An Integrated Model for Supplier Quality Evaluation

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ABSTRACT

An Integrated Model for Supplier Quality Evaluation

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Supplier quality evaluation is a multi-criteria decision-making (MCDM) problem that involves multiple, heterogeneous criteria of different weights. The literature addresses quality, delivery, technology, value and service as the five most common criteria used for supplier quality evaluation. In this thesis, we have considered the most important criteria for evaluating the quality of suppliers based on a review of the literature and observation in practice. They include both qualitative and quantitative criteria to reflect the real attributes of the supplier in question, and are applied in a supplier quality evaluation performed for a large data set.

We propose a three-stage model for performing supplier quality evaluation. In the first stage, we identify the evaluation criteria and assign a weight to each criterion. The analytic hierarchy process (AHP) technique is used in this stage. In the second stage, we address the large size of suppliers' datasets and present a cluster-analysis-based approach to obtain manageable supplier datasets for evaluation purposes. In the third stage, we apply the VIKOR method to evaluate supplier quality in the clusters obtained from the previous stage. A numerical application is provided to demonstrate the proposed approach.

The strength of the proposed model lies in the integrated application of the three techniques, in which each technique is best suited for its respective problem. The model's other chief advantage

is its ability to deal efficiently with the challenge of evaluating large numbers of suppliers and the data pertaining to their attributes.

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Table of Contents

List of Figures

List of Tables

List of Acronyms

AHP	Analytic hierarch process
ANP	Analytic network process
CA	Cluster analysis
CBR	Case-based-reasoning
CFM	Cost factor measure
CI	Consistency Index
CIP	Continuous improvement program
CR	Consistency ratio
DEA	Data envelopment analysis
ELECTRE	ELimination Et Choix Traduisant la REalité (ELimination and Choice Expressing REality)
ETO	Engineer to order
FCM	Fuzzy Cognitive Map
FPP	Fuzzy preference programming
GA	Genetic Algorithm
ISO	International Organization for Standardization
JIT	Multi-attribute utility theory
MCDM	Multi-criteria decision-making
MCGP	Multi-choice goal programming
MILP	Mixed integer linear programming
MOLP	Multi-objective linear programming,

MOMILP	Multi-objective mixed integer linear programming
MP	Mathematical programming
MTO	Make to order
MTS	Make to stock
NNB	Neural network based
OEM	Original equipment manufacturers
PAF	Prevention, Appraisal & Failure
PROMETHEE	Preference Ranking Organization METHod for Enrichment Evaluation
RI	Random index
SA:	Simulated annealing
SMART	Simple multi-attribute rating technique
SOFM	Self-Organizing Feature Map
TCO	Total Cost of Ownership
TEU	Total Expected Utility
TOPSIS	Technique for order preference by similarity to an ideal solution
TQM	Total Quality Management
VIKOR	Vlse Kriterijumska Optimizacija Kompromisno Resenje

Chapter 1:

Introduction

1.1 Introduction

Supply chains are the nervous system that innervates and sustains modern business. Supply chains consist of several organizations, which can be classified into five main categories: suppliers, manufacturers, distributors, retailers and customer (See figure 1.1). These organizations rely on each other, as shown in figure 1.2, which depicts the flow of raw materials directly from supplier to manufacturer all the way to the customer. Alternatively, one manufacturer may receive components from several suppliers and deliver products to many retailers. The concept of the supply chain is premised on the flow of products or services and costs in one direction and the flow of information (or demands) in the other direction. All organizations are directly or indirectly associated with supply chains. Businesses seek to integrate with their supply chain both to minimize their total costs and to increase service levels.

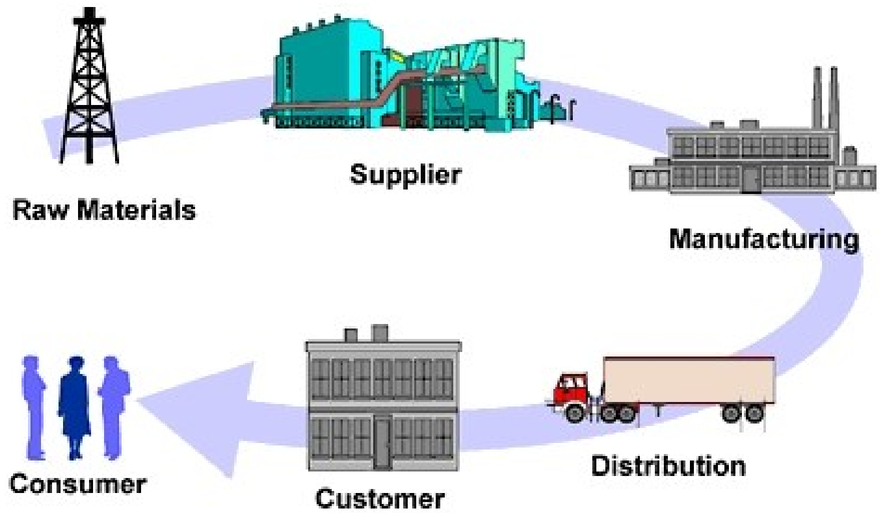

Figure 1. 1: Supply chain members

Flow of the right information between the organizations in supply chains plays an important role in reducing the “bullwhip effect”, as capacity planning to meet consumer demand are based on demand forecasts, not the actual demand. Reducing the bullwhip effect leads to increased profitability, increased product availability, decreased replenishment lead-time, and decreased costs of manufacturing, inventory, transportation, shipping and receiving (Chopra & Meindl, 2007).

Figure 1.2 suggests that between each chain member there is a cycle of ordering and receiving, thereby amounting to four cycles: the procurement cycle between supplier and manufacturer, the manufacturing cycle between manufacturer and distributor, the replenishment cycle between distributor and retailer, and the customer order cycle between retailer and customer (Chopra & Meindl, 2007). However, the cycles in any supply chain are not necessarily obvious. For example, the replenishment cycle of the manufacturer that sells to the end customer directly without intermediates (distributor & retailer) in its supply chain is not immediately apparent to a casual observer.

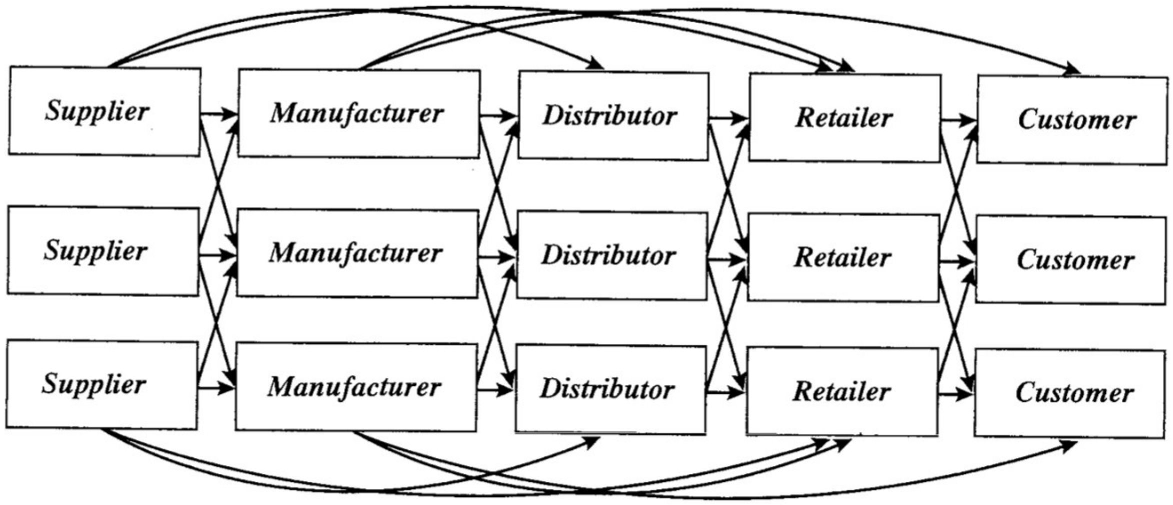

Figure 1.2: Interactions of supply chain members

Figure 1.3 presents a schematic diagram of the four typical cycles among supply chain members. In any given supply chain, however, the cycle of procurement should be identified and recognized clearly as it is the first step in reducing cost of quality in supply chain. In this thesis, we will limit the focus of our study to the procurement function (outsourcing) of organizations.

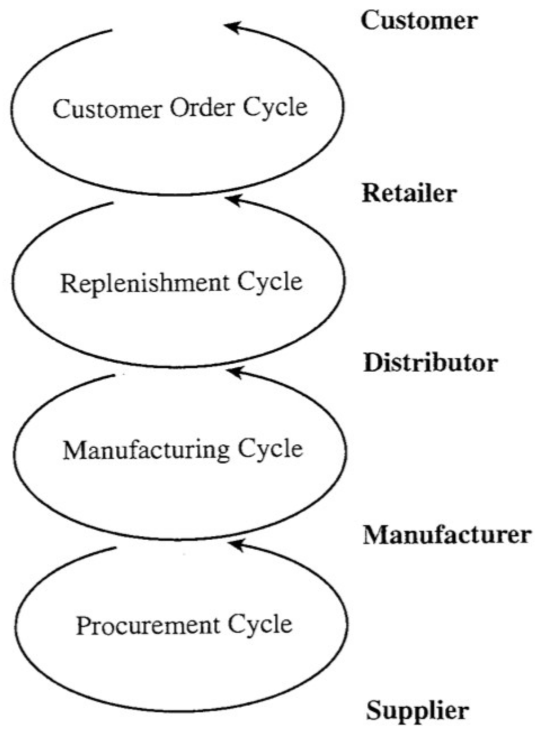

Figure 1.3: The four cycles of supply chain members

1.2 Cost of Quality

Costs of Quality are the costs related to having defective products or services (Groocock, 1974). The Cost of Quality can be categorized as: Prevention costs, Appraisal costs and Failure costs (PAF). According to Groocock (1974), Foster (2010), and Dale & Plunkett (1999), Prevention costs are those related to preventing defects from occurring. They include the costs of supplier quality assurance, supplier assessment, training, and other related domains. Appraisal costs, meanwhile, are the costs associated with inspection or testing of products. They include any type of inspections, testing, material evaluation, supplier monitoring or ISO 9000:2008 qualification activities. Failure costs are those associated with the failure of product quality, which can be either (a) internal costs, which occur during production, or (b) external costs, which involve any product failure after its production, including during its ownership by the customer. Groocock

(1974), however, asserts that this conception of costs fails to emphasize “the purpose of action”. He stressed the importance of relating costs to the purpose of the preventive action taken in relation to the product, and proposed the following four categories of costs:

1. Screening: the costs of finding defective items and separating them from the conformed items;
2. Replacement of defectives: the costs of substituting defective items with conformed items;
3. Prevention of defectives: the costs of preventing defective items from occurring;
4. Improvement of screening: the costs of reducing screening costs by improving the effectiveness of the screening process.

Dale and Plunkett (1999) argue that there is no clear definition of quality costs upon which all can agree. They assert that the PAF Model is no longer applicable to all companies, given the predominance of new concepts such as TQM, according to which many quality-related activities cannot be clearly assigned to any part of the PAF model. Instead, they propose another approach that focuses on the relationship between suppliers, companies and customers. Its central idea is that “the costs categorized under ‘supplier’, ‘company’ and ‘customer’ headings are more closely related to the way companies operate” (Dale & Plunkett, 1999). Suppliers, as providers of material, are one of the most important determiners of quality in any supply chain; therefore examining a supplier’s quality-related activities is of utmost importance.

1.2.1 Supplier Quality

Today, many products are either copied from the original product of its type, reproduced with poor materials, or both. What makes these products substandard is primarily the poor quality of the materials from which they were made. These products tend to be highly unreliable and once they break or malfunction, they cannot be fixed. For example, last year the Chinese police arrested people who manufactured copies of the iPhone (a smart cell phone) that were of very poor quality compared to that of the original, which is trademarked by Apple, Inc (O'Dell, 2012).

