending mainly on the type of research questions (what, where, who, why, and how), the degree of control over behavioral events, and the degree of focus on contemporary events. Each research method has different characteristics and features.

A survey has been known to be an effective research method. It is used to measure customer perceptions, feelings, and attitudes and helps in identifying customer requirements. Kenett (2006) defined the survey as a designed questioning to determine customer perceptions by using samples from the population in order to obtain data that can be analyzed by statistic methods. Gable (1994) defined survey as a research method to collect a large amount of data using questionnaires or interviews. The survey method is used when the aim of the study is to explore the relationship among factors by gathering data from a large number of respondents for the purpose of verification and validation. A systematic procedure needs to be followed when conducting a survey, which includes a sequence of steps: identification of research objectives, selection of the targeted population, determination of the data collection mode, questionnaire and sampling design, data collection, and data analysis (Biemer & Lyberg, 2003). The features of a survey and their degree of importance are shown in Table 2.3.

TABLE 2.3
SURVEY FEATURES

Feature	Degree of Importance
Controllability	Medium
Deductively	Medium
Repeatability	Medium
General Liability	High
Discoverability	Medium
Representability	Medium

Source: Adapted from "Integrating case study and survey research methods: An example in information systems (Gable, 1994)

Pinsonneault and Kraemer (1993) have categorized surveys into three types: exploratory, descriptive, and explanatory. An exploratory survey is used to understand the subjects and main concepts. A descriptive survey is conducted to study different cases and events, and to explore

human opinions and attitudes. An explanatory survey is used to test a theory and the relationships among factors. They have further categorized surveys into two types: cross-sectional and longitudinal. Cross-sectional surveys are used to analyze customer feedback in a single time, whereas longitudinal surveys are used to analyze data over several periods of time.

According to Cohen et al. (2007), a typical questionnaire survey consists of both closed-ended questions and open-ended questions. Closed-ended questions are questions with multiple choices on a scale format, and respondents rate the answer to a given question, whereas open-ended questions are statements with specific information, and respondents can express their opinions in their own words. Closed-ended questions provide simple answers, are faster to code, and are easy to analyze. However, respondents are limited in adding additional comments. Sproull (2002) and Cohen et al. (2007) stated that open-ended questions help to capture customer satisfaction but require more time from respondents to answer the question.

The qualitative data analysis of customer responses to open-ended questions is complex to analyze due to the difficulty in measuring response meanings and variations in respondent characteristics. Table 2.4 shows some characteristics of open-ended and closed-ended questions.

TABLE 2.4

CHARACTERISTICS OF OPEN-ENDED AND CLOSED-ENDED QUESTIONS

Open-Ended Questions	Closed-Ended Questions
Tend to be slower to administer	Tend to be quicker to administer
Can be harder to record responses	Often easier and quicker for the researcher to record responses
May be difficult to code, especially if multiple answers are given	Tend to be easier to code
Do not stifle response	Result in respondents only being able to answer in a predefined way
Result in respondents tending to feel they have been able to speak their mind	Result in respondents only being able to answer in a way that may not match their actual opinion and may become frustrated
Can be used to determine all possible responses before designing a closed-ended question	Can include a section at the end in order to write in a longer response if desired

Source: Adapted from *Practical Research Methods: A User Friendly Guide to Mastering Research* (Dawson, 2002).

2.5 Qualitative and Quantitative Data Analyses Techniques

A comprehensive review of previous studies conducted in the area of quality and customer satisfaction indicated that several qualitative and quantitative techniques have been used to analyze customer feedback. Each technique has different features, characteristics, advantages, and disadvantages. The choice of using either quantitative or qualitative technique depends on the aim of the survey. According to Grigoroudis and Siskos (2010), the qualitative survey method is used when the aim of the survey is to investigate the behavior of the customer, whereas the quantitative survey method is used when the aim of the survey is to examine the attributes and performance of a product or service as well as to determine specific quantitative

indices. Both qualitative and quantitative research methods can be used to collect and analyze customer feedback.

The customer survey includes customer responses to open-ended questions, and several qualitative data techniques can be used to analyze written comments, which include semiotics, qualitative comparative analysis, constant comparison analysis, keywords-in-context (KWIC), word count secondary data analysis, classical content analysis, and text mining (Leech & Onwuegbuzie, 2008).

The literature on qualitative data analysis techniques shows that varieties of techniques have been proposed to analyze qualitative data. Leech and Onwuegbuzie (2008) demonstrated 18 qualitative data analysis techniques and categorized them based on sources of the data collected, including talks, observations, photographs and videos, and documents. The types of qualitative data analysis techniques and their functions are listed in Table 2.5.

TABLE 2.5

TYPES OF QUALITATIVE DATA ANALYSIS TECHNIQUES AND FUNCTIONS

Type of Analysis	Short Description of Analysis
Constant comparison analysis	Systematically reducing data to codes and then developing themes from the codes.
Classical content analysis	Counting the number of codes.
Word count	Counting the total number of words used or the number of times a particular word is used.
Keywords-in-context	Identifying keywords and utilizing the surrounding words to understand the underlying meaning of the keyword.
Domain analysis	Utilizing the relationships between symbols and referents to identify domains
Taxonomic analysis	Creating a system of classification that inventories the domains into a flowchart or diagram to help the researcher understand the relationships among the domains.

TABLE 2.5 (continued)

Type of Analysis	Short Description of Analysis
Componential analysis	Using matrices and/or tables to discover the differences among the subcomponents of domains.
Conversation analysis	Utilizing the behavior of speakers to describe people's methods for producing orderly social interaction.
Discourse analysis	Selecting representative or unique segments of language use, such as several lines of an interview transcript, and then examining the selected lines in detail for rhetorical organization, variability, accountability, and positioning.
Secondary data analysis	Analyzing non-naturalistic data or artifacts that were derived from previous studies.
Latent content analysis	Uncovering underlying meaning of text.
Qualitative comparative analysis	Systematically analyzing similarities and differences across cases, typically being used as a theory-building approach, allowing the analyst to make connections among previously built categories, as well as to test and to develop the categories further.
Narrative analysis	Considering the potential of stories to give meaning to individual's lives, and treating data as stories, enabling researchers to take account of research participants' own evaluations.
Text mining	Analyzing naturally occurring text in order to discover and capture semantic information.
Micro-interlocutor analysis	Analyzing information stemming from one or more focus groups about which participant(s) responds to each question, the order that each participant responds, the characteristics of the response, the nonverbal communication used, and the like.

Source: Adapted from "Qualitative data analysis: A compendium of techniques and a framework for selection for school psychology research and beyond" (Leech, and Onwuegbuzie, 2008).

Qualitative data analysis techniques can be utilized by using computer-assisted qualitative data analysis software programs. However, a singular qualitative data analysis is widely used in much research. Moreover, there is a lack explanation of different qualitative data

analysis and how to use it with computer software. Indeed, there are several CATA programs with different features, functions, and tasks. Using CATA helps in facilitating data analysis, recording conversations, storing respondent data, organizing, and coding qualitative data (Morse & Richards, 2002). In addition, qualitative data can be categorized and coded in a short time (Bazeley, 2006).

Leech and Onwuegbuzie (2011) demonstrated seven types of qualitative data analysis techniques, which can be applied in qualitative research by using NVivo software. The qualitative data analysis techniques are constant comparison analysis, classical content analysis, keywords-in-context, word count, taxonomic analysis, and domain analysis, and componential analysis. According to Leech and Onwuegbuzie (2011), adopting qualitative data analysis procedures yields rigorous qualitative research. Table 2.6 lists the advantages and disadvantages of CATA.

TABLE 2.6
ADVANTAGES AND DISADVANTAGES OF CATA

Advantages	Disadvantages
Helps to alleviate time-consuming and monotonous tasks of cutting/pasting and retrieval of field notes and/or an interview transcript.	In a focus group, the group moves through a different sequence of events, which is important in the analysis but which cannot be recognized by a computer.
Useful aid to those who have tight deadlines.	Programs cannot understand the meaning of the text.
Computer programs can cope with both multiple and overlapping codes, which would be very difficult for researchers.	The software can only support the intellectual processes of the researcher—they cannot substitute for these processes.
Some software can conduct multiple searches in which more than one code is searched much more quickly and efficiently than by researchers.	The software might be beyond an individual budget.

TABLE 2.6 (continued)

Advantages	Disadvantages
Programs can combine codes in complex searches.	Participants can change their opinions and contradict themselves during an interview; a computer cannot do this.
Programs can pick out instances of pre-defined categories, which have been missed by the researcher during the initial analysis.	User-error can lead to undetected mistakes or misleading results.
Computers can be used to help researchers overcome analysis block.	Using computers can lead to an over-emphasis on mechanical procedures.

Source: Adapted from *Practical Research Methods: A User Friendly Guide to Mastering Research* (Dawson, 2002).

According to Punch (1998), qualitative research is a complex method, and many approaches have been developed to analyze qualitative data. These approaches can be interpreted by several viewpoints and practices. Miles and Huberman (1994) described qualitative research methods as integral, overlapping, and complementing research methods.

Tesch (2013) conducted a survey and applied 26 qualitative research approaches to analyze qualitative data obtained from respondents, concluding that each qualitative approach has different features. Creswell (2007) demonstrated five types of qualitative research approaches: narrative study, phenomenology, grounded theory, ethnography, and case study. Each approach has systematic steps and challenges when analyzing qualitative data. Additionally, there are many similarities and differences among qualitative research approaches.

Denzin and Lincoln (1994) described six types of qualitative research: ethnographic research, case study, phenomenological research, grounded theory, participative inquiry, and clinical research. On the other hand, Kasinath (2013) identified seven types of qualitative research approaches or strategies, six the same as Denzin and Lincoln (1994) with one additional approach, the focus group, which is considered an important qualitative data method in qualitative research.

Punch (1998) concluded that there are many techniques to analyze qualitative data because of the diversity of qualitative data analysis. According to Hanson, Balmer, and Giardino (2011), qualitative researchers provide detailed information and generate hypotheses for quantitative research questions. When quantitative study provides inadequate findings, qualitative research is used to explore the study outcomes in detail.

Peshkin (1993) demonstrated the benefits of qualitative research, which relies on understanding respondent views, interpreting human activities, and providing clear descriptions of data gathered. According to Creswell (2013), there are three basic qualitative research methods used in academic social science: ethnography, which is studying a particular culture and understanding peoples' experiences; phenomenology, which is defined as studying personal experience and is also known as subjective reality; and grounded theory, which refers to an inductive type of research based on observations and results in developing a theory from obtained data.

Hanson et al. (2011) illustrated qualitative research sampling methods, sampling plans, and collection methods. The qualitative research sample depends on the research purpose. Therefore, purposeful sampling is widely used in qualitative research. The most important method of sampling in qualitative research is to have a sufficient amount of qualitative data in order to confirm themes. The sampling plan should include various sources of data, such as triangulations (using different sources of data) from respondent interviews, written comments, and observations. The qualitative data collection methods include individual interviews, focus groups, written comments, observations, and document reviews. Hanson et al. (2011) also stated that qualitative data is analyzed in three passes, as shown in Figure 2.4.