Usually, the quality of a product depends on the practices of the supplier. For this reason, most big companies, such as Boeing, for example, carefully choose their suppliers. They know that the standards and operative practices of a supplier have significant impact on buyers' profits, because they determine product quality and affect the development and speed of production processes. In fact, according to the Harvard Business Review on Supply Chain Management (2006), from 1996 to 2002, the top 100 American manufacturers had increased the proportion of their spending on materials from 43 cents per dollar in 1996 to 48 cents in 2002, showing an increasing reliance on suppliers. According to the same source, the top three automobile companies in the US – Ford, GM and Chrysler – could not compete with the two major Japanese car companies, Toyota and Honda. The reason for this is that these latter two companies have been able to build a "close-knit network of vendors", enabling them to produce cars faster than the three US companies (taking approximately half the production time), with more reliable products, by sourcing 70% to 80% of their manufacturing costs to US suppliers. Their success has come from integrating the supplier with the company by sharing of learning from each other's practices. For example, in 1987, Honda sent one of its engineers for 12 months to learn about the candidate supplier who worked there for a year and provided the supplier with suggestions to help them cope with Honda's production strategy. After one year, the candidate supplier agreed to all of Honda's recommendations. Years later, both Honda and the supplier reaped the benefits of this sharing of ideas, and the supplier's business increased steadily over the subsequent five years (Harvard Business Review on Supply Chain Management, 2006). The mutual benefit arose from the companies' cooperation in improving quality. Another example of the importance of selecting the right supplier is that of Boeing, a major manufacturer of aerospace vehicles and products, which has outsourced to Hamilton Sundstrand Company the manufacturing of nine systems of its 787 Dreamliner aircraft (Trent, 2008). As an aerospace manufacturer, Boeing has placed a high priority on choosing the highest quality suppliers to avoid crises and delay in delivery schedules. The chief reason behind its choice of Hamilton Sundstrand is that this company applies a lean strategy and closely involves suppliers in its business. In keeping with this approach, Hamilton Sundstrand sent a team of its workers to work on-site with its supplier for several months.

1.2.2 Benchmarking Quality

According to Boyer and Verma (2010), benchmarking is the process of comparing the practices of a company to the best practices of other companies. Benchmarking of quality involves comparing the quality performance of a given company with that of the best one in its practice domain. Many companies copy the best practices of other successful companies in order to gain maximum competitive advantage. The philosophy of Toyota JIT, for example, has been adopted by many companies. The examples mentioned in the previous sub-section of this chapter involve benchmarking of quality, where the buyer involved with a supplier ensures its fit with the buyer's regulations. Undoubtedly, the importance of benchmarking has grown to become a standard metric for improving quality.

1.3 Outsourcing Strategy

Most companies today depend on outsourcing to build their products. Outsourcing strategy has shown its effectiveness in increasing organizational profits through the development of better products when outsourced from the right supplier. According to Simchi-Levi (2003), outsourcing has the following benefits:

1. **Creating economies of scale**. This refers to the aggregation of orders from different customers to one supplier. This helps the supplier to reduce its manufacturing and purchasing costs, which leads to mutual benefits for both the supplier and the buyers alike, through the sale of the product at low cost.
2. **Risk pooling**. Outsourcing leads to reduced uncertainty in management of demands, since the demand is aggregated at the supplier facility from many buyers. This allows the supplier to handle the uncertainty of demand in a more efficient way.
3. **Reduction of capital investment**. Making the decision to outsource exempts the buyer from investing in manufacturing of the products. However, the capital investment that suppliers make is affordable for them, since they are dealing with many customers.
4. **Focus on core competency**. Outsourcing products that the buyer is not best at producing enables the buyer to focus on its core strengths.
5. **Increase in flexibility**. This can be achieved through faster reaction to customer demands, decreasing the duration of the product development cycle time and enhancing the company's ability to apply new technologies.

Any company would like to enjoy these benefits, but outsourcing may not be always the best strategy for a company to employ. Although relying on other companies has some benefits, it has some risks as well. In some instances, a company may be better off manufacturing supply components in-house.

The decision to outsource is made by a company's procurement or purchasing department. The decision involves many factors, and it gets more complex as the number of factors increase. We explore this issue in more detail in chapter 2. However, the challenging question that arises for outsourcing decisions is this: among the many suppliers available to a buyer, which one should it choose and on the basis of what factors?

1.3.1 Assessing Suppliers Quality

Once the decision to procure components from outside suppliers is made, a company typically has to choose from a large set of suppliers. Some of these suppliers may be local and others foreign (global). Most companies prefer local suppliers, but several factors may influence a company's decision to look globally for more distant suppliers. Some of these factors include superior quality and lower price of the components provided. Supplier quality evaluation involves many criteria to be considered when it comes to deciding which supplier to deal with. This makes it a multi-criteria decision-making problem, since some supplier attributes need to be maximized while the others need to be minimized. So, before looking for a supplier, companies typically need to examine a large list of criteria to evaluate the candidate suppliers. Moreover, as the number of relevant criteria increase, the decision of choosing the right supplier becomes more complex. Consequently, a combination of approaches or methods may be required to address this complexity problem. However, before employing such methods, a buyer should examine a list of criteria to evaluate suppliers and determine the weights to be given to each criterion.

1.4 Motivation

The problem of evaluating supplier quality is an interesting and complicated MCDM problem. Evidence of its complexity can be found from the fact that it is still an active subject in the literature, despite the presence of a many number of methodologies in literature. Dealing with multi-criteria problems forces decision-makers to accept trade-offs between criteria. There is no other way to generate solution for such problems except by seeking compromises as a supplier might be dominant in one criterion, but not in the others.

In this thesis, we propose a modeling framework for analyzing the quality of a large number of suppliers from different environments. Our review of the literature pertaining to supplier quality evaluation has not revealed any previous study for large sets. Most researchers have applied their model on a small set of suppliers. Some have evaluated suppliers based on very few criteria and in some cases; criteria may not be carefully evaluated. Unfortunately, most of their models do not provide a mechanism for efficient analysis of a large number of suppliers. It is commonly known that as the number of suppliers and criteria increase, the problem of evaluation becomes more difficult and needs more time to be resolved. Therefore, we propose to develop a comprehensive and efficient model to analyze this type of problem for tracking or monitoring the quality performance of suppliers.

1.5 Contribution

The proposed modeling framework integrates three methods that have heretofore been used separately for the purpose of evaluating supplier quality. Each of the methods was adopted for its strengths and advantages with respect to the problem under study. The first method is based on the Analytic Hierarchy Process (AHP) and concentrates on determining criteria and their weights. AHP has the ability to handle qualitative and quantitative criteria, simplifies the problem through building hierarchy, and is widely used and approved by many researchers and consultants for the purpose of prioritizing criteria.

The second method based on cluster analysis (CA) is used to manage large supplier data sets in such a way that suppliers with similar attributes are grouped together in clusters. Cluster analysis has the ability to group similar objects – in this case, suppliers – into clusters. Suppliers in a given cluster are more alike in many aspects than those in other clusters. CA technique was chosen for its ability to handle a large number of data efficiently and to guarantee that the best suppliers are not eliminated at least at the initial levels (Holt, 1996).

The third method based on VIKOR (Vlse Kriterijumska Optimizacija Kompromisno Resenje) technique is used to rank suppliers and select the best supplier(s) based on the overall criteria. The VIKOR method was selected for its ability to find the compromise solution that is closest to the ideal solution. The compromise solution is most likely to be accepted by decision-makers since it was developed on the basis of "the majority of criteria" rule (Opricovic & Tzeng, 2004).

Integrating these methods confers their respective advantages upon the model and enables it to handle the supplier quality evaluation problem in different ways: managing large data sets, evaluating or analyzing them, and ranking them quickly and efficiently. Moreover, this model can be used to monitor selected suppliers' performance after a period of cooperation through comparison of results at different stages and under different situations. The strength of the proposed model is that it works with both small and large sets of supplier data:, however, its chief purpose is to analyze large data sets, as demonstrated in chapter 5. In short, this model is capable of handling the multi-criteria problem on any scale of information.

1.6 Thesis Outline

Chapter 2 presents the problem statement.

Chapter 3 presents a literature review on supplier quality evaluation criteria and methods.

Chapter 4 defines the criteria and sets out the proposed model. The model consists of three stages. The first stage is used to determine the weight of each criterion. The second stage is used to pre-qualify suppliers. The third stage is used for selecting the best supplier.

Chapter 5 applies the proposed model by introducing the problem and applying the three stages model to the information presented.

Chapter 6 states the conclusions and future works.

Chapter 2:

Problem Statement

In this thesis, we address the problem of supplier quality evaluation, which is a multi-criteria decision-making problem. The problem consists of evaluating a large number of alternatives (suppliers) under a given set of criteria (quantitative or qualitative). According to Zanakis *et al*. (1998), most existing methods of supplier evaluation and selection are not suitable for application to a large number of alternatives, since these methods tend to generate inconsistencies. For this reason, the large data sets of suppliers must be treated in a way that overcomes this problem. To this end, the model will solve the following challenges:

1. How do buyers deal with large numbers of suppliers in heterogeneous business environments, that is, under different geographical location, product type and product volume conditions?
2. Which criteria should buyers use for supplier quality evaluation?
3. How should buyers rank criteria or decide criteria weights?
4. How should buyers deal with qualitative and quantitative criteria?
5. How should buyers generate supplier quality rankings?

All these issues will be answered in this thesis to achieve the goal of the proposed model.

Chapter 3:

Literature Review

3.1 Introduction

We will present the literature review on supplier selection and supplier quality evaluation under three categories:

- Pre-qualification of suppliers.
- Supplier quality evaluation models.
- Supplier selection (the best alternative) using outranking methods.

Figure 3.1 presents the commonly used methods reported in the literature to address the above problems.

3.1.1 Pre-Qualification of Suppliers

The purpose of Pre-qualification models is to reduce the set of all suppliers to a small and manageable set of suppliers. De Boer *et al.* (2001) introduce four methodologies for pre-qualification of suppliers. These methods are presented as follows:

3.1.1.1 Categorical methods

In this method, criteria are listed in matrix form along with the list of suppliers. Suppliers that do not satisfy a particular criterion are given a (-) mark, those that satisfy it receive a (+) mark, and those that are neutral in respect of the criterion receive a (0) mark. The supplier with the most (+) marks is selected (Lam *et al.*, 2010). This method is traditional and has limited applications.

3.1.1.2 Data envelopment analysis (DEA)

DEA is a linear programming method that calculates the ratio of weighted outputs to weighted inputs. This method is used to find the efficiency for each supplier by taking the ratio of the weight of the summed outputs to the weight of the summed inputs. Then, the supplier with the highest ratio is considered the best choice (De Boer *et al.*, 2001).

3.1.1.3 Cluster analysis (CA)

CA relies on a classification algorithm to group the suppliers in a number of clusters so that similar suppliers occur within defined classes. This algorithm can be applied either through hierarchical clustering or *k*-mean clustering to find out the set of suppliers that are qualified (Holt, 1998). It is important that the rating be expressed numerically.

3.1.1.4 Case-based-reasoning (CBR)

CBR uses artificial intelligence to generate relevant information for decision-makers on the basis of the similar and previous situations (De Boer *et al.*, 2001) for supplier selection purposes.

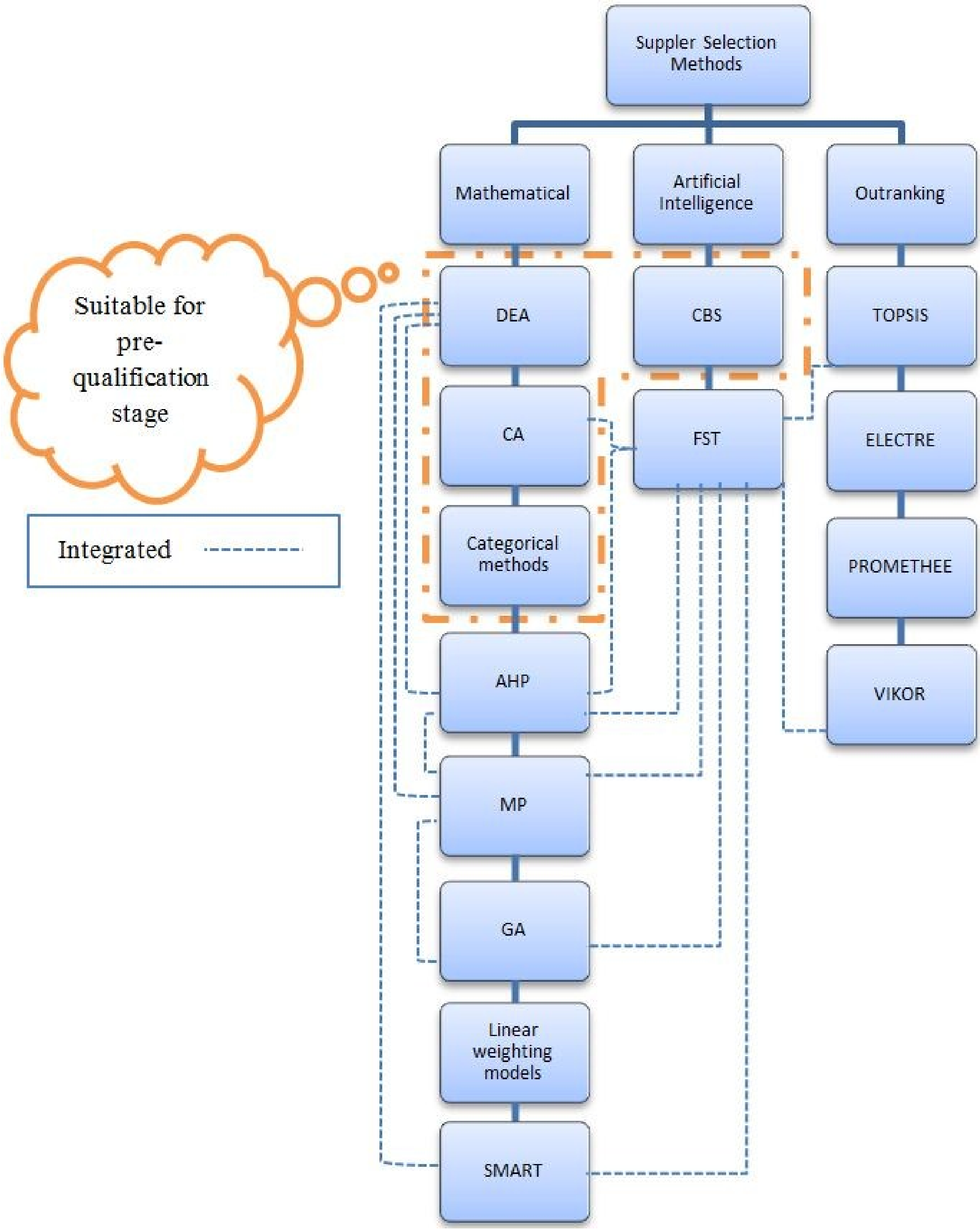

Figure 3. 1: Supplier quality evaluation and selection methods

3.1.2 Supplier Quality Evaluation Models

The supplier quality evaluation models can be categorized as follows:

3.1.2.1 Analytic Hierarchy Process (AHP)

AHP has been widely used for the purpose of supplier quality evaluation (Liu and Hai, 2005). The AHP method involves breaking down a complex problem into different levels. Once these levels have been identified, pairwise comparison is performed to find the interrelationships among them (Lam *et al.*, 2010). The AHP method has been combined with other methods such as Fuzzy theory, linear programming, goal programming and data envelopment analysis (Vaidya & Kumar, 2006) for the purpose of supplier selection.

3.1.2.2 Simple multi-attribute rating technique (SMART) / MAUT

(SMART) / MAUT method has the ability to deal with deterministic and stochastic decision environments. It is like the AHP method, which breaks down the complex problem to less complex problems and then evaluates the criteria. It can deal with both quantitative and qualitative criteria (Lam *et al.*, 2010). Barla (2003) was able to apply this method in five steps for glass manufacturing. The steps consist of generating criteria; selecting the attribute; developing the SMART criteria by giving a number between 0-100 to each attribute; determining the proportion valve of the attribute; and constructing the SMART evaluation form, in which the supplier that has the highest Total Expected Utility (TEU) is ranked as the first choice, and so on.

3.1.2.3 Analytic Network Process (ANP)

ANP is an advanced form of AHP where interaction between criteria and alternatives are considered. This method is used widely in supplier selection. It is used to detect or find the interaction between equivalent levels of criteria and to reduce the judgmental forecast error (Lam *et al.*, 2010).

3.1.2.4 Mathematical Programming

In Mathematical Programming (MP) methods, the decision-maker formulates the problem and proposes an objective function which needs to be maximized or minimized. However, one of the disadvantages of these methods is that they deal only with quantitative criteria (De Boer *et al*., 2001).Researchers have successfully applied mathematical programming to solve the supplier quality evaluation problem. Five techniques of mathematical programming are more commonly used. These are linear programming, integer programming, non-linear programming, goal programming and multi-objective programming.

3.1.2.5 Genetic Algorithm (GA)

The GA works as a search algorithm, through which the good chromosomes survive, to be reproduced again, enabling a solution to be found in a short search period. Ding *et al*. (2005), used GA as an optimizer in simulation operations to solve the supplier quality evaluation problem.

3.1.2.6 Fuzzy Set Theory

This method has been integrated with many other methods to select the right supplier. The benefit of this method is its capacity in dealing with the imprecision and uncertainty of subjective judgment. It can work with qualitative and quantitative variables. When used with qualitative data, linguistic values are selected based on the triangular fuzzy numbers concept. It is also used to assess the weight to be given to criteria. For more information, the reader may refer to Chen *et al.* (2006), who integrated this method with the AHP and TOPIS methods.

3.1.2.7 Linear weighting models

According to De Boer *et al*. (2001), the linear weighting method is a straightforward approach whereby the weight given to a criterion is multiplied by its corresponding criterion value, and then the rating for each alternative is summed and the one that has the highest rating is selected. This method was used in the basic model. However, different versions were later suggested with little improvement.

3.1.3 Selection of the Best Alternative Using Outranking Methods

A variety of ranking methods have been proposed in literature to find the best supplier. Some of these are TOPSIS, ELECTRE, PROMETHEE and VIKOR. A general overview of these methods is given below:

3.1.3.1 TOPSIS

This method finds the best solution based on the shortest distance to the ideal solution and farthest distance from the negative-ideal solution (Lai *et al*., 1994). It can be used with both qualitative and quantitative criteria. The final results of the rankings are based on the alternative distance from the positive ideal and negative-ideal solution. The first-ranked alternative has the shorter value and is the best choice.

3.1.3.2 ELECTRE

This is considered to be the first outranking technique applied for the purpose of ranking alternatives. The honor of its discovery goes back to Roy and SEMA Company in 1965 (Figueira *et al*., 2005). ELECTRE is a preference-based model. For example, if there are alternatives (a) and (b), it compares them to find whether (a) or (b) is strictly preferred to the other, or there is no difference between them, or they are incomparable. Since the original ELECTRE method, a number of versions have come up. Some of these are ELECTRE II, ELECTRE III, and ELECTRE IS, each of these is applicable to a specific type of problem.

3.1.3.3 PROMETHEE

PROMETHEE is similar to the ELECTRE method, but the concept differs in that this method considers the outranking flows for evaluating alternatives. The concept is built on pairwise comparison between alternatives, and calculating two outranking flows for each alternative, namely positive and negative outranking flows. The positive outranking flow gives a measure of how the alternative outranks all the others, while the negative outranking flow gives a measure of how the alternative is outranked by all the others. The higher the alternative value is in positive flow, the better the alternative is; the lower the alternative is in positive flow, the better the other alternatives are (Figueira *et al.*, 2005). As with ELECTRE, a number of versions of this method have been created, such as PROMETHEE I, PROMETHEE II, and PROMETHEE GAIA.

3.1.3.4 VIKOR

VIKOR method finds the compromise solution from a set of alternatives based on the nearest distance to the ideal solution. The method can be applied to a mixture of data. It uses L_p –metric procedures to generate the compromise solution. Its strongest feature is its consideration of “the maximum group utility" rule by integrating the weight of the decision-making strategy (v) into its calculation. Voting is considered to be by majority rule where the weight of the decision-making strategy is greater than 0.5, "by consensus" if equal 0.5, or "by veto" if less than 0.5 (Opricovic & Tzeng, 2004; 2007).

Table 3.1 illustrates the advantages and limitations of some supplier quality evaluation methods developed based on the work of Jain *et al.*, (2009).

Categorical		Mathematical programming		Analytic hierarchy process	
Advantages	**Limitations**	**Advantages**	**Limitations**	**Advantages**	**Limitations**
Can include both qualitative and quantitative criteria	Equal weight to all criteria	Can guarantee optimum solution	Difficult to include multiple decision makers	Hierarchical representation of a system, can be used to describe how changes in priority at upper levels affect the priority of criteria in lower levels	Use of statistical method is clearly not straightforward for most users and it makes the process quite cumbersome
Easy implementation	Subjective	Objective evaluation	Requires arbitrary aspirations levels	Stable and flexible; stable in that small changes have a small effect and flexible in that additions to a well-structured hierarchy do not disrupt the performance	Cannot effectively take into account risk and uncertainty in assessing the suppliers' potential performance because it presumes that the relative importance of criteria affecting suppliers' performance is known with certainty

Table 3.1: Difference between categorical, MP and AHP methods

Categorical		Mathematical programming		Analytic hierarchy process	
Advantages	**Limitations**	**Advantages**	**Limitations**	**Advantages**	**Limitations**
Lowest implementation cost			In LP/MIP. Allow only one objective function and the rest are constraints	The suppliers' performance can be monitored or at least visible to the buyer to a certain extent leading to better management of suppliers	This may be a time-consuming activity as consensus may need to be reached by reviewing the models with team members
Requires minimum data			Objective function coefficients should be determined prior to making the model		Characteristic property of AHP is that it is fully comparison based that this might not always be realistic. In addition, the assumption of comparability is not valid due to lack of information or unwillingness to compare two alternatives with respect to some criterion i.e. it is costly to obtain necessary information

Table 3.1: Difference between categorical, MP and AHP methods

3.2 Supplier Quality Evaluation Criteria

Table 3.2 presents the most commonly used supplier quality evaluation criteria and methods reported in literature. Supplier quality evaluation criteria were first proposed by Dickson in 1966, when he listed 23 criteria for supplier quality evaluation based on a survey of purchasing agents and managers. Dickson's criteria for supplier quality evaluation are presented in Table 3.3.

It can be seen in table 3.3, that quality is the most important criterion for supplier quality evaluation, followed by delivery. However, this survey was conducted 45 years ago, in 1966. Nowadays, many salient features of supply and production have changed with globalization and technological progress. However, most of these criteria are still valid for evaluation purposes. Weber *et al.* (1991), studied all the literature pertaining to supplier quality evaluation criteria that had been published from Dickson's paper until 1991. They found that each of the 74 articles has at least one of the criteria that Dickson mentioned. Moreover, 64% of these articles mentioned at least two of Dickson's criteria. Weber *et al.* (1991), also studied thirteen articles related to JIT philosophy in order to see which of Dickson's criteria were mentioned in them. Their results are listed in table 3.4.

Author	Method	Criteria
Aksoy & Öztürk (2011)	NNB	Quality, JIT Delivery performance, Location and Price
Chen et al (2006)	Fuzzy TOPSIS	Profitability of supplier, Relationship closeness, Technological capability, Conformance quality and conflict resolution
Shemshadi et al (2011)	Fuzzy VIKOR	Products quality, Effort to establish cooperation, Supplier's technical level, Supplier's delay on delivery and Price/Cost
Bhattacharya et al (2010)	AHP-QFD-CFM	Delivery, Quality, Responsiveness, Management, Discipline, Financial position, Facility and Technical capabilities
Chou & Chang (2008)	Fuzzy SMART	Cost, Quality, Delivery, Organizational culture and strategy and Technical capacity
Lin (2009)	ANP-FPP-MOLP	Quality, Delivery, Price and Technique
Kilincci & Onal (2011)	Fuzzy AHP	Financial status, Management approach, Technical ability, Quality systems and process, Geographical location, Production facility and capacity, Working with Kanban approach, Product price, Handling, Product Quality, Follow-up, Technical support, Lead time and Professionalism
Sanayei et al (2010)	Fuzzy VIKOR	Product quality, On-time delivery, Price, Supplier's technological level and Flexibility
Dulmin & Mininno (2003)	PROMETHEE GAIA	Mark-up, Processing time, Prototyping time, Design revision time, Quality system, Co-design and Technological levels
Liao & Kao (2011)	fuzzy TOPSIS-MCGP	Relationship closeness, Quality of product, Delivery capabilities, Warranty level and Experience time
Liao & Kao (2010)	Taguchi loss function, AHP-MCGP	Product quality, Delivery time, Price, Service satisfaction, Warranty degree, Experience time and Financial stability
Toloo & Nalchigar (2011)	DEA-MILP	General
Z.H.,Che (2012)	CA-SA-AHP and Taguchi method	Production cost, Product quality and Production time
Demirtas & Üstün (2008)	ANP-MOMILP	Quality, Costs, Opportunities and Risks
Ghodsypour & O'Brien (1998)	AHP and LP	Cost, Quality, On-time Delivery and Capacity