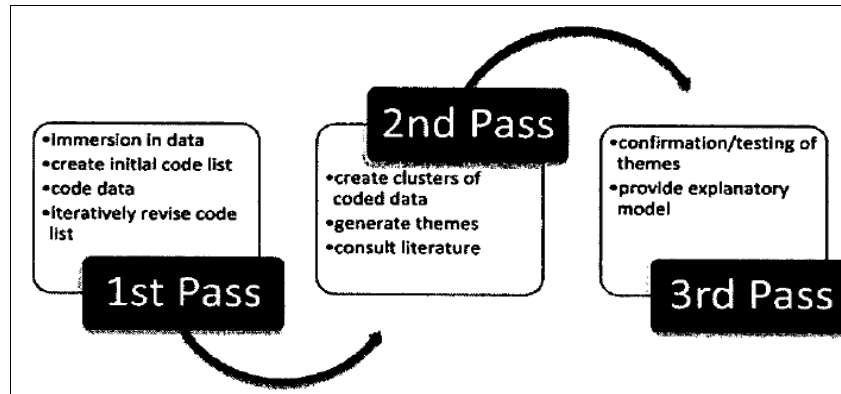


Figure 2.4: Data analysis passes
(Source: Hanson et al., 2011)

The first pass includes establishing a codes list and continuous revising the data. The second pass involves clustering coded data and generating themes. The final pass requires investigating the relationships among themes and interpreting findings. The main disadvantage of qualitative research is the time consumed, because it requires multiple iterations to have a better understanding of the data. Furthermore, several researchers need to be involved in the study to discuss the areas of agreements and disagreements.

The literature on qualitative research validity shows a variety of methods used to validate qualitative study. Lincoln and Guba (1985) demonstrate a set of criteria to assess qualitative research, which includes credibility (internal validity), transferability (external validity), dependability (reliability), and confirmability (objectivity). Another classification by Maxwell (1992) proposed five types of validation in qualitative research: descriptive validity, interpretive validity, theoretical validity, evaluative validity, and generalizability.

Hayes (1997) demonstrated the importance of survey reliability and illustrated three types of reliability, including test-retest, parallel form, split half, and Cronbach's alpha. Test-retest reliability shows the stability of customer satisfaction over time, while parallel form reliability indicates the generalizations of items included in a survey of the content domain. Split-half

reliability is used by dividing the items into two parts and calculates the correlated reliability for the purpose of determining if the survey items measure the same thing. Cronbach's alpha is primarily used to explore the degree to which items are interrelated.

According to Bowman (1984), many professionals in the management field have provided a detailed description of using reliability and validity in analyzing qualitative data. Kassarian (1977) indicated that the selection of categories and units of measurement increases or decreases the validity of the study.

Krippendorff (2012) proposed three kinds of reliability when analyzing qualitative data: stability, reproducibility, and accuracy. Reliability of the data analysis depends on several judges who assess the process of the same contents, whereas validity of the data is measured by the extent to which an instrument used can measure the collected data.

Short, Broberg, Coglisier, and Brigham (2010) demonstrated the validation methods for assessing entrepreneurial orientation dimensions using CATA: content validity, external validity, reliability, dimensionality, and predict validity. Content validity refers to expert opinion and measure assessment (Nunnally & Bernstein, 1994). External validity is the measurement ability to generalize survey findings across multiple sources of data (Cook, Campbell, & Day, 1979). Reliability is the degree to which the measurement is consistent, stable, predictable, and dependable (Kerlinger & Lee, 2000). Dimensionality ensures that the dimension is loaded in a single factor to satisfy discriminant validity (Nunnally & Bernstein, 1994). Predict validity is identified by Cronbach and Meehl (1955) as the ability of measurement scores to predict other scores on criterion measure. One previous study has indicated that predicted validity has been rarely used in qualitative research (Neuendorf, 2002).

Hanson et al. (2011) concluded that there are different methods for establishing trustworthiness in qualitative research. Additionally, Lincoln and Guba (1985) and Kuper, Lingard, and Levinson (2008) demonstrated trustworthiness and validity in qualitative research. One method for establishing trustworthiness is credibility (internal validity) and can be examined by the following methods: triangulation (collecting data from various sources), detailed evidence (gathering sufficient data), prolonged observation (collecting observations for long periods of time), and skillful interview technique (selecting questions that provide deep information). Another method is transferability (external validity) and can be obtained by providing a complete description of the sample, setting, and findings. A third method is dependability (reliability) and can be explored by the following methods: multiple analyzers (different researchers to analyze collected data), peer debriefing (discussing knowledge developed during data analysis), rigorous procedure (systematic sampling, data collection, and data analysis), and member checking (providing recommendation from research participants). The final method is conformability (objectivity) and can be investigated by recording study steps, data analysis and interpretation for audit purposes.

Quantitative data analysis is a widely used research method, which is employed by researchers and practitioners to analyze numerical data by using several statistical and mathematical techniques. According to Sekaran (2003), quantitative data analysis has three main objectives: first, to obtain the descriptive data that are related to the study, such as the mean, the range, the standard deviation, and the variance; second, to test the goodness of the data by using validity and reliability analysis; and third, to develop a hypothesis test for the research. According to Montgomery (2009), several statistical analysis techniques can be used for analyzing quantitative data such as independent sample t-test, which is a test of the significant

differences between two sample means, the analysis of variance (ANOVA), which is used to compare differences among means of independent samples. Juran and Godfrey (1999) outlined the purpose of regression analysis, which is prediction through a regression equation, exploring the relationships among variables in a quantitative manner and calculating regression coefficients. Moreover, the least squares regression method leads to identification of the most important independent variable in that data and is easier to measure than the dependent variable.

According to Hair, Black, Babin, Anderson, and Tatham (2010), factor analysis is a multivariate statistical analysis technique that reduces a large number of variables and results in underlying factors with groups of items. Factor analysis provides an indication of the internal reliability of a measure used in the study, determines the interrelationship among various variables, and investigates the dimensionality of survey items.

Naumann and Giel (1995) identified six issues related to customer satisfaction surveys, including volatility, bias, validity, meaningfulness, awareness and salience, and reliability. However, reliability and validity are the most important issues in any survey. Survey variables include two kinds of errors: systematic and random. These errors are related to validity and reliability (Grigoroudis & Siskos, 2010).

Survey validation is an important tool to determine the ability of an instrument in measuring what is required to measure, whereas reliability of a survey provides a clear indication of the overall preciseness of a measure. Hayes (1997) stated that “unlike mathematical indices of reliability, there is no one statistic that provides an overall index of the validity of inferences about score.” Consequently, considerable attention is necessary when designing a survey, in order to obtain reliable and valid data from customer surveys.

Previous studies on quantitative research show that a variety of reliable and validation methods have been developed by researchers. The three main types of survey validation as illustrated by Hayes (1997) are content validity, criterion validity, and construct validity. Content validity refers to how well the variables in the survey represent the complete domain of customer opinions, while criterion validity focuses on determining the statistical relationship between requirements in order to obtain a future prediction. Construct validity refers to identification of the relationships among variables.

Lawshe (1975) developed a method to calculate the content validity ratio (CVR). Here, an expert is responsible for rating the questions of the survey on a three-point scale. A CVR value is estimated for each question, and the questions can be either included or excluded from the survey based on CVR values. Construct validity shows the relationship between different variables in the survey and includes convergent validity and discriminate validity. Convergent validity reveals a correlation among variables, while discriminate validity indicates no correlation among variables. In contrast, Vavra (1997) demonstrated four types of validity: content, construct, predictive, and convergent.

2.6 Techniques Used to Identify Customer Requirements

The quantitative data are easy to analyze and handle because of the advancement of statistical software with different features and functions. On the other hand, qualitative data obtained from customer feedback is not easy to analyze due to the difficulty in measuring the meaning of responses. Numerous studies have been conducted in the area of customer feedback analysis, and several techniques are helpful in analyzing customer requirements: critical incident (CI) (Flanagan, 1954), concept mapping (CM) (Jackson & Trochim, 2002), and semantic differential (SD) (Snider & Osgood, 1969).

2.6.1 Critical Incident Technique

The CI technique is used for gathering direct observations of human behavior. This useful technique involving analyzing open-ended questions was developed by Flanagan (1954) to evaluate critical requirements in job performance. It is based on a collection and a systematic categorization of critical incidents identified by customers by applying the content analysis method. According to Lockwood (1994) and Stauss (1993), the CI approach is a qualitative data analysis used to identify customer requirements and improve service quality.

Butterfield, Bergen, Amundson, and Maglio (2009) describe the CI technique as a procedure for obtaining human behavior based on memorable experiences of individuals and collecting data on previous observations. Its main principle is obtaining valuable information from customer comments. Hayes (1997) states that this approach helps in gathering customer experience and describing the service received by customers in human behavior terms or using specific adjectives.

Many studies have shown that the CI technique has been used effectively in many areas of research, including job analysis (Kanyangale & MacLachlan, 1995; Redmann, Lambrecht, and Stitt-Gohdes, 2000), education (Le Mare & Sohbat, 2002; Tirri & Koro-Ljungberg, 2002), and marketing (Derbaix & Vanhamme, 2003).

In previous years, the CI technique has been referred to in various terms, such as the critical incident report, as expressed by Kluender (1987); the critical event technique, as identified by Kunak (1989); critical incident analysis, as named by Gould (1999); and critical incident study technique, according to Cottrell, Kilminster, Jolly, and Grant (2002). Flanagan (1954) explained the CI concept, method, and procedure in detail as five steps: identifying the

general purpose of the study, developing plans and specifications, collecting the data, analyzing the data, and interpreting the results.

The CI method must be conducted in a systematic way to ensure that all critical incidents are categorized into satisfaction items, and the satisfaction items are grouped into customer requirements. Hayes (1997) describes CI method as categorizing all similar (CIs) into different and labeled as customer requirements. The overall incidents represent the quality dimension, and the remaining requirements identified are expressed as a comprehensive list of customer requirements.

It is important to ensure the quality of satisfaction items and customer requirements in order to obtain valuable results. According to Hayes (1997), in order to ensure the quality of allocation process, two people are needed to judge the similarity of critical incidents and satisfaction items. The first judge must follow the procedure of the allocation process, whereas the second judge must have customer requirements categorized by the first judge and ask to allocate the CIs into customer requirements and satisfaction items.

The main feature of the CI technique is that procedure is flexible and can be modified according to research purposes. Moreover, this technique has many benefits to researchers, as the end result forms quality dimensions that represent customer requirements. Grove and Fisk (1997) indicate that the CI technique provides useful results compared to other qualitative data analysis methods. Gremler (2004) states that the CI approach helps researchers to obtain a deep understanding and real insight into customer behavior. However, the technique is time-consuming, and it is difficult to analyze and interpret customer comments. Because the CI approach deals with only qualitative data of specific behavior and observation, it does not provide solutions to problems. According to Vianden (2012), limitations of the CI technique

include misunderstanding the comments obtained from customers and improper coding of answers to open-ended questions. In addition, the approach relies on rare events and is applicable only for analyzing open-ended questions. Furthermore, respondents may have forgotten the events that occurred over the past period of time, and only a few sets of data can be obtained.

2.6.2 Concept Mapping Technique

The CM technique has been utilized to analyze open-ended questions. It utilizes two methodologies that are code-based and word-based text analysis techniques to analyze research questions and “develop survey questions.” The main feature of CM is that it involves the respondent in the coding of the text and uses original respondent statements as units of analysis. Additionally, it enables sorters to code the data as well as allowing the data structure to emerge by using multidimensional scaling and cluster analysis of the collected individual coding data. Coding decisions made by researchers can affect the reliability and validity of the survey results. Several studies have been conducted with methods that provide the greatest reliability and validity in representing content in the text (Gerbner, Holsti, Krippendorff, Paisley, & Stone, 1969; Pool, 1959).

Ryan and Bernard (2000) proposed two approaches for analyzing free-flowing text: words as units of analysis, and codes as units of analysis. Another form of CM is a more formal group process tool that consists of a sequence of structured group activities connected to a series of multivariate statistical analyses that process the group input and generate maps (Trochim, 1993).

Concept mapping is similar to “word-based approaches” since it allows for visual representation of the conceptual similarities through statistical mapping and it is similar to “code-based approaches” because it allows human judgment to cluster these similarities

thematically. On the other hand, the difference between CM and word-based approaches is that it retains context by using intact respondent statements as a unit of analysis instead of words, and the difference between CM and code-based approaches is that it uses statistical analysis based on respondent judgments.