Table 3.2: Supplier quality evaluation criteria and methods

Author	Method	Criteria
Chen & Yang (2011)	Fuzzy AHP and Fuzzy TOPSIS	Product price, Product quality, Delivery time and Risk
Chan and Chan (2004)	AHP	Cost, Quality, Delivery, Service, Flexibility and Innovation
Hong *et al*. (2005)	CA and MINP	Quality, Price, Frequency and Quantity
Choy *et al*. (2005)	CBR	Price, Quantity, Delivery, Innovation level, Level of technology, Culture, Commercial awareness, Production flexibility, Ease of communication and Current reputation
Jain *et al*. (2004)	Fuzzy GA	Part rejection rate, Delivery performance, Residual stress and Surface finish
Wang *et al*. (2004)	AHP-GP	Delivery reliability, Flexibility and responsiveness, Cost and Assets
Talluri and Narasimhan (2003)	LP	Price, Rejects and Late deliveries
Sarkis and Talluri (2002)	ANP	Cost, Quality, Time, Flexibility, Culture, Technology and Relationship
Barla (2003)	SMART	Quality organization, Service, Geographical condition, Reliability of subcontractor, Capability of subcontractor and Financial condition
Ramanathan (2007)	DEA-TCO-AHP	Costs Manufacturing, Quality costs, Technology and After-sales service
Karpak *et al*. (2001)	GP	Product cost, Quality of castings purchased, Capacities of each supplier, Demand and Delivery reliability of castings purchased
Wadhwa and Ravindran (2007)	Weighted objective, GP and Compromise programming	Price, Lead time and Quality
Aydin Keskin *et al.* (2010)	Fuzzy ART	Producing critical/safety part, Producing similar part, Having technically adequate employee and equipment, Having adequate production capacity, Existing test capability, measurement and control apparatus, Ability of managing diversification, Ability of design and improvement, Financial capability to reach raw material, semi-finished product and other resources, Suitable price policy and payment periods, Using/providing its certificates effectively, Existent dispatching performance or dispatching problems, Ability of packing, transportation and logistics demands, Geographical location, Applications of work safety and labor health and Environmental effects and preventive actions

Table 3.2: Supplier quality evaluation criteria and methods

Author	Method	Criteria
Xiao *et al*. (2012)	FCM-fuzzy soft	Quality risk of the product, Service risk, Supplier's profile risk and Long-term cooperation risk
Zeydan *et al*. (2011)	fuzzy AHP, fuzzy TOPSIS-DEA	New Project Management, Supplier Management, Quality and Environmental Management, Production Process Management, Test and Inspection Management, Corrective & Preventive Actions Management, Defect Ratio, Warranty Cost Ratio and Quality Management
Florez-Lopez (2007)	fuzzy SOFM	Responsiveness, Commit to improvement, Delivery mistakes, Cost reduction effort, Delivery delays, Price, Reliability, Commit to quality, Fluctuation on costs, Order mistakes, Outgoing quality, Timely communication, Customer service and Technical assistance

NNB:Neural Network Based, CFM: cost factor measure, ANP: Analytic network process, FPP: Fuzzy preference programming, MOLP: Multi-objective linear programming, MCGP: multi-choice goal programming, MILP: mixed integer linear programming, SA: simulated annealing, MOMILP: multi-objective mixed integer linear programming TCO: Total Cost of Ownership, FCM: Fuzzy Cognitive Map, SOFM: Self-Organizing Feature Map.

Table 3.2: Supplier quality evaluation criteria and methods

Rank	Factor	Mean Rating	Evaluation
1	Quality	3.508	Extreme importance
2	Delivery	3.417	Considerable importance
3	Performance History	2.998	
4	Warranties and claim policies	2.849	
5	Production facilities and capacity	2.775	
6	Price	2.758	
7	Technical capability	2.545	
8	Financial position	2.514	
9	Procedural compliance	2.488	Average importance
10	Communication system	2.426	
11	Reputation and position in industry	2.412	
12	Desire for business	2.256	
13	Management and organization	2.216	
14	Operating controls	2.211	
15	Repair service	2.187	
16	Attitude	2.12	
17	Impression	2.054	
18	Packaging ability	2.009	
19	Labor relations record	2.003	
20	Geographical location	1.872	
21	Amount of past business	1.597	
22	Training aids	1.537	
23	Reciprocal arrangements	0.61	Slight importance

Table 3. 3: Dickson's supplier quality evaluation criteria

Criteria	Number of mentioned out of 13	Ranked in Dickson's Table
Quality	13	1
Delivery	13	2
Price	8	5
Geographical location	7	20
Production facilities & capacity	6	6

Table 3.4: Mentioned criteria in JIT's articles as concluded by Weber *et al.*, (1991)

Notice that even with 45 years difference; these criteria still have relevance. Dickson's table ranked geographical location as 20th out of the 23 criteria (average importance). When it comes to supplier quality evaluation using JIT philosophy criteria, it might be considered in a more advanced position than under Dickson's ranking.

Huang and Keskar (2007) proposed comprehensive metrics for supplier quality evaluation of original equipment manufacturers (OEMs). They came up with a list of metrics for seven categories under three divisions: "reliability, responsiveness and flexibility" in the product-related division; "cost and financial" and "assets and infrastructure" in the supplier-related division; and safety and environment in the society division. Additionally, they considered three types of products in their construction of the metrics: make to stock (MTS), make to order (MTO), and engineer to order (ETO). They came up with a total of 101 metrics for supplier quality evaluation for OEMs. For the list of metrics, the reader may refer to the original paper by Huang and Keskar (2007).

3.3 Practices in Supplier Quality Evaluation

A. ISO 9000 and ISO 14000 Standards

The International Organization for Standardization (ISO) is well-known for developing a set of standards that "makes the development, manufacturing, and supply of products and services more efficient, safer and cleaner" (Boyer & Verma, 2010). The ISO has created several standards, but the best-known ones are ISO 9000 and ISO 14000. ISO 9000 is used for assessing quality requirements, while ISO 14000 is a standard for environmental quality management. Both are known as "generic management system standards" because they can be applied to any product, service or material (Boyer & Verma, 2010). An ISO certificate can be given to any organization after it prepares its documents containing a description of its business practices in line with the guidelines provided by ISO. According to Liao *et al*. (2004), acquiring ISO 9000 has the following benefits for an organization:

1. **Access to markets**. ISO 9000 certification helps organizations maintain their number of customers or even increase them. The European Community Council requires specific sectors to have them in order to establish their work.
2. **Customer demand**. It is required by customers who prefer that suppliers have it.
3. **Improvement of the company's quality system**. Getting the certificate helps the organization to improve its quality system and prepare itself for auditing or surveillance by the ISO.
4. **Other advantages**. The certificate is well-known around the world, and can improve quality through improving an organization’s overall competitiveness.

B. Boeing Quality Management System Requirements for suppliers

On its website, www.boeingsuppliers.com, Boeing has listed its requirements for the suppliers that it prefers to work with. Some of these suppliers’ requirements for quality management systems include the following (for all requirements, the reader may refer to Boeing, 2012):

1. Has ISO 9001 as supplemented by 9100 and not limited to AS9100C, EN9100 and JISQ 9100;
2. Has AS/EN/JISQ 9100 certified by an accredited Certification Body listed in the International Aerospace Quality Group's (IAQG) OASIS database;

3. Maintains AS/EN/JISQ 9100 transition timeline; and
4. Manages the variation of key characteristics (KCs) by having statistical control and capability of KCs, and identifies improvement opportunities and implementation of improvement actions.

C. Bombardier's suppliers

Bombardier is an aerospace manufacturer that deals with a large number of suppliers – nearly 3000 suppliers from 20 countries (Bombardier, 2012). According to their website (2012) Bombardier has two types of supplier qualification criteria: those directly related to aircraft and those indirectly related to aircraft. Suppliers who have products directly related to aircraft must have the following requirements: AS 9100, National Aerospace and Defense Contractor Accreditation Program (NADCAP) and quality requirements. Meanwhile, suppliers supplying products indirectly related to aircraft must meet these requirements: ISO 9000 (for tooling, tooling fabrication and cutting tools) and if possible ISO 14000. However, in general, Bombardier considers the following criteria for all suppliers during the process of selection:

1. Willingness and ability to share market risk;
2. Ongoing performance;
3. Systems or service facilities' capabilities;
4. Financial strength;
5. Location; and
6. Certifications.

Moreover, Bombardier's preferred suppliers must sign onto a commitment to keep high labor standards and to regularly self-audit their performance. In these agreements, Bombardier retains the right to investigate and audit suppliers in the following areas:

1. Human rights and labor law
2. Health
3. Safety
4. Environment and governance standards
5. Anti-corruption behavior and
6. Ethics

Bombardier asks its candidate suppliers who have all the above-mentioned criteria to fill out a supplier pre-selection form for the purpose of evaluating the quality of the supplier when Bombardier needs a supplier. In addition, Bombardier selects the suppliers that match its strategic focus on delivering superior engineering, quality and supply chain excellence.

D. Bell Helicopter Supplier Quality

Bell Helicopter chooses its suppliers based on an approved list of suppliers. This list contains 14 criteria, as following (Bell Helicopter Textron Company, 2012):

1. Position in Industry
2. Technology
3. Capacity
4. Competitiveness

5. Responsible for Engineering, Development and testing
6. Warranty Commitment
7. Full Service Capabilities (Program management and design capable)
8. Participation in Cost Reduction Programs
9. Progressive Culture with Continuous Improvement Philosophy
10. Service and Support
11. Responsiveness to requests for quotes, technical assistance and e-business
12. Effective Problem Resolution
13. Proactive Approach to Defect Prevention and Continuous Improvement
14. Location

Suppliers that meet these criteria provide Bell Helicopter with high service level “in the areas of quality and delivery performance, cost reduction, technology, diversity content, quality system and registration”. Suppliers, who do not deliver this level of service, are asked to do corrective actions otherwise they will be removed from the list of suppliers.

E. Rolls Royce

Rolls Royce selects their suppliers based on supplier’s overall capability evaluation that involves three factors: economical, environmental and social (Rolls Royce, 2012). Moreover, the process of approving candidate suppliers, when appropriate, is performed through Supplier Total Evaluation process. This process has several assessments to keep supplier providing the highest level of performance and assessing supplier capability.

Rolls Royce has supplier quality and development organization that includes the following tasks:

1. Supplier approval and maintenance: responsible for the approved supplier list.
2. Supplier development: responsible for supplier' development, improvement, control of nonconformance and for driving root cause analysis for supply chain problems.
3. Supplier Quality: responsible for verification of products in the supply chain through process' observation, inspection and documentation review.
4. ME-P: Manufacturing Engineers responsible for advice supplier about a product or process related issues and to ensure that suppliers have the manufacturing capability.

F. IBM

IBM has minimum requirements for its suppliers and sub-suppliers. One of these requirements is that supplier should have quality program that controls its manufacturing process. Moreover, supplier should measure quality on a continuous basis and report it to IBM. To prevent defective products from occurring, process controls are required. Any quality related problems should be studied and analyzed so that the cause is identified and a set of correction actions is proposed. Supplier or sub-supplier should conduct a continuous improvement to reduce defects and maintains agreed annual goals (IBM, 2011).

G. GE Energy

According to GE Energy (2006), supplier should have ISO 9001-2000 certification or any equivalent certification in order to ensure that the production will be in control and fit to GE specifications. However, supplier with no certificate could satisfy above requirements after successfully completing a quality systems audit.

GE has the following requirements to approve suppliers:

1. Properly executed Mutual Non-Disclosure Agreement (MNDA)
2. Acknowledgement of the GE Integrity Guide for Suppliers, Contractors, and Consultants
3. Quality system assessment
4. Technical assessment
5. Environmental, Health and Safety (EHS) and Employment Practices compliance
6. Financial viability assessment.

H. Dell

To do business with Dell, supplier needs to meet some standards. The suppliers at Dell need to cover following priorities and standards (Dell, 2012):

1) Certification and Standards: ISO 14001, occupational health and safety management system standard OHSAS 18001 and ISO 9001. And are willing for

2) Capability Building and Assessment:

   a) Training

   b) Continuous Improvement

   c) Quarterly Business Reviews

   d) Monitoring

3.4 Multiple Criteria Decision Making

Multiple Criteria Decision Making (MCDM) problems involve selecting or choosing the best alternative(s) from a given set of alternatives based on certain criteria. Often in such problems, the decision-maker confronts conflicting objectives, and no solution is easily evident due to intangibility of criteria and the complexity of the problem. In such circumstances, the decision-maker needs to separate different type of criteria and allocate weights or preferences. The best solution is a compromise, since the decision-maker tries to find an alternative by trading-off the criteria. As the number of criteria and alternatives increase, the problem becomes more complex as what de Boer *et al*. (2001), clarify in Figure 3.2.

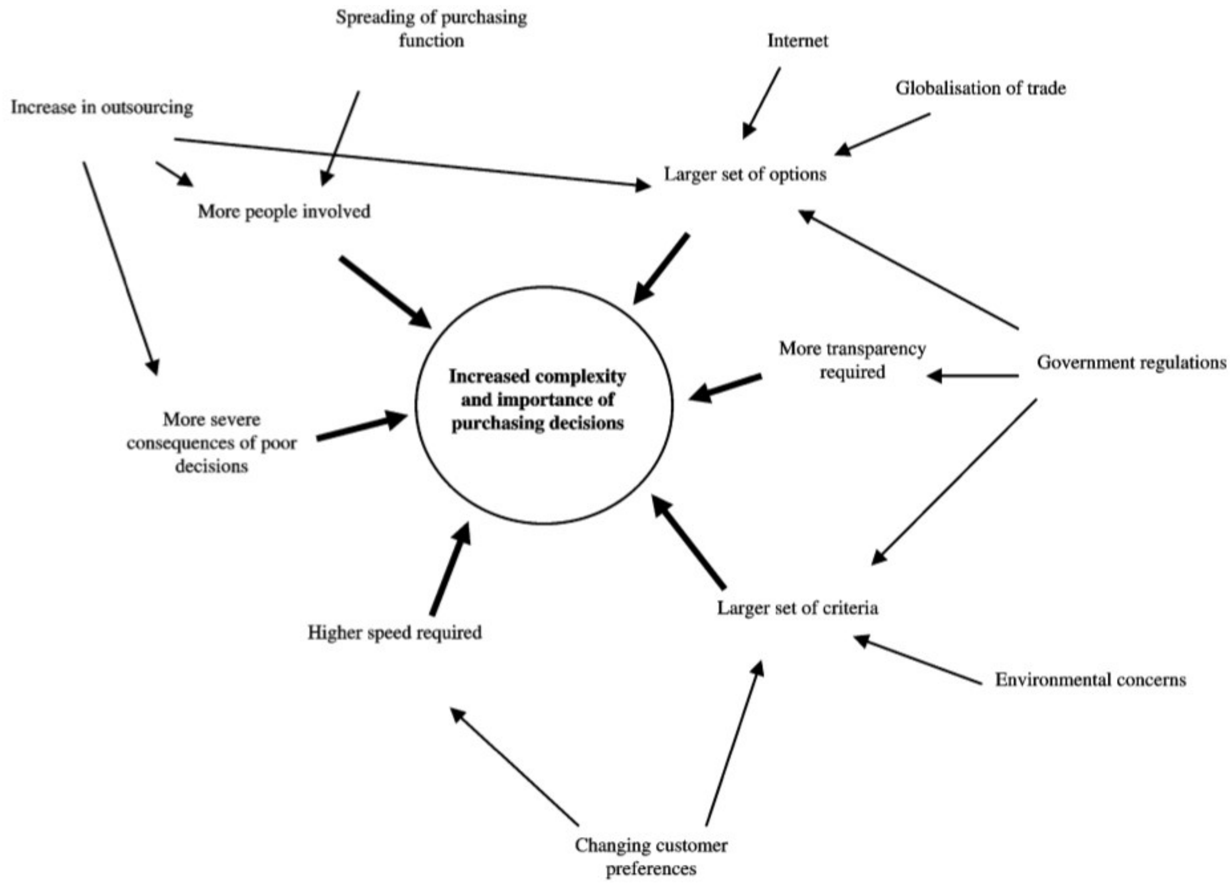

Figure 3.2: Critical factors affecting purchasing decision making (adopted from de Boer *et al*., 2001)

Therefore, a model or method that solves conflicting objectives in MCDM problems is needed. Before that, however, the decision-maker needs to list the criteria on which the evaluation method will be based and how the alternative preferences will be decided. In addition, the decision-maker has to provide weights to each criterion. Many approaches to solve MCDM problems have been proposed in literature. Some of these are AHP, TOPSIS, and VIKOR which have been discussed in section 3.1.2.

Chapter 4:

Supplier Quality Evaluation and Selection Methodology

4.1 Introduction

In this chapter, we present our methodology for supplier quality evaluation and best supplier (s) selection. The proposed model consists of three stages. The first stage is devoted to determining the weight of each criterion or variable. The second stage focuses on pre-qualifying suppliers and grouping them based on similar characteristics. The final stage deals with evaluating supplier quality and finding the best solution. These stages are summarized in Figure 4.1.

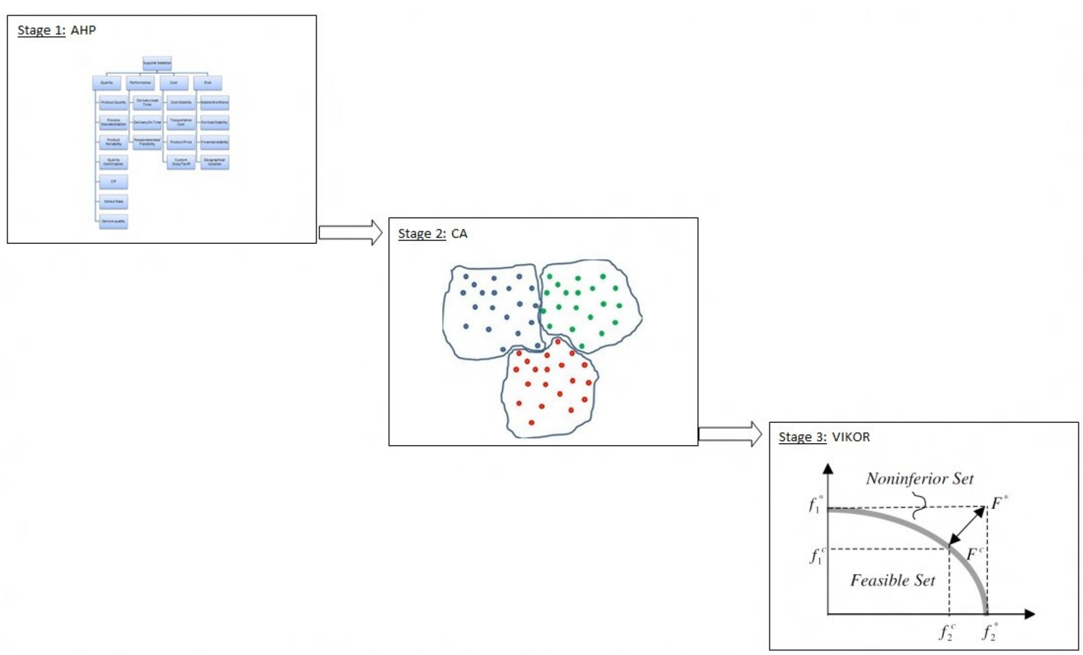

Figure 4.1: The proposed model

4.2 First Stage: Determining the criteria and their weights

This stage is concerned with finding criteria and sub-criteria for supplier quality evaluation and assigning them appropriate weights. As mentioned in chapter three, there are a number of methods that can help decision-makers assign weight to the variables. In the proposed model, AHP technique has been considered. Vaidya & Kumar (2006) conducted an overview of applications that had used AHP. From 150 papers, they found that most of the researchers used this method for selection and evaluation purposes. The applications of these papers were in engineering, personal and social categories. Moreover, many researchers such as Narasimhan (1983), Nydick & Hill (1992) and Partovi *et al*. (1989), suggested using AHP for supplier evaluation and selection because of its ability to deal with qualitative and numerical attributes. However, AHP is more efficient when the pairwise comparisons at each level are reasonably small (Partovi, 1994). Saaty (1980) suggests that each level should be limited to 9 pairwise comparisons. AHP, however, is not a good method to apply for supplier quality evaluation from a large set of alternatives. Hence, to overcome these problems, it will be used to structure the criteria/sub-criteria and determine their weights. The procedure is as follows: first, define the problem; next, build the hierarchy; then, perform pairwise comparisons; and finally, evaluate the weights.

4.2.1 Defining the Problem

The first step in AHP is defining the objective of the problem. This will help in framing right criteria/sub-criteria for use in next stage of AHP.

4.2.2 Structuring the Hierarchy

After defining the problem objective, decision-makers build the hierarchy. The hierarchy is a kind of chart or tree used to simplify the problem by decomposing it into a hierarchy of criteria, sub-criteria and alternatives. It consists of several levels. The first level or level one contains the problem objective as stated in step one. Level two contains the main criteria. Level three contains the sub-criteria associated with the main criteria. At the last level are the alternatives for evaluation.

4.2.3 Criteria Description

We propose four main criteria namely quality, performance, cost and risk for supplier quality evaluation. Each of these criteria can be divided into several sub-criteria. Figure 4.2 presents the hierarchy of the four criteria and their sub-criteria. The main criteria and sub-criteria are described as following:

4.2.3.1 Quality

This is the most important criterion for any organization that is looking to build a strong reputation through satisfying its customers' needs. It can be measured using the following sub-criteria:

1. Product quality (C01)

The quality of the product fits in with customer regulation, as the organization seeks to gain their customers' satisfaction about the product. In short, product quality is the essence of what the customers need.

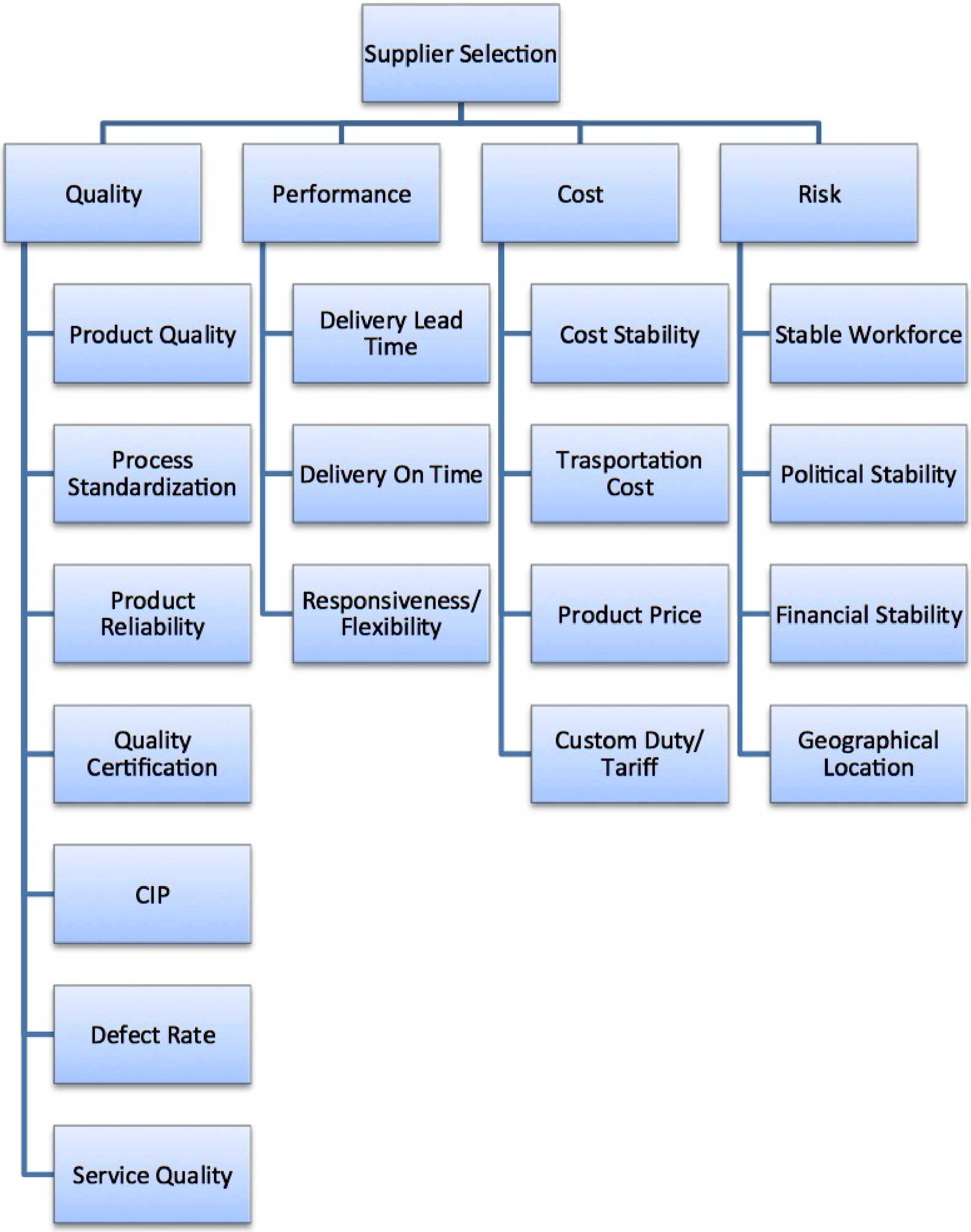

Figure 4.2: Hierarchy for the supplier quality evaluation

2. Process standardization (C05)

This is a binary factor; either the supplier has process standardization or it does not. Process standardization pertains to the use of standard methods, techniques and components.