The reliability of concept mapping can be evaluated in many ways (Trochim, 1993). The “stability” of the method can be examined by repeating the sort, then evaluating the correlation between the two sort matrices. The main benefit of “reliability” to the CM method is the high level of “accuracy” of each coder compared to other notions of inter-coder reliability.

Krippendorff (2012) proposed four common reliability issues: some units are harder to code than others, some categories are harder to understand than others, subsets of the categories can sometimes be confused with larger categories, and individual coders may be careless, inconsistent, or interdependent.

There are two types of construct validity in content analysis. The first, semantic validity, is the “degree to which a method is sensitive to the symbolic meanings that are relevant to a given context” (Krippendorff, 2012). The second, sampling validity, “assesses the degree to which available data are either an unbiased sample from a universe of interest or sufficiently similar to another sample of the sample universe, so that data can be taken as statistically representative of that universe” (Krippendorff, 2012).

Jackson and Trochim (2002) outlined five steps of concept mapping: create units of analysis, use MDS analysis of the pile-sort data, cluster analysis of the MDS coordinates to decide on a final cluster solution, and label the clusters. CM results can be interpreted in several ways. Because the data represent a structured conceptualization of the data, it is possible to evaluate the map for regions of meaning. A region on the map, which forms a cluster, is grouped

together with other regional groups of clusters. Decisions about regional distinctions are conducted by theoretical preconceptions or through group discussion.

Concept mapping can be used to create items and define dimensions in the process of scale development (Jackson & Trochim, 2002). It can also be used to show how different groups of people might generate different CM solutions depending on their experience, which can guide researchers in identifying boundary conditions for a theory. CM enables researchers to identify the similarity between concepts and categories of the concept such as a combination of human judgment, respondent experience. Furthermore, it saves time and improves some of the reliability and validity challenges of “word-based” and “code-based” methods.

Concept mapping of open-ended survey questions is considered to be a well-suited method when the researcher does not want to create bias or suggest relationships by forcing the data into a preconceived coding scheme, when existing coding schemes or theoretical frameworks do not exist or when the purpose of the research is to explore possibilities for conceptual categories, and when there are competing theoretical explanations or frameworks. A limitation of the CM methodology is that of resource restriction and sorter burden. Condition judgments, such as if-then judgments, could generate several problems during the reduction stage. In addition, answers such as “I do not know” to questions could create many redundancies and could be excluded from analysis (Jackson & Trochim, 2002).

The main feature of concept mapping is that a group of sorters from the target population is involved in coding the data. The results represent the final units of analysis, which are analyzed using MDS and cluster analysis. This approach is preferred over CI and SD methods due to the mathematical properties of the analysis used (Coxon & Davies, 1982; Kruskal & Wish, 1978). MDS is a statistical technique used to analyze and visualize the data in

multidimensional space. It allows for a comprehensive evaluation, dimensions, identification, and interpretation of perceptions. According to Wish and Carroll (1982) MDS helps to project all data in multiple dimensions, provides graphical representations, and facilitates understanding of the customer perceptions.

Kruskal and Wish (1978) demonstrated some of the advantages of using MDS, pointing out that MDS can be utilized to analyze both metric and nonmetric data. Metric data are quantitative data, such as interval or ratio data, whereas nonmetric data are qualitative data, such as a number of proximity (similarity or dissimilarity). Moreover, MDS maps provide meaning to patterns or regions with related variables.

According to Malhotra and Birks (2007), MDS involves six steps: (1) formulating the problem, (2) obtaining input data, (3) choosing an MDS model, (4) setting the number of dimensions, (5) labeling the dimensions and interpreting the configuration, and (6) evaluating reliability and validity. The two main difficulties in the application of MDS are choosing an appropriate number of dimensions to represent the data and interpreting the resulting structures. Choosing a large number of dimensions results in over fitting the data. In contrast, choosing a small number of dimensions results in an inaccurate interpretation of data structure (Shinkareva, Wang, & Wedell, 2013). A goodness of fit with the stress and the coefficient of determination (R-squared) values are useful in obtaining an appropriate number of dimensions, measuring the adequacy of the MDS solutions, and obtaining information about how well the model fits the data: the smaller the stress value, the better the fit. A scree plot or scree test is commonly used, whereby stress values are plotted against the number of dimensions. A clear elbow indicates an appropriate number of dimensions that need to be considered. Kruskal's stress-I is used to measure the goodness of fit. It is equal to the square root of the normalized Stress. Smaller

values of stress are desirable, values less than 0.20 are considered acceptable (Kruskal & Wish, 1978).

Malhotra and Birks (2007) indicated that the number of dimensions may be determined based on prior knowledge from past research, interpretation of the spatial map in two or three dimensions, elbow criterion that shows a clear change in a certain point, ease of use of two-dimensional maps, or by using statistical approaches. The interpretation of the MDS map is conducted through the cluster analysis method in order to identify the structures of data within the map. These predictions do not change the MDS solution. However, confirmatory studies must be used to validate these interpretations. Borg and Groenen (2005), provide a useful discussion on confirmatory studies.

2.6.3 Semantic Deferential Technique

The SD technique is a measurement tool of customer responses to obtain the connotative meaning of words as well as to find the attitude towards the concepts. It was developed by Osgood, May, and Miron (1957) to measure the concept's meaning by using bipolar scales and a pair of adjectives consisting of words in contrasting meaning. They conducted a factorial analysis and observed that scales yielded three dimensions: evaluation (good-bad, positive-negative, and true-false), potency (strong-weak, hard-soft, and heavy-light), and activity (active-passive, hot-cold, fast-slow). Table 2.7 presents four adjective pairs high in value, activity, and strength dimensions.

TABLE 2.7
POLAR ADJECTIVE PAIRS

Evaluation Dimension	Activity Dimension	Potency Dimension
Good-Bad	Active-Passive	Strong-Weak
Beautiful-Ugly	Energetic-Inert	Large-Small
Friendly-Unfriendly	Fast-Slow	Hard-Soft
Wise-Foolish	Excitable-Calm	Heavy-Light

Source: Adapted from *Cross-Cultural Universals of Affective Meaning* (Osgood et al., 1975)

The SD technique can be used in many applications and is widely utilized in different cultures (Eagly & Chaiken, 1998). According to Schütte (2005), this technique is a very useful method because several paired words lead to an effective interaction between consumers and the object as well as enhance understanding of peoples' perceptions and exceptions. Hsu, Chuang and Chang (2000) conducted a study of different types of telephone designs and used many pairs of adjective words to measure perception differences among users and designers. Results indicated that users' and designers' perceptions are completely different. Shields (2007) applied the SD method to discover attitudes and opinions of health staff and parents about the care of hospitalized children in four countries. That study revealed that the SD technique is easy to use and can be translated into different languages because antonyms are used in most languages. In addition, this approach is useful for fieldwork analysis and cross-cultural and quantitative studies.

According to Mondragon, Company, and Vergara (2005), the SD technique can be applied to the evaluation of machine tool design. Their study results indicate that this method helps in selecting an appropriate machine tool design based on the perceptions of different groups of people.

However, the three dimensions of Osgood et al. (1957) are in disagreement by many researchers. Heise (1969) concluded that the SD technique has several methodological issues, which are inaccuracy of metric scale, bias errors, rating variations due to individual differences, lack of reproduction of basic dimensions, individual variations in the semantic space size and characters, scale concept-interactions not occurring in design studies, and real scale-concept interaction considerations with different domains.

Osgood (1952) illustrated the evaluation methods of the SD technique: objectivity, reliability, validity, sensitivity, comparability, and utility. Since the SD results in quantitative data, objectivity means that the scale sets can be used for other equivalent subjects and still obtain the same results. Reliability indicates that the survey is reliable since the results of the study revealed a high-reliability coefficient value. Another indication of stability is using judges who are involved in the study. Validity refers to face validity and experimental checks such as attitude correlation and changes in sign meaning. Sensitivity means the ability of the survey to reflect a distinction in meaning. Comparability focuses on the ability of a survey method to be used in other cultures, the ability of the method to reflect the qualities of experience, the ability to compare different concepts, and the ability to compare different individuals. The utility includes semantic norms, individual variations in meaning, changes in meaning, quantification of subjective language meaning, and cross-cultural communication problems.

2.7 Dimensionality Reduction Techniques

The datasets with large numbers of variables are difficult to analyze and handle. Many studies showed that the large multidimensional data set can be reduced to smaller dimensions by applying several dimensionality reduction techniques. Tsai (2011) outlined the advantages of

dimensionality reduction, which include reduces the time and storage space, removes of redundancy in the data, helps to visualize the data when reduced to lower dimensions. Moreover, the dimensionality reductions techniques allow to explore hidden structure provide a better understanding of the data gathered, and the data can be visualized on the conceptual map. The linear dimensionality reduction techniques are used only when the data are linear in nature whereas the nonlinear techniques are used when the relationships among the variables are nonlinear.

According to Cunningham and Ghahramani (2015), the advantages of using linear dimensionality reduction techniques are: capturing the covariance and dynamical structure of the data, obtaining the correlation and the relationships among datasets.

Several dimensionality reduction techniques have been developed with a variety of names. The most popular linear dimensionality reduction techniques are Principal Component Analysis (PCA) (Pearson, 1901) and Multidimensional Scaling (MDS) (Cox & Cox, 2000; Kruskal & Wish, 1978). PCA is a statistical procedure that allows performing a linear reduction of the dimensions and account for maximizing the variability in the data. MDS another technique that can be utilized to visualize the data obtained from similarity or dissimilarity matrix on the conceptual map. The Latent Semantic Analysis (LSA) (Deerwester, Dumais, Furnas, Landauer, & Harshman, 1990) is widely used for document classification, information retrieval, and natural language processing: synonymy and polysemy. The nonlinear techniques for dimensionality reduction are Locally Linear Embedding (LLE) (Roweis & Saul, 2000) and Isometric Feature Mapping (Isomap) (Tenenbaum, de Silva, & Langford, 2000).

CHAPTER 3

DISCUSSION

This chapter presents findings from the literature review that identify the research gap in this investigation and the relevance regarding customer feedback analysis, customer requirements identification, and the multidimensional scaling technique. The literature maintained that customer satisfaction is considered a primary goal of quality. Hayes (1997) stated that quality should be defined so that the quality of products and services can be improved. The most effective way to measure quality is by looking at those factors that impact customer satisfaction (Fornell, 1992). According to Cengiz (2010), this can be achieved when customer needs are understood and identified.

Advancements in technology have raised the need to utilize CATA in organizing, managing, and analyzing open-ended questions. Furthermore, the literature has illustrated that there are few guidelines on how to analyze customer responses to open-ended questions and that there is a need for dynamic validation of customer feedback. In addition, reliability and validity are important measures, which are used to evaluate the quality of the survey instrument.

Previous studies have indicated that researchers avoid using qualitative data analysis due to text complexity and the constraints of time and budget, compared to quantitative data analysis. Today, many computer programs are available for analyzing qualitative data. Moreover, the increasing availability of CATA and statistical software programs has made the analysis of customer written comments much easier.

MDS is a popular technique that helps to explicitly summarize customer requirements. In addition, customer comments can be visualized in a multidimensional space or map. The

representation of the data structure results in an underlying relationship among items (Kruskal & Wish, 1978).

Utilizing MDS for analyzing customer comments provides a way of reducing all comments to a small set and representing explicit perceptions. Indeed, the development of a customer requirements framework becomes essential to interpreting their perceptions and fully understanding their requirements, especially with the large number of comments and the complex meanings of customer responses to open-ended questions.

Although all qualitative data analysis techniques are helpful in identifying customer requirements, MDS has not been effectively utilized to discover the implicit perceptions of customer requirements. This research is aimed at modifying MDS to aid in interpreting emerging customer perceptions and discovering new customer requirements.