3. Product reliability (C06)

This sub-criterion represents the robustness of the product, in terms of its number of failures and the likelihood of its durability in retaining the same performance and efficiency.

4. Quality certification (C07)

It involves obtaining quality certificate in any kind of quality that has been gained through satisfying certificate requirements, such as ISO 9000 or any other quality certification.

5. Continuous improvement program (CIP) (C09)

This includes presence of a program or initiative whereby the organization continuously tries to improve the quality of product or production process or adapts to new technology.

6. Defect rate (C14)

This is the rate at which products are rejected by customers because of defects. For example, 2 to 15 defects per 100,000 products.

7. Service quality (C04)

The service quality level is measured in terms of empathy, ease of communication, and user friendliness.

4.2.3.2 Cost

Cost or price is also a significant factor in supplier selection. Customers are always looking for the minimum product cost so they can maximize their profit or the value of their purchase. The sub-criteria related to this criterion are:

1. Cost stability (C08)

Cost stability refers to how often the supplier changes its product cost. Put another way, this is a measure of whether the customer has a long-term agreement with the supplier.

2. Transportation cost (C15)

The assumption of transportation cost variations depends on the supplier's location. It is different for local, international and global suppliers.

3. Product price (C17)

It is the purchase price of product expressed in dollars.

4. Custom cost/ Tariff (C18)

This sub-criterion applies to global suppliers for their customs charges.

4.2.3.3 Performance

The performance of the supplier is its ability to react to and meet the customer's needs within the agreement period or as quickly as possible. This criterion can be measured through the following attributes:

1. Responsiveness/ Flexibility (C03)

This is the ability of the supplier to respond to any change from the customer in terms of any increase in the product quantity or an urgent order.

2. Delivery on time (C02)

This is the ability of the supplier to deliver a shipment at the right time.

3. Delivery lead time (C16)

It is the time from ordering the item until it arrives at the point of sales. For example, this is assumed to be between 2 and 4 days for local suppliers, 3 and 7 days for national suppliers and between 12 and 20 days for global suppliers in our thesis.

4.2.3.4 Risk

Risk is an important factor that buyers should consider and study carefully, especially when dealing with global suppliers. It can affect the ability to meet the customer's expectations, such as receiving late shipment or low quality products. The following sub-criteria are related to risk:

1. Workforce stability (C10)

This represents the satisfaction of the employees with their job and the environment that they work in.

2. Political stability (C11)

This is an important factor, especially when the supplier is international. Political change in a given country can change business policies and practices, and therefore affect the long-term partnership between supplier and buyer.

3. Financial stability (C12)

The financial status of the supplier is important for a long-term partnership with buyers. It is the backbone that gives supplier the ability to improve, adapt to new technologies and survive among its competitors.

4. Geographical location (C13)

The geographical locations of suppliers are classified as local, national and global respectively.

Table 4.1 summarizes the different values assumed for the various criteria and sub-criteria presented above for study purposes in our thesis.

Code	Sub-Criteria	Scale	Objective	Data Type
C01	Product quality	[1-7]	Maximize	Nominal
C02	Delivery on time	[1-7]	Maximize	Nominal
C03	Responsiveness/ Flexibility	[1-7]	Maximize	Nominal
C04	Service quality	[1-7]	Maximize	Nominal
C05	Process standardization	[0-1]	Maximize	Binary
C06	Product reliability	[1-7]	Maximize	Nominal
C07	Quality certification	[0-1]	Maximize	Binary
C08	Cost stability	[0-1]	Maximize	Binary
C09	CIP	[0-1]	Maximize	Binary
C10	Stable Workforce	[0-1]	Maximize	Binary
C11	Political stability	[1-7]	Maximize	Nominal
C12	Financial stability	[1-7]	Maximize	Nominal
C13	Geographical location	[1-2-3]	Minimize	Nominal
C14	Defect rate	[2-15]/100,000 items	Minimize	Continuous
C15	Transportation cost	L/N [1000-1750], G [1500-2500]	Minimize	Continuous
C16	Delivery lead time	L [2-4], N [3-7] & G [12-20]	Minimize	Continuous
C17	Product price	L [$250-$350], N [$200-$300] & G [$100-$200]	Minimize	Continuous
C18	Custom cost/ Tariff	10% of C17	Minimize	Continuous

Table 4.1: Sub-criteria assumption

The qualitative criteria in this thesis are of two types: nominal and binary. The nominal value is par value, where a specific value assigns to specific expression of word. However, binary value is either 0 (not present) or 1 (present).

4.2.4 Finding the Weights

In this step, a pairwise comparison is conducted for each element at the same level and with respect to the one above it using the principle of AHP (Saaty, 1980). For example, a pairwise comparison should be done between the main criteria at first. Then, another comparison should be done to the set of sub-criteria below each of the main criteria. Saaty (2008) suggests that the pairwise comparison be done through the use of a scale. This scale is shown in table 4.2. The next step is using the pairwise matrix to rank the priorities of criteria by using the eigenvector approach. In this approach, the matrix is multiplied by itself and then each row is summed. After that, the summed rows will be normalized. This will be done again to the last matrix by repeating the same procedure. Then, the results will be compared to the previous one. If the results nearly match, the process stops; otherwise, the process will be repeated until no differences between two consecutive calculations appear.

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption

Table 4.2: AHP pairwise comparison scale adopted from (Saaty, 2008)

4.2.5 Evaluating the Pairwise Comparison Results

Since the decision-maker's judgment could be subjective or random, an evaluation of the outputs of the previous step should be done to check the inconsistency of the results. Saaty (1982) recommended that the value of consistency ratio should be equal to or less than 10% in order to accept the inconsistency. Otherwise, a revision should be done. To check for inconsistencies, a consistency ratio (CR) should be applied as follows:

1. First, find the eigenvalue (λ_{Max}) by multiplying the pairwise matrix with the weight matrix.
2. Then, divide the result over its corresponding weight. The eigenvalue is the average of the results.
3. After finding the eigenvalue, calculate the Consistency Index (CI) as $CI = (\lambda_{\text{Max}} - n)/n - 1$, where n is the matrix size.
4. The final step is to calculate the Consistency Ratio (CR) by using the formula $CR = CI/RI$, where RI is the random index. Saaty (1982) suggested some values for the random index and they are listed in table 4.3.

Matrix size (n)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Random Index (RI)	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 4.3: Random index for each matrix size (adopted from Saaty, 1982)

4.3 Second Stage: Finding the Suppliers Groups

In this stage, cluster analysis (CA) technique is used to find supplier groups with similar characteristics. According to Holt (1996), cluster analysis has a number of advantages when used for supplier quality evaluation:

1. The possibility of eliminating the best suppliers is removed at the earlier stages;
2. The resources of the buyer are maximized; and
3. The use of specified criteria under the CA process leads to better investigation for all suppliers.

These advantages make cluster analysis a good choice for use in the supplier pre-qualification stage, since all of the suppliers are classified to groups with similar attributes.

Two techniques of CA have been found to be suitable for supplier pre-qualification – hierarchical clustering and *k*-means clustering (Holt, 1996). The first one is usually used as a supplement or aid to the second one in deciding the number of clusters to use (*k*).

4.3.1 Hierarchical Cluster Analysis

Hierarchical cluster analysis can be classified into two types: agglomerative methods and divisive methods. In the agglomerative method, there are (*n*) numbers of clusters; each individual piece of data represents a cluster until all of them are grouped into one cluster. However, the divisive method works in the opposite way, starting with one cluster that has all the data, then partitioning them into more clusters until they form (*n*) number of clusters. To apply either of these methods, a similarity or dissimilarity (distance) measure needs to be chosen to find the ways in which the two objects are similar or dissimilar. Everitt *et al*. (2001), listed a number of measures to measure dissimilarity. These are:

1. Euclidean distance. This is the most commonly used measure. It calculates the distance between two objects by using this formula, $d_{ij} = \sqrt{\sum_{k=1}^{p}\left(x_{ik} - x_{jk}\right)^2}$, where x_{ik} and x_{jk} are the objects for individuals i and j under the k^{th} variable value of the p-dimensional.
2. City block distance or Manhattan distance this is the sum of the absolute distances between two objects under the k^{th} variable value of the p-dimensional.

$$d_{ij} = \sum_{k=1}^{p}\left|x_{ik} - x_{jk}\right|$$

3. Minkowski distance. Both previous methods are a special case of this measure.

$$d_{ij} = \left(\sum_{k=1}^{p}\left|x_{ik} - x_{jk}\right|^r\right)^{1/r} \quad r \geq 1$$

For the rest of the measures, the reader may refer to Everitt *et al*. (2001) and Gan *et al*. (2007). These measures are used to find the distance or dissimilarity between two objects. However, to join or link the data or objects to a number of clusters another measure needs to be applied. It is called linkage measure or method. Some of these are:

1. **Single linkage or nearest-neighbor distance**. In this method, the linkage is done by taking the smallest distance between any two individual objects.
2. **Complete linkage or farthest-neighbor distance**. This is the opposite of single linkage. The linkage is done by taking the furthest distance between any two objects.
3. **Average linkage or Unweighted pair-group method using the average approach (UPGMA).** This method uses the average distance between memberships (or samples

of memberships) of one cluster and the other clusters. The linkage is performed on the basis of this distance.

The result of the linkage of objects (element) to clusters is a dendrogram. A dendrogram is a diagram showing which the linkages between cluster objects and the distances at which they are joined to each other in their respective clusters. An example of a dendrogram is figure 4.3.

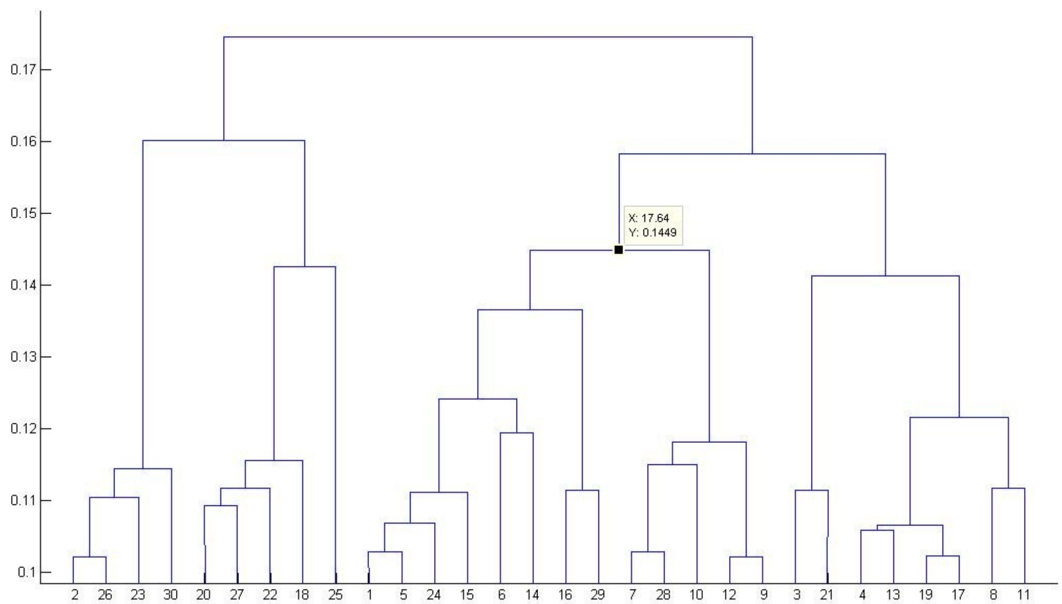

Figure 4.3: Example of dendrogram

Hierarchical clustering is a good technique to use when dealing with small data sets. It would be too laborious and time consuming to be applied to large data sets. Moreover, Kaufman and Rousseeuw (1990) remark that once the hierarchical technique adds any object to a cluster, it remains in that cluster. This means that if an object is mistakenly classified to a cluster, it will remain misclassified. For these reasons, hierarchical clustering might not be a good technique to use with large data sets.

4.3.2 *k*-means Cluster Analysis

This is a type of partitional clustering. *k*-means clustering has the ability to deal with large sets of data more efficiently than hierarchical clustering. It uses an iteration procedure to form the clusters. *k*-means cluster analysis consists of five steps (Khan & Ahmad, 2004):

Step 1. Determining the number of clusters (*k)*

Step 2. Choosing initial seeds or centroids for each cluster

Step 3. Determining the distance from centroid to each object

Step 4. Grouping objects based on minimum distance and

Step 5. If the clusters are stable (the position of objects are not changed from the previous iteration), end. Otherwise, start over from step 2 and update the cluster centroids.

The most common distance measure used with *k*-means clustering is Euclidean distance (Mu-Chun & Chien-Hsing, 2001).

4.3.3 Pre-qualifying Procedure

To pre-qualify suppliers before subjecting to quality evaluation, following steps need to be considered:

1. Normalizing of data;
2. Multiplying Sub-criteria weights by normalized data;
3. Determining the number of clusters by using hierarchical clustering;
4. Applying *k*-means clustering to qualify the suppliers; and
5. Analyzing the results.

4.3.3.1 Normalizing Data

Since the variables have different units, a normalization process has to be done to make the data dimensionless and bring in the range between 0 and 1. This process allows the variables to contribute equally to the dissimilarity or similarity measure when applied in cluster analysis (Romesburg, 1984). A number of formulas have been proposed in literature for normalization. Some of them, as listed by Milligan & Cooper (1988) are presented as follows:

$$Z_1 = (X - \bar{X})/s$$

$$Z_2 = X/s$$

$$Z_3 = X \Big/ \max_j X_{ij}$$

$$Z_4 = X \Big/ \left(\max_J X_{ij} - \min_J X_{ij} \right)$$

$$Z_5 = \left(X - \min_J X_{ij} \right) \Big/ \left(\max_J X_{ij} - \min_J X_{ij} \right)$$

Where X is the data value, $\bar{X}$ is the average and s is the standard deviation. Each of these formulas has its advantages and disadvantages. For example, Z_1 "may not perform properly if there are substantial differences among the within-cluster standard deviations" (Milligan & Cooper, 1988). Milligan & Cooper (1988) conclude that Z_4 and Z_5 are better than the others when they are used for cluster analysis because they form the original cluster structure better than the others. Moreover, they indicate that using Z_4 or Z_5 in Euclidean distances would provide the same results if applied on same data.

4.3.3.2 Multiplying Sub-criteria Weights by Normalized Data

The purpose of this step is to make use of the criteria/sub-criteria weights given to criteria in the clustering process so that the suppliers with the most similar proprieties fall in the same cluster. If this step is neglected, there can be no guarantee that the best suppliers will occur within one or two clusters. Integrating the sub-criteria weights to the data leads to better investigation of all the suppliers. For example, if the weights are not considered and an element (supplier in our case) is good in 10 variables, the results might change when weights are considered. The element might show as good in only 3 or 4 criteria instead of 10 during the clustering process, and vice versa. This explains why it is important to consider the weights at this stage.

4.3.3.3 Determine the Number of Clusters

To pre-qualify the suppliers, the number of clusters needs to be known. Since determining the number of clusters is critical, researchers have proposed a number of methods to find the value of *k*. But none of the proposed methods so far has been commonly agreed upon by the researchers, and therefore the problem still exists. One of the ways to determine the value of *k* or the number of clusters is through the dendrogram, which is obtained from hierarchical clustering. The best cut is used to find the distinct clusters inherent within it (Holt, 1996). The best cut has been defined by Romesburg (1984) to be the largest width of range between two joint distances. It is clarified in Figure 4.4. This figure shows that the best cut is between distance 0.1583 and 0.1449, since the width of range between the two joint distances $d_{ij} = 0.1583 - 0.1449 = 0.0134$ is the higher among the others (0.0024, 0.0048, and 0.0124). In this case, the suitable number of clusters is four ($k = 4$), as seen in Figure 4.5.

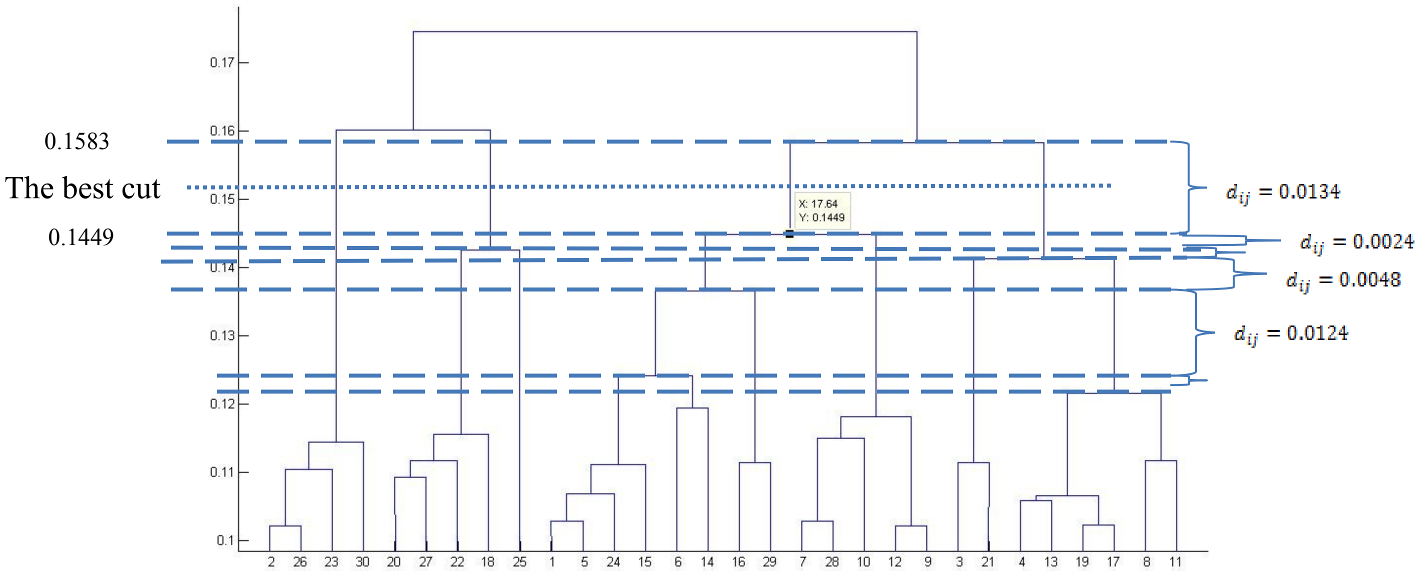

Figure 4.4: Dendrogram showing best cut

4.3.3.4 Applying k-means clustering to qualify the suppliers

k-means clustering is a very well-known technique due to its ability to deal efficiently with large data sets as long as the initial number of (*k*) clusters is known. This is why it is has been considered for use in this stage of the process. To execute this technique, SPSS software will be used.

4.3.3.5 Analyzing the Clustering Results

To find which cluster has the best group of suppliers, an analysis needs to be performed. The analysis will be done based on the center of each cluster. This center is the weighted average of the different criteria centers present in each cluster. The cluster that has the highest mean will have the best suppliers (Holt, 1996). Since the sub-criteria weights are already integrated with the data, the cluster with the highest mean will have the best suppliers satisfying those weights.

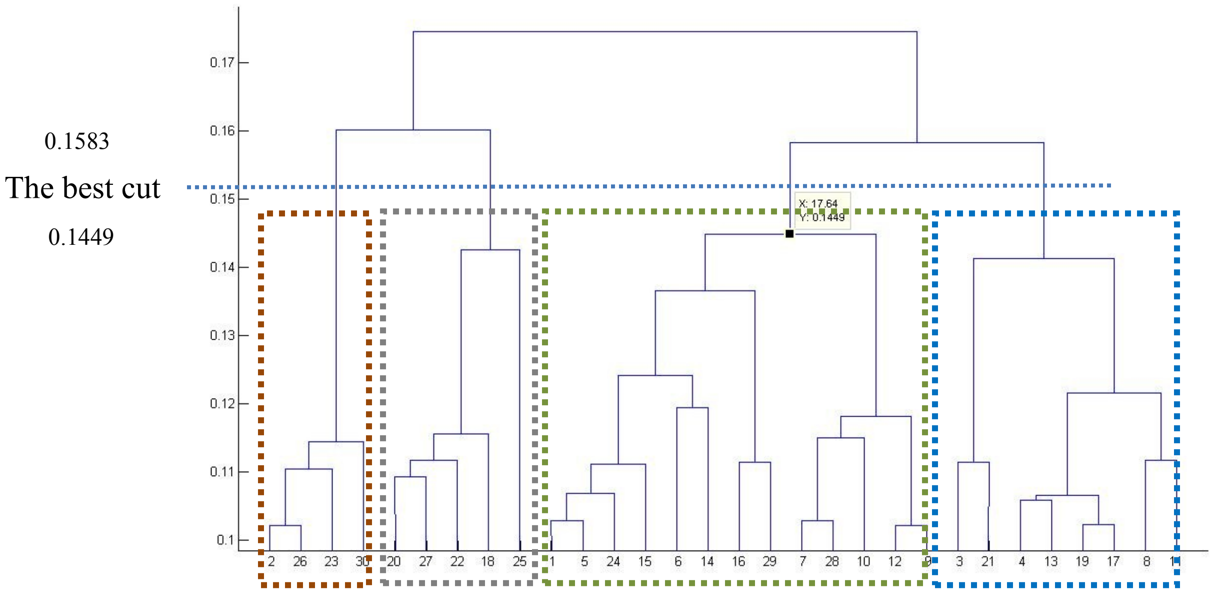

Figure 4.5: Dendrogram showing best cut and cluster memberships

4.4 Third Stage: Supplier Quality Evaluation using VIKOR

Clustering reduces the time and effort involved in evaluating a large number of alternatives. In this stage, we evaluate the quality of suppliers present in the best cluster using outranking method called VIKOR. The details of this method are presented as follows:

4.4.1 VIKOR

VIKOR is a MCDM based on outranking principle. It is used to find the compromise ranking list, the compromise solution and the weight stability intervals (Opricovic & Tzeng, 2004). The method was developed from the L_P – metric which is used in compromise programming as an aggregation function. The method uses L_P – metric concepts to find the compromise solution that is the closest to the ideal solution. The L_P – metric has the following form

$$L_{p,j} = \left\{ \sum_{i=1}^{n} \left[w_i \, (f_i^* - f_{ij})/(f_i^* - f_i^-) \right]^p \right\}^{1/p}$$

$1 \leq p \leq \infty, \qquad j = 1,2, \ldots, J.$

Figure 4.6 shows the relationship between a compromise solution (F^c) and the ideal solution (F^*) in the L_P –metric.

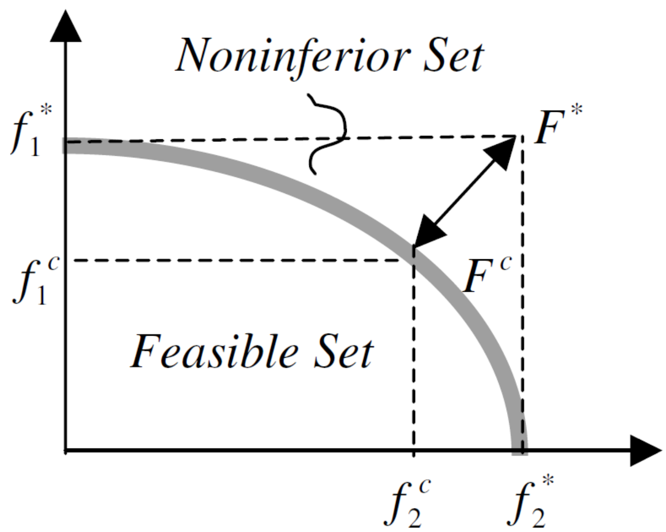

Figure 4.6: Ideal and compromise solutions adopted from (Opricovic & Tzeng, 2004)

VIKOR Method has the following steps:

1. Find the best of f_i^* and the worst of f_i^- of all criterion $(i = 1,2 \ldots n)$ as follows:
   a. If i represents a benefit, then: $f_i^* = \max_j f_{ij}$ and $f_i^- = \min_j f_{ij}$
   b. If i represents a cost, then: $f_i^* = \min_j f_{ij}$ and $f_i^- = \max_j f_{ij}$
2. Compute linear normalization for all alternatives $d_{ij} = (f_i^* - f_{ij})/(f_i^* - f_i^-)$ (4.1)
3. Find the values $S_j = \sum_{i=1}^{n} w_i d_{ij}$ and $R_j = \max_i w_i d_{ij}$ of all alternatives $(j = 1,2 \ldots J)$.

   Where w_i is the weight of criterion.

4. Compute the values $Q_j = v\,(S_j - S^*)/(S^- - S^*) + (1-v)\,(R_j - R^*)/(R^- - R^*)$ of all alternatives. Where $S^* = \min_j S_j$ and $S^- = \max_j S_j$, $R^* = \min_j R_j$ and $R^- = \max_j R_j$ and v is the weight of the strategy of "the majority of criteria".
5. Rank the alternatives, sorting by the values S, R and Q, in decreasing order.
6. The compromise solution is the first ranked alternative (a') by Q if a'
   a. has the acceptable advantage that $Q(a'') - Q(a') \geq 1/(J-1)$, (Note: if $J \leq 4$ then $1/(J-1) = 0.25$ (Chen & Wang, 2009) where a'' is the alternative with second position in the ranking list by Q; and
   b. has the acceptable stability in decision making, so that it will be the best ranked by S or/and R.