The following sections describe the research procedure and the steps needed to develop a framework for discovering customer requirements.

3.1 Research Motivation

Analyzing customer responses to open-ended questions have helped designers become more aware of the importance of improving the quality of products and of including features that meet customer needs. Incidentally, researchers often focus on analyzing customer responses to closed-ended questions and disregard the analysis of their written comments. In addition, there is a clear gap in the literature for the systematic description of obtaining complete insights of customer perceptions and discovering implicit customer requirements based on their perspectives.

According to Punch (1998), qualitative research is a complex method, and many approaches have been developed to analyze qualitative data. The need to use an effective and

valuable procedure to measure customer satisfaction is important in order to achieve higher quality products and services. Consequently, dynamic validation of customer requirements helps in assessing customer requirements and meeting customer needs and expectations. Moreover, the MDS approach can be utilized for the visualization and interpretation of customer requirements.

While several qualitative data analysis methods draw considerable attention to transforming data into findings, limited attempts have been made to develop a framework for determining customer requirements. Furthermore, there are no guidelines for obtaining an in-depth understanding of customer requirements using advanced computer programs.

There are two important issues in MDS: choosing the number of dimensions for data representation, and interpreting the data structure resulting from the MDS procedure. Hence, this research will be focused on the steps involved in conducting MDS, specifically targeting steps four and five, as mentioned previously: setting the number of dimensions, and interpreting the dimensions and data points. In the literature, the most common method used to identify the number of dimensions is the scree plot or the elbow test, where the line indicating the slope shows a clear change. In addition, the main goal of MDS is to produce a conceptual map that best fits the input matrix (square matrix) in a set number of dimensions. However, the interpretation of the conceptual map in more than three dimensions is difficult and complicated, especially when a large number of comments are involved. Therefore, displaying the comments on a three-dimensional map will aid in looking for meaningful patterns in the conceptual map, followed by a graphical representation of the comments in a separate projection plane to provide a better understanding of the relationship among comments. Moreover, a matrix reduction method will facilitate data analysis and provides an accurate interpretation of customer requirements.

All research efforts have been aimed at the development and validation of instruments for measuring customer satisfaction with a limited utilization of MDS. In addition, the literature on customer satisfaction has shown qualitative data analysis techniques aimed at summarizing, simplifying, and visualizing the cluster of data obtained. To the best of the author's knowledge, no techniques for discovering customer requirements have been developed.

Indeed, the improper utilization of MDS can lead to a lack of interpretation of customer requirements. Thus, the main purpose of this research is to develop a framework that can be used to discover customer requirements, identify the hidden structure of customer perceptions, and explain the relationship among objects.

In this research, efforts have been made to propose a framework for discovering customer requirements and provide a methodology for the dynamic validation of customer satisfaction surveys.

3.2 Research Objectives

Several techniques have been used to identify customer requirements and measure overall of customer satisfaction. However, the MDS technique has not been utilized to discover implicit customer requirements based on customer feedback. This research aims to overcome the limitations of the MDS technique to allow for the following:

1. Validating the design of customer satisfaction surveys.
2. Discovering new and emerging customer requirements, based on customer feedback.

This research was motivated by the fact that quality and customer satisfaction are dynamic concepts that challenge the product designer and service provider. Research efforts are based on the idea that a deep understanding of customer requirements would be beneficial to update the survey items as well as to discover implicit requirements based on customer

viewpoints. This leads to obtaining a comprehensive evaluation of requirements and could help in capturing trends in the relative importance of requirements over time.

3.3 Research Procedure

This research focused on overcoming the limitations of the MDS technique to allow for discovering customer requirements, based on customer feedback. In order to achieve the research objectives, the following tasks were conducted:

1. Develop a computer-assisted method for identifying new or emerging customer requirements.
2. Provide an appropriate method for reducing the similarity matrices used as input for MDS.
3. Develop a computer algorithm that assists in matrix reduction and plotting customer requirements on a two-dimensional MDS (conceptual) map.

CHAPTER 4

THE DEVELOPMENT OF NEW MULTIDIMENSIONAL SCALING FRAMEWORK

This chapter describes the subsequent stages for developing the new framework for discovering customer requirements based on Multidimensional scaling as well as illustrates data analysis of customer feedback, and research findings.

4.1 Notation

The following symbols are used for estimating the coordinates of the units in two dimensions.

d_{ij} Euclidean Distance

A Similarity Matrix

a_{ij} The overall sorters rate on each unit

x_i, y_i The coordinate of first unit

x_j, y_j The coordinate of second unit

Λ_n Eigenvalues

E_n Eigenvectors

4.2 Mathematical Formulation of Multidimensional Scaling Framework

The similarity matrix A is a matrix of dimensions $N \times N$, where N is the total number of units (comments). The overall sorters rate on each unit is represented by (a_{ij}) , row i and column j , where $(a_{ij}) > 0, i, j = \{1, 2, 3, \dots, n\}$.

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{i1} & a_{i2} & a_{i3} & \dots & a_{in} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \dots & a_{nn} \end{bmatrix}$$

The above similarity matrix A is created by the summation of each sorter matrix.

Zand, Wang, and Hilchey (2015) demonstrated the procedure for calculating the coordinates of the units. The matrix of squared similarity is calculated:

$$P=A^2 \quad (4.1)$$

The matrix (J) is the matrix that double-centers the similarity matrix by subtracting the row and column means from every element of the matrix:

$$J = I - \frac{1}{v}k \quad (4.2)$$

Where, (I) is the identity matrix, (v) is the total numbers of units, and $(k_{ij}) = 1$

The Matrix B is obtained by using this equation:

$$B = -\frac{1}{2}.J.P.J \quad (4.3)$$

The eigenvalues $\lambda_1, \lambda_2, \dots, \lambda_n$ and eigenvectors e_1, e_2, \dots, e_n of B are calculated. For a two-dimensional representation of the units, the first two largest eigenvalues and their corresponding eigenvectors of B are extracted. The final coordinates of the units are obtained by multiplying eigenvalues and eigenvectors. The diagonal matrix of the square roots of the eigenvalues (Λ_n) is:

$$\Lambda_n = \begin{pmatrix} \lambda_1 & 0 & 0 & 0 \\ 0 & \lambda_2 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & \lambda_n \end{pmatrix} \quad (4.4)$$

The matrix A of relative coordinates (Dim1, Dim2) in two- dimensions is then calculated by multiplying the matrix of eigenvectors (E_n) and the diagonal matrix of the square roots of the eigenvalues (Λ_n):

$$\text{Final Units Coordinates} = E_n . \Lambda_n^{1/2} \quad (4.5)$$

In order to reduce dimension m with $m < N$, where N is the total numbers of units, only the first m of a ranked list of the (λ) and (e) are selected (Zand, Wang & Hilchey, 2015).

The main goal in an MDS-analysis is looking for a multidimensional space in which the Euclidean distance (d_{ij}) distances between the units correspond, as good as possible, with the proximities in the similarity matrix. The coordinates (Dim1, Dim2) on the conceptual map are the Euclidean distances between two units. This is the most familiar distance function and allows for identifying the location of units configurations derived by MDS.

The two-dimensional representation is chosen based on scree plot to visualize the units on the conceptual map. Removing duplicate units in rows and columns with equal total (Euclidean difference equal to zero) procedure is applied, which results in reducing the original similarity matrix to a minimum size ($N \leq 3$). According to Zand, Wang, and Hilchey (2015), the convenient measure of similarity between two units (x_i, y_i) and (x_j, y_j) is defined by the following equation:

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (4.6)$$

In order to perform a matrix reduction based on identical rows and columns, the following procedure is applied:

Using equation (5.6), Let $d_{ij} = 0$

$$(x_i - x_j)^2 + (y_i - y_j)^2 = 0 \quad (4.7)$$

$$(x_i - x_j)^2 = (y_i - y_j)^2 \quad (4.8)$$

Taking the square root of equation (4.8):

$$(x_i - x_j) = (y_i - y_j) \quad (4.9)$$

$$\text{Let } (x_i - x_j) = 0, (y_i - y_j) = 0 \quad (4.10)$$

$$x_i = x_j, y_i = y_j \quad (4.11)$$

This is to indicate that both units have the same Euclidean distance in (Dim1, Dim2) and shows as a single point on the conceptual map. Unlike the traditional MDS procedures, the matrix is reduced before performing MDS by eliminating the identical rows and columns followed by applying matrix reduction by aggregation procedure.

4.3 The Traditional Multidimensional Scaling Approach

As in traditional procedures, the MDS approach begins by collecting customer comments through direct interviews, focus groups, comment cards, or surveys with open-ended questions, and identifying the units of analysis. Long comments should be divided into simple units (comments) and ambiguous comments deleted. Resulting units are classified into current or emerging requirements. All emerging requirements (N) are compiled and saved in a document for further analysis. Sorters are invited to group similar units together. This involves grouping similar units in piles by each sorter. The results are scored on a 0, 1 frequency matrix. The cells in each NxN matrix contain 1 if the associated row and column are grouped together by the sorter in the same pile; otherwise, a zero is assigned to the cell. This step results in the construction of one diagonal matrix for each participating sorter. These matrices are then combined by adding scores in each cell across all sorters resulting in an NxN similarity matrix. The size of the similarity matrix depends on the number of statements (units of analysis) to be analyzed. The larger the numbers of units, the larger size of the similarity matrix. As such, row (column) totals represent the level of agreement among sorters: the higher the total, the higher the level of agreement, and vice versa.

4.4 The New Multidimensional Scaling Framework

The proposed framework for discovering customer requirements is shown schematically in Figure 4.1.

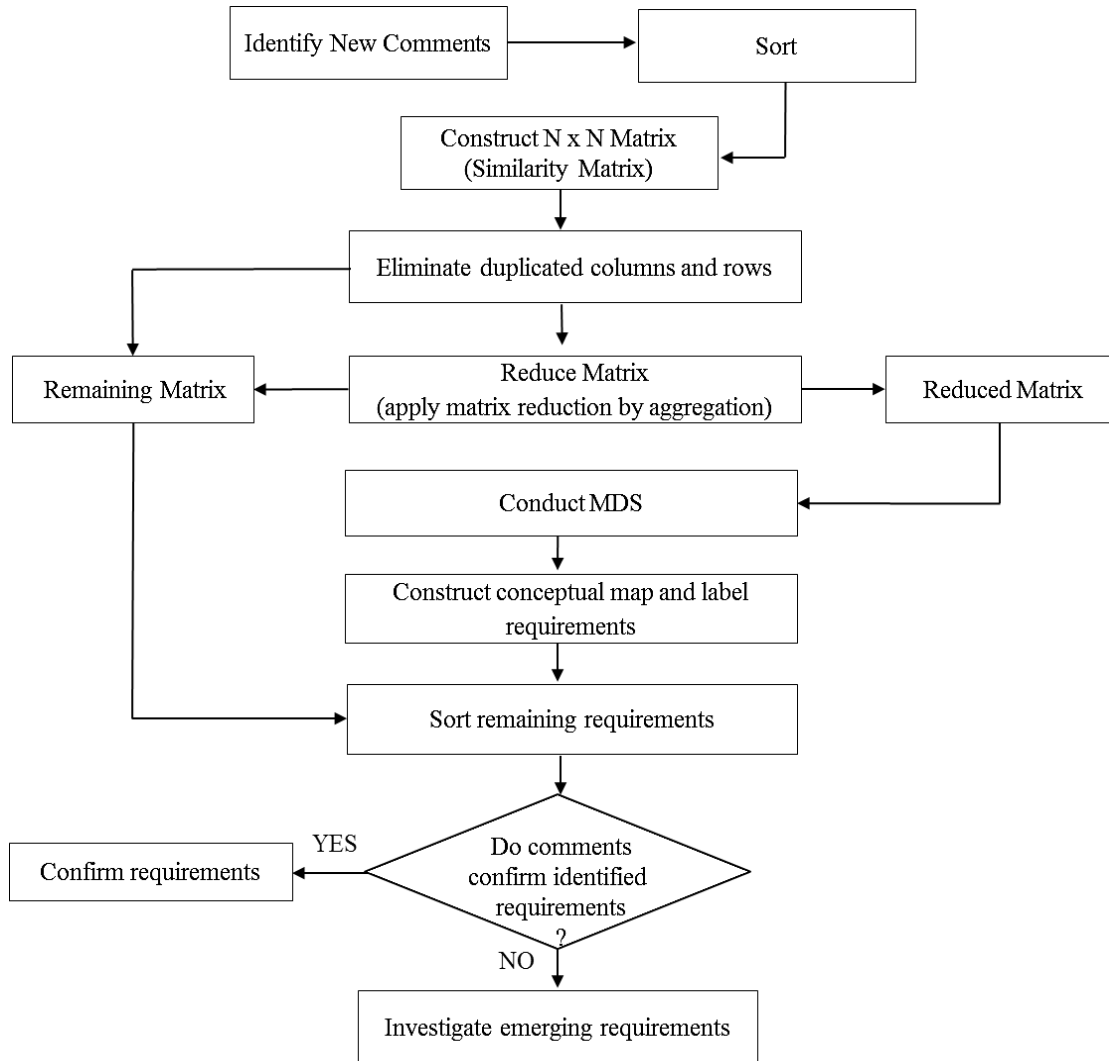


Figure 4.1: Proposed framework for discovering customer requirements

It starts by following the mentioned three steps of MDS procedures. Next, unlike the traditional MDS approach the matrix is reduced in two steps before performing MDS. First, the identical rows and columns are removed. Second, the matrix is reduced by aggregation procedure as proposed by Aoki (1968) to minimize the matrix size. A special algorithm was developed to support the two reduction steps while retaining aggregate elements of the original matrix. A similarity matrix A can be reduced while retaining aggregate elements of the original matrix as follows:

1. Use an aggregation matrix (M) that includes rows and columns ($m \times n$) by eliminating column (j_n) from the similarity matrix (A).
2. Post-multiply the matrix A by M .
3. Pre-multiply AM by M^T , where (M^T) is a matrix transpose to obtain a similarity matrix ($m \times m$).
4. Find the product $M^T M$ and compute its inverse, $(M^T M)^{-1}$ to obtain a similarity matrix ($n \times n$).
5. Compute $M^T A M (M^T M)^{-1}$.

This result in forming a reduced matrix ($n \times n$) and all removed comments are placed in a remaining matrix. The reduced matrix should be at least 3×3 which is the minimum size required for a two-dimensional solution. At this point, the reduced matrix is used as the input for MDS analysis, through which the appropriate number of dimensions is determined before constructing a conceptual map. As such, the chances of producing a two-dimensional map are much higher compared to the conventional procedure.

Once the conceptual map is constructed, it is examined for patterns and labels. The assigned labels represent new requirements that the sorters could not easily group in one pile. These are difficult to extract by the conventional procedure.

This framework requires that all comments from the remaining matrix are restored under the identified labels (requirements). This task may be performed by the researcher or a group of sorters familiar with the product or service being evaluated. Comments that match the labels offer a confirmation of the requirements, whereas comments that do not match any of the labels represent emerging requirements to be investigated in future studies.

The following section represents an illustrative application of the proposed framework and the results obtained.

4.4.1 Illustrative Application

To illustrate the advantages of the proposed framework, the data from Attar and Weheba (2015) was utilized. The survey was designed and administrated to analyze student responses to open-ended questions with the objective of identifying and understanding the possible structure underlying the interrelationships among comments on the multidimensional scaling map. The survey included a total of ten questions, three of which are open-ended questions. The following steps were applied to identify student requirements: collecting data, forming piles of similar units, evaluating the interrater reliability, utilizing MDS, and reviewing and naming the cluster. The steps taken to analyze student feedback and an effort to validate the survey design are explained in detail.

4.4.2 Data Collection

The survey was administrated 23 times during the 2013 and 2014 fall semesters following in-class presentations. Student responses to the three open-ended questions were collected, resulting in a total of 1,190 written comments. A list of all comments was prepared and used to create units of analysis. In order to reduce the time required to analyze the large number of comments and achieve high reliability, NVivo 10 software was utilized for data analysis.

As shown in Figure 4.2, six nodes were created with NVivo, each representing one of the original six key requirements. An additional node termed “others” was created to include comments that do not pertain to any of the six key requirements. Each unit of analysis was placed in one of seven nodes by the researcher.

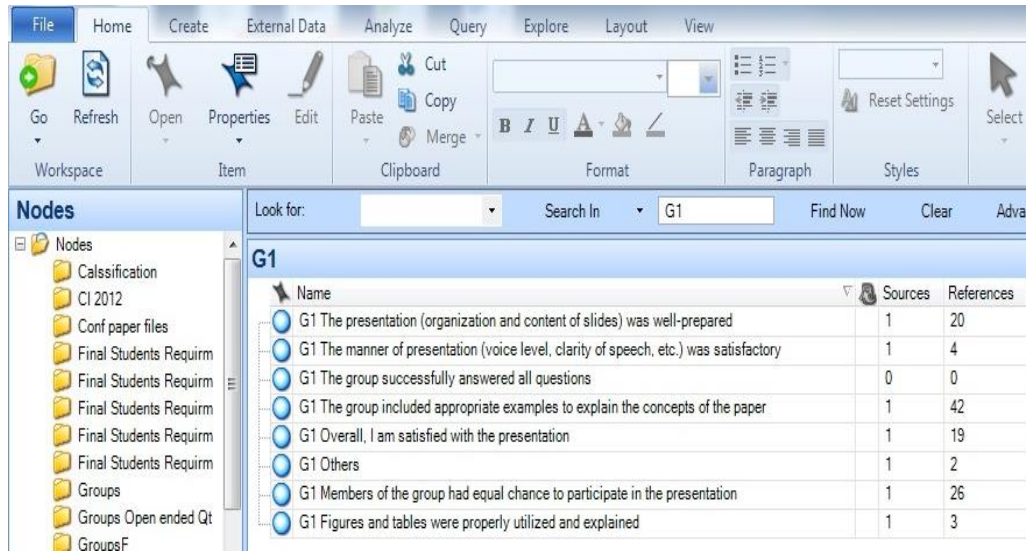


Figure 4.2: Snapshot of NVivo 10

The results are summarized in Figure 4.3. As shown, efforts to prepare the presentation (Q1), and the use of appropriate examples to explain the concept (Q3) appear to represent the most important requirements. In addition, a total of 30 units was classified under the “others” node for further analysis. The list of units (comments) is shown in Appendix B.

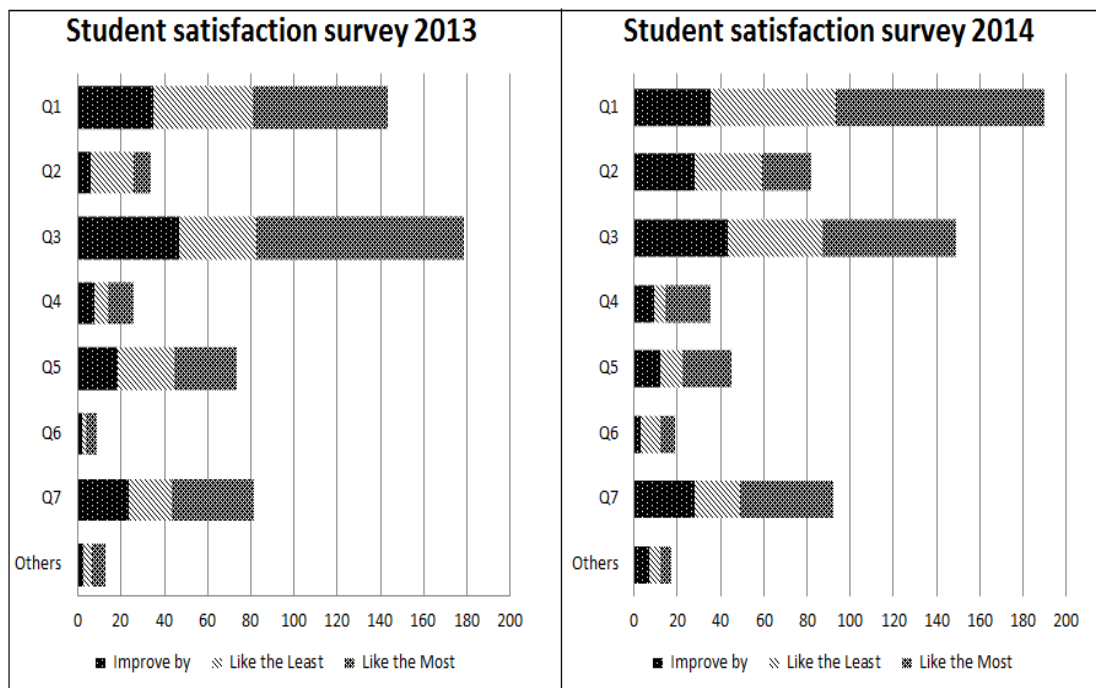
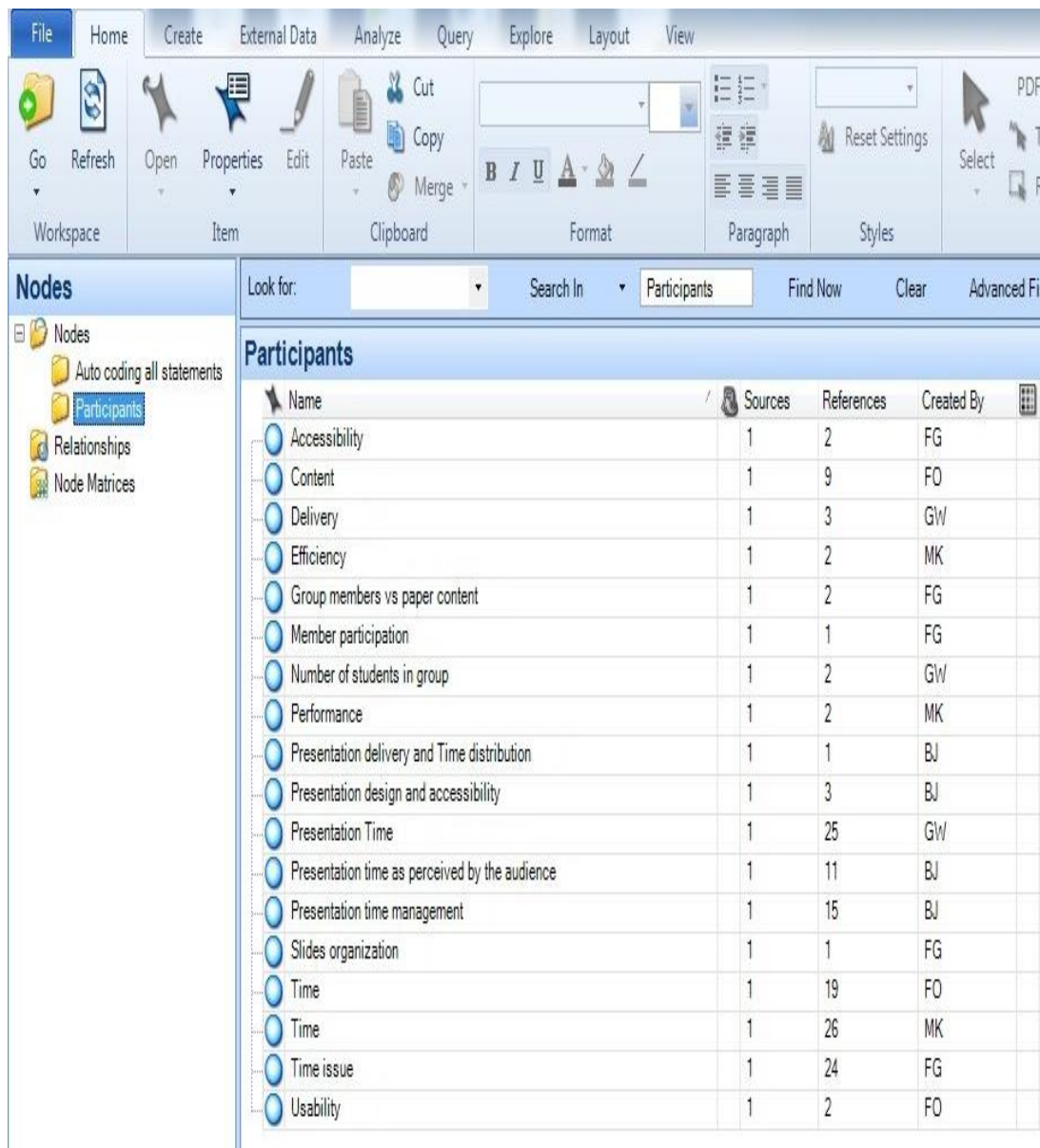


Figure 4.3: Distribution of comments in open-ended questions

4.4.3 Data Analysis Using Traditional MDS

The concept mapping procedure was applied to analyze the 30 units identified from student comments. Five students volunteered to sort and label these units utilizing NVivo. The sorters were provided instructions on the use of NVivo and the steps needed to create nodes, sort comments, and save the results. Each sorter was asked to group similar units into one node and to provide a name for each node. This resulted in a total of 18 nodes, as shown in Figure 4.4.



Name	Sources	References	Created By
Accessibility	1	2	FG
Content	1	9	FO
Delivery	1	3	GW
Efficiency	1	2	MK
Group members vs paper content	1	2	FG
Member participation	1	1	FG
Number of students in group	1	2	GW
Performance	1	2	MK
Presentation delivery and Time distribution	1	1	BJ
Presentation design and accessibility	1	3	BJ
Presentation Time	1	25	GW
Presentation time as perceived by the audience	1	11	BJ
Presentation time management	1	15	BJ
Slides organization	1	1	FG
Time	1	19	FO
Time	1	26	MK
Time issue	1	24	FG
Usability	1	2	FO

Figure 4.4: Clusters of requirements

These results were used to prepare a 30x30 binary matrix for each sorter. The matrix cells were filled with 1 for the units grouped together, and with 0 otherwise. The five matrices were combined to form the similarity matrix, a part of which is shown in Figure 4.5.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
S1	5	3	4	4	5	3	5	0	4	1
S2	3	5	4	4	3	2	3	0	3	1
S3	4	4	5	5	4	2	4	0	3	2
S4	4	4	5	5	4	2	4	0	3	2
S5	5	3	4	4	5	3	5	0	4	1
S6	3	2	2	2	3	5	3	1	4	0
S7	5	3	4	4	5	3	5	0	4	1
S8	0	0	0	0	0	1	0	5	0	2
S9	4	3	3	3	4	4	4	0	5	0
S10	1	1	2	2	1	0	1	2	0	5
S11	4	3	3	3	4	4	4	0	5	0

Figure 4.5: Partial representation of 30x30 similarity matrix

To evaluate reliability (internal consistency), the correlation between each sorter's binary matrix and the total similarity matrix was calculated as recommended by Nunnally and Bernstein (1978). As shown in Table 4.1, these values were consequently used to estimate the corrected reliability by utilizing the Spearman-Brown prophecy formula.

TABLE 4.1

CORRELATION COEFFICIENTS AS MEASURES
OF INDIVIDUAL TO TOTAL RELIABILITY

Sorter	Corrected Reliability	Correlation Coefficients
GW	0.992	0.9632
FG	0.88	0.5954
MK	0.979	0.9028
FO	0.982	0.9172
BJ	0.95	0.7931

In addition, an estimate of the Cronbach alpha coefficient of 0.9690 was obtained, thus indicating a high level of agreement among sorters. According to Malhotra and Birks (2007), Kruskal's stress-I is the most commonly used measure for goodness of fit in MDS analysis. A scree plot or scree test is used, whereby stress values are plotted against the number of dimensions. A clear elbow indicates numbers of dimensions that need to be considered and stress values less than 0.20 are considered acceptable.

As such, the similarity matrix was used as input for the MDS procedure in the Statistical Package for the Social Sciences (SPSS) software. The clear elbow suggested two dimensional solutions as shown in the Figure 4.6 and the calculated stress-I is 0.1289, which indicated an acceptable stress value.

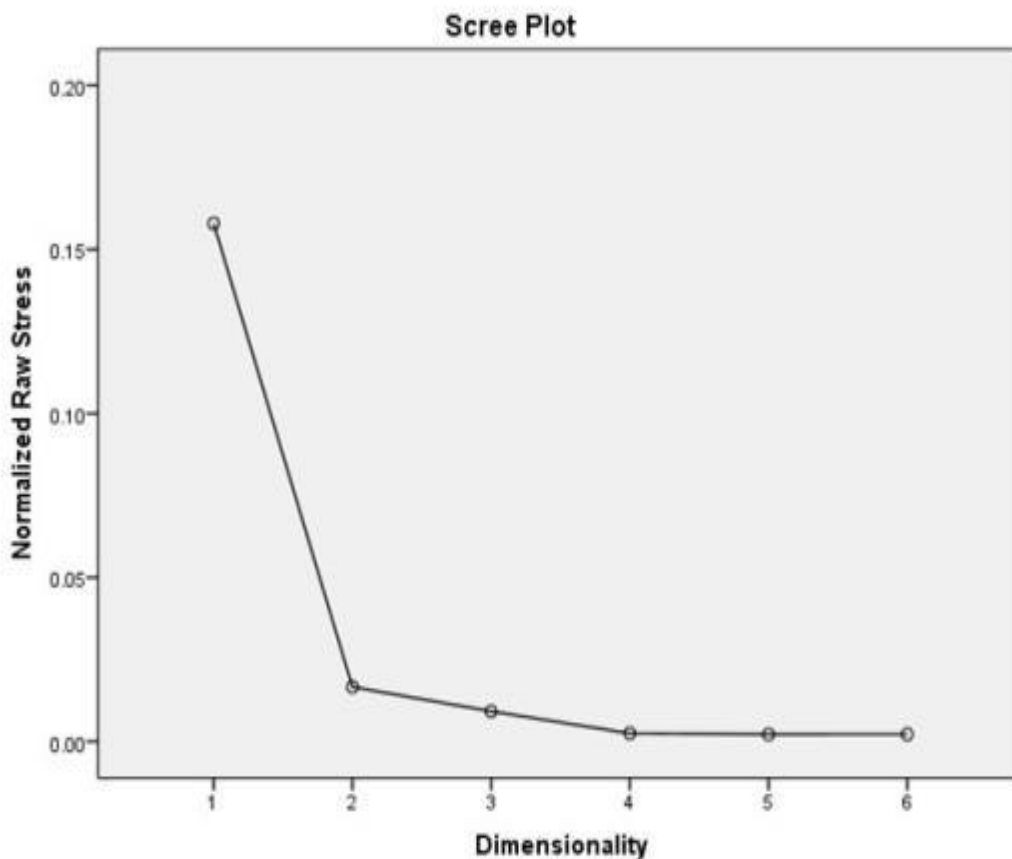


Figure 4.6: MDS scree plot based on similarity matrix

Then, the MDS generated a two-dimensional map based on Euclidean distances computed from the similarity matrix as shown in Figure 4.7. Clusters indicate units of analysis (comments) that were compiled together most often by the sorters.

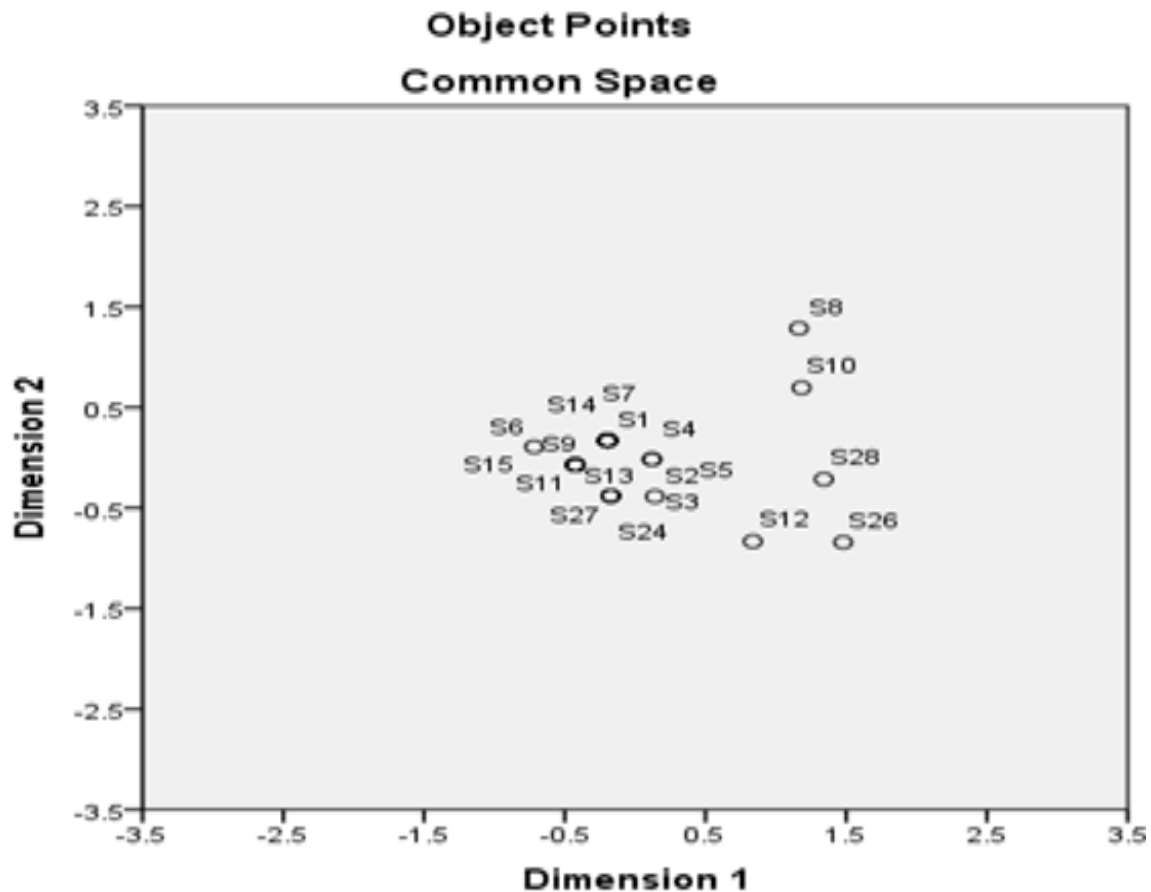


Figure 4.7: Two-dimensional map generated by MDS

In order to identify the optimum number of clusters, a two-stage sequence was followed. In the first stage, a hierarchical cluster analysis utilizing Ward’s method with squared Euclidean distance was used. This resulted in generating two final clusters based on unit similarities. In the second stage, cluster analysis was rerun with the two final clusters to help locate each unit of analysis to the specific cluster. The two final clusters with units were reviewed, examined, and named by the sorters as “presentation time” and “presentation availability.” Figure 4.8 shows the two identified clusters.

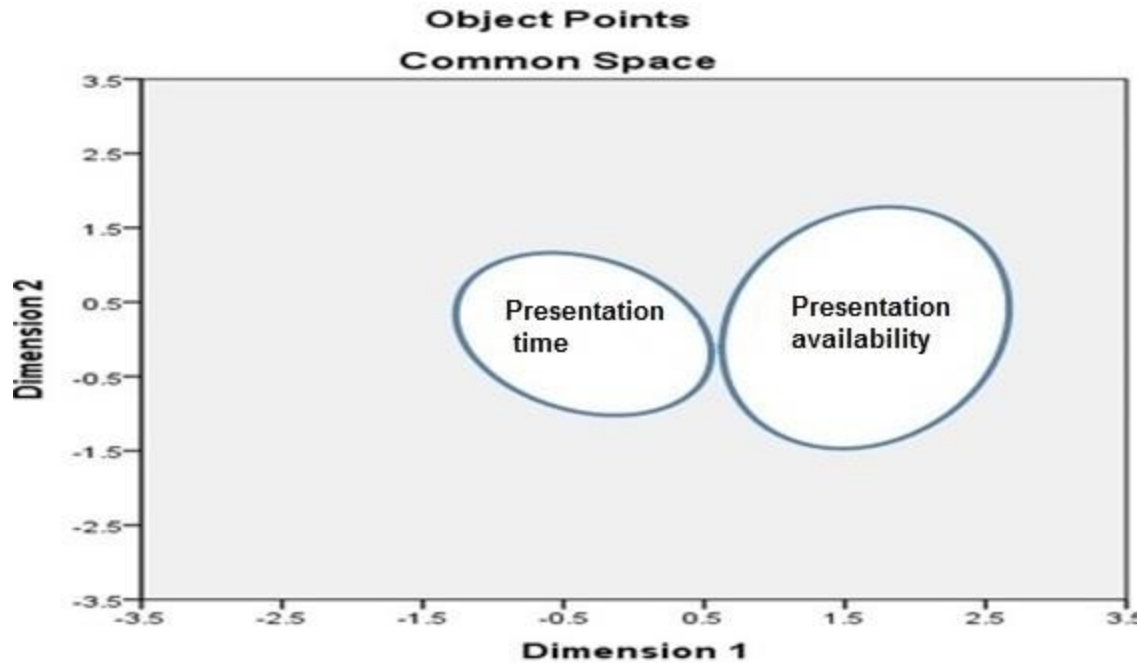


Figure 4.8: Final two clusters of student requirements

As a result, student responses to open-ended questions were difficult to compile without filtering comments. Moreover, some of the comments included more than one unit of analysis. In order to advance the analysis, complex comments were divided into a number of units.

Using CATA, the researchers performed an analysis without involving respondents in the initial steps. By utilizing NVivo, sorters were able to group similar units efficiently and in a manageable way. The time required to construct the concept map was reduced by utilizing the SPSS software. The results indicated that the student requirements are dynamic and need to be validated over time. The survey was updated by adding two questions with appropriate scales to measure student satisfaction with future presentations. The perception of the presentation's quality survey is shown in Appendix C.

The original study was conducted to update the design of a student satisfaction survey. Thirty units (comments) were considered for analysis. The traditional concept mapping

procedure was applied, and two new requirements were identified based on the clusters shown in Figure 4.8.

4.4.4 Data Analysis Using the New Framework

A follow-up investigation was conducted and further examination of the scatter revealed some hidden requirements that were forced to fit in a two-dimensional space. According to Borg and Groenen, (2005) three-dimensional MDS configurations are hard to understand, in particular when projected on the conceptual map. It is easier to look at the complete three-dimensional space at a certain projection plane. A three-dimensional representation of the scatter is shown in Figure 4.9.

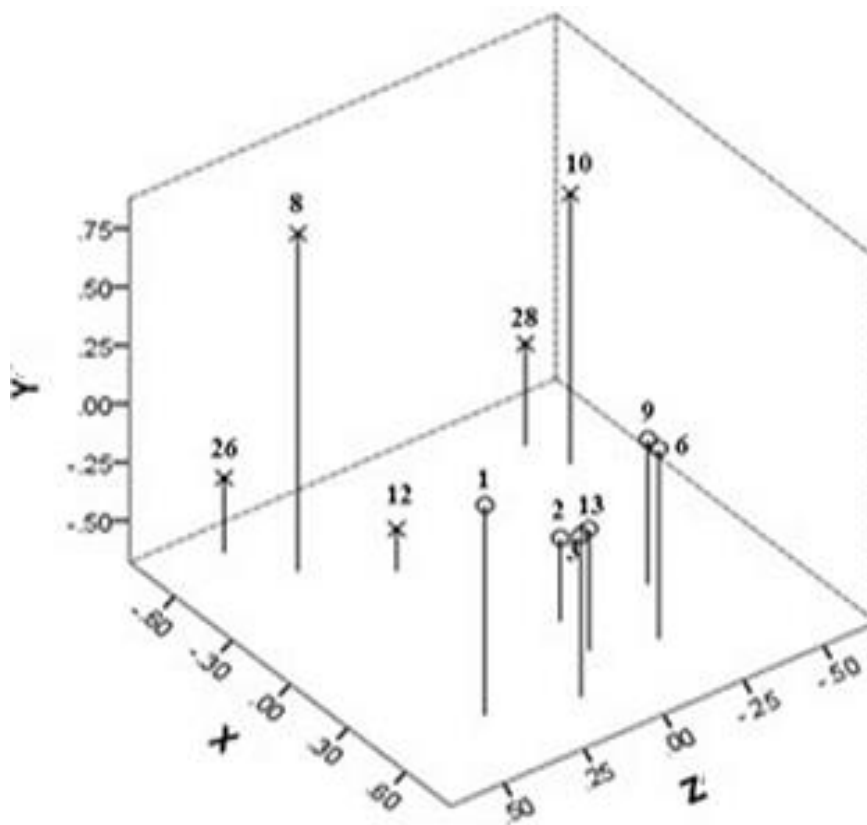


Figure 4.9: Three-dimensional representation of 30 comments

Such a configuration suggests that a three-dimensional MDS representation may reveal some hidden requirements. Next, three projections were prepared using SPSS, as shown in Figure 4.10. A projection of the scatter in the Y-Z plan suggests a different structure and support the need for another representation.

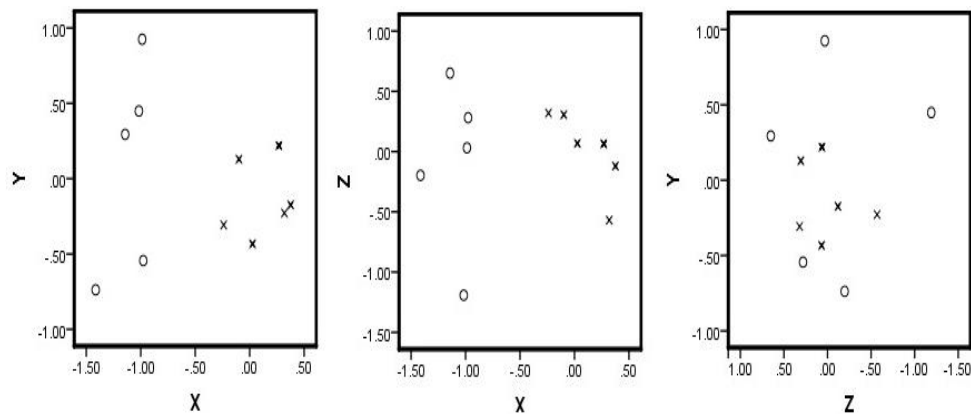


Figure 4.10: Three different projections of the scatter

The 30x30 similarity matrix was used and gradually reduced by removing duplicated rows and columns that are identical. After that, an aggregation matrix procedure was conducted and results in obtaining the 7x7 matrix as shown in Figure 4.10. The matrix was found to be of minimum size and the remaining 23 comments were separated in a 23x23 matrix.

	S1	S3	S8	S9	S10	S26	S28
S1	-1.1491	-4.4937	-0.1181	-3.2672	-1.4628	-3.0563	-2.2595
S3	11.0164	15.6081	-0.3475	10.6688	5.2442	3.9177	6.0809
S8	0.2480	-0.4179	5.2679	0.5159	1.6020	-0.0360	-0.7170
S9	11.8921	11.3374	1.2190	15.1110	1.6643	1.4219	2.0431
S10	1.0580	2.3567	1.9554	0.0134	5.2542	0.8252	2.5397
S26	1.8986	3.3572	0.8940	1.7926	1.3526	8.1941	4.2734
S28	0.2077	0.2865	0.2408	-0.5515	1.3196	0.7932	4.0564

Figure 4.11: Reduced 7x7 matrix

Next, SPSS was used to conduct MDS. The scree plot shown in Figure 4.12 supports a two-dimensional representation of the data and it shows that there are no major reductions in the

stress beyond two dimensional solutions. The calculated stress-I is 0.1612, which indicates an acceptable stress value. Finally, a conceptual map was generated using two dimensions, as shown in Figure 4.13.

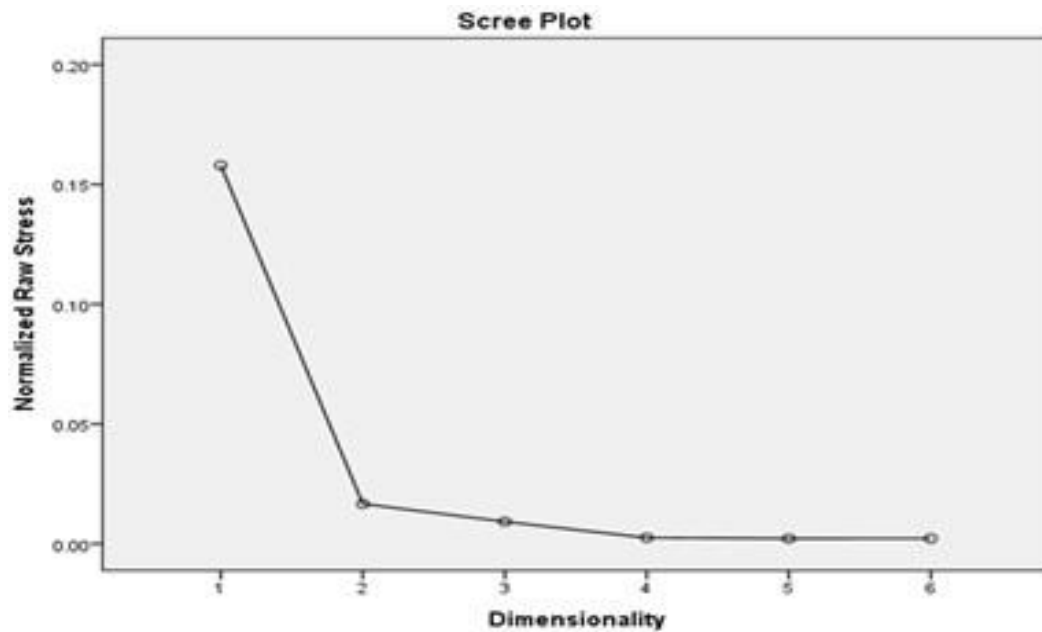


Figure 4.12: MDS scree plot based on reduced matrix

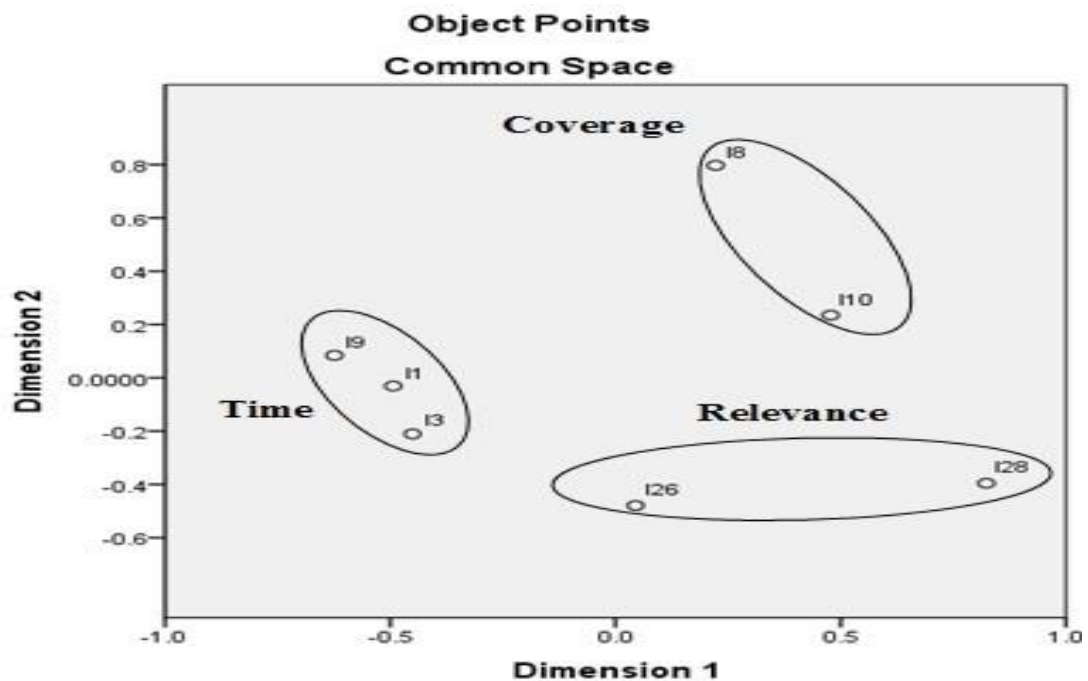


Figure 4.13: Conceptual map from reduced matrix

4.4.5 Findings

The traditional MDS approach revealed two clusters namely, “presentation time” and “presentation availability”. In contrast, the new MDS framework allowed for identifying three clusters that were labelled as presentation time, relevance, and coverage. The researcher was able to sort all remaining 23 comments, except two, into the three piles. The two comments not sorted were considered as emerging requirements. A group discussion with the sorters offered a confirmation of these findings. These results as compared to what was reported by Attar and Weheba (2015) support the value of the new framework and highlight its advantages over the conventional approach.

CHAPTER 5

CONCLUSIONS AND FUTURE RESEARCH

This chapter provides a summary of the research efforts, concluding remarks, and directions for future research.

5.1 Conclusions

An extensive review of the literature revealed that MDS has generally been utilized to summarize qualitative data in order to help researchers identify general structures. Given the difficulties encountered in interpreting structures in more than two dimensions, researchers are often tempted to represent scatters with considerably fewer dimensions. Excessive reductions in dimensionality may hide new requirements or cause them to falsely merge with others. The size of the similarity matrix depends on the number of comments (units of analysis) to be analyzed. In studies involving a large number of units, it may be more beneficial to reduce the size of the similarity matrix before preparing the MDS map. In other words, the researcher should seek a considerably smaller matrix representation. This would increase the chances that rare units (representing new requirements) are represented on the MDS map. Consequently, this research was aimed at the development of a new framework for performing MDS with the objective of validating known requirements and discovering new needs.

In achieving this objective, a new MDS-based framework for discovering customer requirements was developed. The proposed framework is represented in Figure 4.1 and includes six steps. In the first step, customer requirements are gathered and used to generate a total of N units of analysis. In the second step, these units are sorted by a selected group of customers. The results are used to construct a similarity matrix in the third step. It is worth noting here that these three steps are similar to the steps followed in the traditional approach. In the fourth step,

however, the matrix is reduced to a minimum size using a computer-aided algorithm. This reduction results in obtaining two different matrices, namely a reduced matrix and a remaining matrix. The reduced matrix is analyzed first using MDS and a conceptual map is constructed and labelled. To safeguard against excessive reduction, all units from the remaining matrix are considered in the last step to either confirm requirements or form new clusters.

An illustrative example was used based on a study by Attar and Weheba (2015). Application of the proposed framework resulted in identifying two emerging requirements that would have been overlooked by the traditional approach. These results were confirmed through a follow-up investigation by Attar and Weheba (2016). It is hoped that the new framework will help product designers as well as quality engineers gain a better understanding of customer requirements and their emerging needs.

5.2 Future Research

The current research could serve as a starting point for further investigations in the field of quality and customer satisfaction. The framework is easy to implement, and allows for identifying and discovering implicit customer requirements. It can be used to validate results of the traditional MDS and study the impact of representing the data in two dimensions. However, applications of the proposed framework could be further facilitated by the development of software with functions impeded to support all the steps involved. This would contribute to the reliability of results and help minimize bias.

Based on the literature review and the results of this research, the following areas are suggested for future research.

- Dynamic Validation of Survey Design:

Because quality and customer satisfaction are dynamic concepts, customer expectations and perceptions are expected to follow. Surveys designed to measure customer satisfaction need to be validated periodically. Future research may target development of appropriate indices that can be used to determine both the magnitude and direction of the changes needed.

- Correlates of requirements:

In this research, it was assumed that the data were obtained from a homogeneous group of customers. No attempt was made to segment the data, for example by age, gender, race, marital status, or nationality. This may be useful in applications involving products or services offered to a large population of users. Future research in this area would target applications of the proposed framework to establish subgroups in the population based on newly identified needs. One of the objectives would be to correlate new requirements to a specific segment of customers.

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APPENDICES

APPENDIX A

MATLAB ALGORITHM FOR MATRIX REDUCTION

```
close all; clear all; clc
M30m=xlsread('M30.xlsx','Data','B2:AE33');
Ma=sum(M30m);
R=zeros(30,1);
for i=1:30;
    Rep=0;
    for j=i+1:30
        if Ma(i)==Ma(j)
            Rep=Rep+1;
            R(j)=1;
        end
    end
end
r=0;rr=0;
for i=1:30
    if R(i)==0
        r=r+1;
        Mr1(r,:)=M30m(i,:);
        IMr1(r)=i;
    else
        rr=rr+1;
        Mrr1(rr,:)=M30m(i,:);
        IMrr1(rr)=i;
    end
end
fprintf('Comments numbers are');
IMr1
fprintf('First reduced matrix');
r=0;rr=0;
for i=1:30
    if R(i)==0
        r=r+1;
        Mr(:,r)=Mr1(:,i);
    else
        rr=rr+1;
        Mrr(:,rr)=Mrr1(:,i);
    end
end
end
Mra=sum(Mr);
R1=zeros(length(Mra),1);
for i=1:length(Mra)
    Rep=0;
```



```

    for j=i+1:length(Mra)
        if Mra(i)==Mra(j)
            Rep=Rep+2;
            R1(j)=1;
            R1(i)=1;
        end
    end
end
r=0;rr=0;
for i=1:length(Mra)
    if R1(i)==0
        r=r+1;
        Mr2(r,:)=Mr(i,:);
        IMr2(r)=IMr1(i);
    else
        rr=rr+1;
        Mrr2(rr,:)=Mr(i,:);
        IMrr2(rr)=IMrr1(i);
    end
end
r=0;rr=0;
for i=1:length(Mra)
    if R1(i)==0
        r=r+1;
        Mrf(:,r)=Mr2(:,i);
    else
        rr=rr+1;
        Mrrf(:,rr)=Mrr2(:,i);
    end
end
Mrfa=sum(Mrf);
R2=zeros(length(Mrfa),1);
for i=1:length(Mrfa)
    Rep=0;
    for j=i+1:length(Mrfa)
        if Mrfa(i)==Mrfa(j)
            Rep=Rep+2;
            R2(j)=1;
            R2(i)=1;
        end
    end
end
r=0;rr=0;
for i=1:length(Mrfa)
    if R2(i)==0
        r=r+1;

```

```

        Mr22(r,:)=Mrf(i,:);
        IMr22(r)=IMr2(i);
    else
        rr=rr+1;
        Mr22(rr,:)=Mrf(i,:);
        IMrr22(rr)=IMr2(i);
    end
end
r=0;rr=0;
for i=1:length(Mrfa)
    if R2(i)==0
        r=r+1;
        Mrf2(:,r)=Mr22(:,i);
    else
        rr=rr+1;
        Mrf2(:,rr)=Mr22(:,i);
    end
end
end
if size(Mrf2,1)<3;
    Mr
end
% Mrfa=sum(Mrf);
s= sum(Mr);
stdv = std(Mr);
R_with_sum = zeros(length(s),1);
R_with_stdv = zeros(length(s),1);
for i=1:length(s)
    Rep=0;
    Rep1=0;
    for j=1:length(s)
        if i ~= j
            if s(i)==s(j)
                Rep=Rep+1;
                R_with_sum(i)=1;
            end
            if stdv(i)==stdv(j)
                Rep1=Rep1+1;
                R_with_stdv(i)=1;
            end
        end
    end
end
end
jjj=1;
for i=1:length(s)
    if R_with_sum(i,1)==0
        IMrrr(jjj)=IMr1(i);
    end
end

```

```

        nuMr(:,jjj)=Mr(:,i);
        jjj=jjj+1;
    end
end
M = nuMr
A = Mr
B = A*M
C = transpose(M)
D = C*B
E = C*M
F = inv(E)
fprintf('Comments numbers are')
IMrrr
fprintf('Second reduced matrix');
G=F*C*B
fprintf('This is the matrix with minimum size');

```

APPENDIX B

LIST OF COMMENTS

S1	Presented the paper on time
S2	Focus more on the applications
S3	Covered material in paper in good time
S4	The paper was presented briefly
S5	Did not exceed the time
S6	Too long but understandable
S7	Time management
S8	Number of students in group
S9	It was a long presentation
S10	Everyone did so well
S11	It was lengthy
S12	Record presentation using Panopto
S13	Presentation was long
S14	Timing and easy decipher to the audience
S15	Was bit lengthy
S16	Time management and distribution
S17	Time usage, more explanations
S18	Presentation time and manner
S19	Finish the presentation as soon as possible
S20	Too lengthy and most of the topics were vague
S21	Time management
S22	The time was appropriate
S23	It was not long
S24	The presentation time management
S25	Too long
S26	Access to PowerPoints slides
S27	The length of the presentation
S28	We need verbatim form the text
S29	Too long presentation
S30	Time management and table explanation

APPENDIX C

SATISFACTION SURVEY

IME 854: Quality Engineering Fall 2015						
Perceptions of Presentation's Quality						
Topic: _____			Date: _____			
Please tell us about yourself:						
Your gender	<input type="checkbox"/> Male	<input type="checkbox"/> Female				
Your age group	<input type="checkbox"/> Under 30	<input type="checkbox"/> Above 30				
Your status	<input type="checkbox"/> Single	<input type="checkbox"/> Married				
Are you an international student?	<input type="checkbox"/> Yes	<input type="checkbox"/> No				
What is your degree program?	<input type="checkbox"/> Master	<input type="checkbox"/> PhD				
What is your department?	<input type="checkbox"/> IME	<input type="checkbox"/> Other	Specify: _____			
Did you read this paper before class?	<input type="checkbox"/> Yes	<input type="checkbox"/> No				
Please evaluate the presentation:						
#	Question	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
1	The organization and content of the slides are adequate	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2	Figures and tables were properly utilized and explained	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3	Appropriate examples were used to explain the concepts covered in the paper	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4	The presenters had equal chance to participate in the presentation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5	The group utilized appropriate time to represent the paper	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6	Overall, the manner of presentation (voice level, clarity of speech, etc.) was satisfactory	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7	The group successfully answered all questions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8	The slides provided are useful and will help me remember the topics presented	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9	In general, I am satisfied with this presentation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10	What did you like most about the presentation?					
11	What did you like least about the presentation?					
12	In what ways would you like to see this presentation improved?					