   If a' is not satisfied by point (b) then, the compromise solutions is a' and a''.

   But if a' is not satisfied by point (a), then the compromise solutions consists of $a', a'', \ldots a^M$. Where a^M is determined by the relation $Q(a^M) - Q(a') < 1/(J-1)$ for maximum M.

4.4.2 VIKOR Method and Outranking Methods

Opricovic and Tzeng (2007) perform a comparison between VIKOR and other outranking methods. They demonstrate that VIKOR finds the compromise solution that is the closest to the ideal solution by using linear normalization formula. On the other hand, TOPSIS ranks the solution based on the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution by using vector normalization formula. They argue that TOPSIS does not consider the relative importance of the distance from ideal and negative points. However, the comparison between VIKOR and ELECTRE II has shown that both produce the same results when a linear criterion function is considered. Similarly, both VIKOR and PROMETHEE III also produce the same results.

The VIKOR method has the advantages of considering maximum group utility (the majority rule) by minimizing S and considering minimum individual regret of the opponent by minimizing R.

Chapter 5:

Numerical Example

5.1 Introduction

In this chapter, a numerical example to demonstrate the proposed model is presented. Let us consider an organization ABC who is dealing with 625 suppliers in a heterogeneous business environment. These suppliers consist of 130 local suppliers, 195 national suppliers and 300 global suppliers. Firstly, we cluster the suppliers based on three criteria: product type, supplier location and product volume. The results of the first level of clustering are 250 suppliers, which consist of 48 local suppliers, 88 national suppliers and 114 international suppliers. This step was performed to reduce computational complexity. Now, detailed analysis of quality of these 250 suppliers will be performed using the proposed model. 18 sub-criteria will be used. Thirteen of them are qualitative and the other five are numerical data. The criteria data were randomly generated using Excel. The data generated for these suppliers are listed in Table A.1 in Appendix A.

The criteria are a mixture of qualitative and quantitative variables. To treat the problem in a numerical way, the qualitative data have been quantified using the following scale:

For nominal variables, the criteria are quantified into 7 scales: very low (VL) quantify to 1, low (L) to 2 and so on as seen in Table 5.1.

Very Low (VL)	Low (L)	Medium Low (ML)	Medium (M)	Medium High (MH)	High (H)	Very High (VH)
1	2	3	4	5	6	7

Table 5.1: Linguistic Scale

However, for binary variables 1 represents YES or present, and 0 represents NO or absent. For the geographical location criterion, 1 has been assigned to local suppliers, 2 to national suppliers and 3 to global suppliers. Table A.2 in appendix A shows the data after they have been quantified. The data have been normalized so that all criteria will be unitless and in the range of 0 and 1 as listed in table A.3. For the normalization process, the following formulas have been used:

$$x_{ij}^* = \frac{x_{ij} - \min_j x_{ij}}{\max_j x_{ij} - \min_j x_{ij}} \qquad (5.1)$$ if the variable needs to be maximized and

$$x_{ij}^* = \frac{(1/x_{ij}) - \min_j (1/x_{ij})}{\max_j (1/x_{ij}) - \min_j (1/x_{ij})} \qquad (5.2)$$ if the variable needs to be minimized

5.2 The Three Stages Solution Approach

The solution will be achieved in three stages. Stage one will be focused on finding the right weight for each criterion using the AHP technique. In the second stage, the clustering technique will be applied to reduce the huge supplier data into manageable groups. Then each cluster members will be analyzed in order to find which cluster has the best set of suppliers. The chosen group will be then subject to VIKOR method in third stage for supplier quality evaluation

5.2.1 First Stage: Analytic Hierarchy Process

The purpose of using this technique is to find the appropriate weight for each criterion along with the weights to be given to their sub-criteria. To conduct this method Excel Spreadsheet will be used. The four main criteria were compared with each other to find their weights, and the results are as shown in Table 5.2.

	Quality	**Service**	**Cost**	**Risk**	**Weight**
Quality	1	4	3	8	0.550
Performance	1/4	1	1/2	5	0.154
Cost	1/3	2	1	7	0.253
Risk	1/8	1/5	1/7	1	0.043

Table 5.2: The evaluation of main criteria

After this comparison, all sub-criteria under each main criterion were evaluated. The results of these evaluations are presented as follows:

	C01	**C05**	**C06**	**C07**	**C09**	**C14**	**C04**	**Weight**
C01	1	3	3	6	5	2	5	0.327
C05	1/3	1	1/2	5	2	1/3	6	0.127
C06	1/3	2	1	5	4	1/2	4	0.169
C07	1/6	1/5	1/5	1	½	1/6	3	0.044
C09	1/5	½	1/4	2	1	1/3	3	0.067
C14	1/2	3	2	6	3	1	5	0.233
C04	1/5	1/6	1/4	1/3	1/3	1/5	1	0.033

Table 5.3: The evaluation of sub-criteria with respect to quality criterion

	C03	**C02**	**C16**	**Weight**
C03	1	1/2	2	0.311
C02	2	1	2	0.493
C16	1/2	1/2	1	0.196

Table 5.4: The evaluation of sub-criteria with respect to performance criterion

	C08	C15	C17	C18	Weight
C08	1	2	1	4	0.344
C15	1/2	1	1/2	6	0.233
C17	1	2	1	5	0.360
C18	1/4	1/6	1/5	1	0.063

Table 5.5: The evaluation of sub-criteria with respect to cost criterion

	C10	C11	C12	C13	Weight
C10	1	1/2	1/2	3	0.197
C11	2	1	1/2	3	0.280
C12	2	2	1	5	0.443
C13	1/3	1/3	1/5	1	0.081

Table 5.6: The evaluation of sub-criteria with respect to risk criterion

To check that these weights are consistent, verification was performed. For the results to be considered valid, the consistency ratio should be less than 0.1 or 10% of all pairwise comparisons. The results of this test are shown in Table 5.7. It can be seen that all the CRs < 0.1 for each of the pairwise comparison results., therefore the results are consistent.

	λ_{MAX}	CI	RI	CR
Main criteria	4.131	0.043655	0.9	0.048506
Quality sub-criteria	7.481	0.080201	1.32	0.060758
Performance sub-criteria	3.054	0.026811	0.58	0.046225
Cost sub-criteria	4.129	0.043013	0.9	0.047793
Risk sub-criteria	4.065	0.021602	0.9	0.024002

Table 5.7: Consistency test for the criteria

After all the weights are verified to be consistent, the next step is to multiply the main criteria weight with their corresponding sub-criteria weight to make the sum of the weights of all sub-criteria equal to 1. Table 5.8 gives a summary of the AHP results.

		Sub-Criteria W.	Criteria W. x Sub-Criteria W.
C01	**Product quality**	0.327	0.180
C02	**Delivery On time**	0.493	0.076
C03	**Responsiveness/ Flexibility**	0.311	0.048
C04	**Service quality**	0.033	0.018
C05	**Process standardization**	0.127	0.070
C06	**Product reliability**	0.169	0.093
C07	**Quality certification**	0.044	0.024
C08	**Cost stability**	0.344	0.087
C09	**CIP**	0.067	0.037
C10	**Stable Workforce**	0.197	0.009
C11	**Political stability**	0.280	0.012
C12	**Financial stability**	0.443	0.019
C13	**Geographical location**	0.081	0.003
C14	**Defect rate**	0.233	0.128
C15	**Transportation cost**	0.233	0.059
C16	**Delivery lead time**	0.196	0.030
C17	**Product price**	0.360	0.091
C18	**Customs cost/ Tariff**	0.063	0.016

Table 5.8: Weights of all sub-criteria

4.2.2 Second Stage: Cluster Analysis

In this stage, a dendrogram will be used form hierarchical cluster analysis to determine the number of clusters, then *k*-means cluster analysis will be performed to find the groups. Before performing the analysis, the clusters need to be guaranteed to have similar attributes for suppliers. Therefore, the weights determined from the use of the AHP technique will be multiplied with their corresponding normalized value to make sure that the best suppliers fall in the same group respecting the criteria weights. The input data (normalized) for cluster analysis is presented in Table A.3. The dendrogram produced by using the SPSS program with Euclidean distance measures and the within-group linkage method, is shown in Figure 5.1.

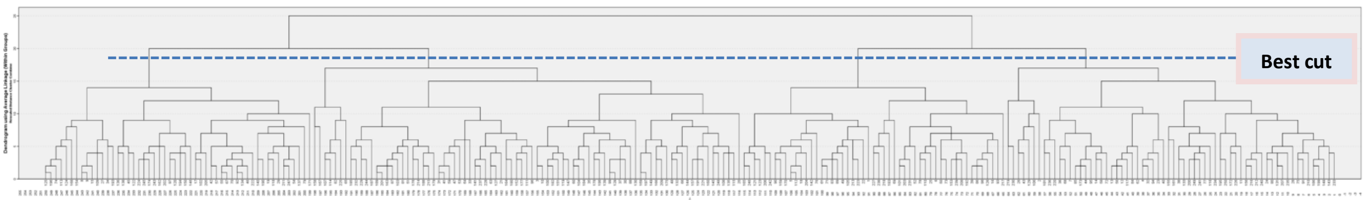

Figure 5.1: Dendrogram for hierarchical analysis

The dendrogram shows that the number of clusters is 4, where the best cut is occurred. Now that the analysis has produced a clear idea of the possible number of $k = 4$, k-means clustering can be applied. The results of the k-means cluster analysis are shown in Table 5.9.

	Cluster 1			**Cluster 2**	**Cluster 3**					**Cluster 4**			
1	S004	S077	S181	S002	S003	S057	S124	S176	S250	S001	S086	S165	S227
2	S007	S084	S186	S020	S008	S059	S125	S177		S005	S087	S166	S229
3	S012	S085	S199	S033	S009	S060	S127	S180		S006	S089	S169	S231
4	S013	S091	S200	S037	S010	S063	S128	S182		S016	S090	S170	S232
5	S014	S094	S202	S064	S011	S067	S132	S184		S018	S093	S179	S238
6	S017	S095	S207	S065	S015	S070	S134	S190		S022	S098	S185	S239
7	S023	S102	S210	S079	S019	S074	S136	S191		S025	S101	S188	S242
8	S024	S106	S212	S082	S021	S092	S137	S193		S039	S103	S189	S246
9	S026	S116	S220	S088	S027	S096	S138	S194		S048	S105	S192	
10	S028	S117	S224	S107	S029	S097	S140	S195		S049	S108	S197	
11	S032	S129	S226	S114	S030	S099	S141	S196		S050	S110	S201	
12	S036	S131	S230	S130	S031	S100	S145	S198		S051	S112	S203	
13	S038	S133	S233	S139	S034	S104	S146	S205		S052	S121	S204	
14	S040	S143	S234	S154	S035	S109	S147	S211		S061	S123	S206	
15	S043	S148	S235	S158	S041	S111	S151	S214		S066	S126	S208	
16	S044	S150	S236	S167	S042	S113	S152	S216		S069	S135	S209	
17	S056	S155	S240	S171	S045	S114	S157	S222		S071	S142	S213	
18	S058	S156	S241	S178	S046	S115	S160	S228		S073	S144	S215	
19	S062	S161	S243	S183	S047	S118	S162	S237		S076	S149	S217	
20	S068	S172	S245	S187	S053	S119	S164	S244		S078	S153	S218	
21	S072	S173	S249	S219	S054	S120	S168	S247		S081	S159	S221	
22	S075	S174		S225	S055	S122	S175	S248		S083	S163	S223	

Table 5.9: Clusters' memberships

The next step is to analyze these clusters and find the best cluster among them. This will be done by considering centers for the 18 sub-criteria in each cluster. Then, an average cluster center will be calculated using the weighted average of the 18 sub-criteria cluster centers. This step will be performed for each cluster. The cluster that has the highest average cluster mean is considered to be the best. Table 5.10 lists the center of 18 sub-criteria and average cluster center for the four clusters. It can be deduced that cluster number one is the best cluster among the group. Please note that the data used in clustering was normalized using equations (5.1) & (5.2).

	Cluster 1 65	**Cluster 2** 22	**Cluster 3** 89	**Cluster 4** 74
C01	0.132189	0.034021	0.027247	0.133913
C02	0.037684	0.03673	0.038162	0.035489
C03	0.025697	0.024946	0.023325	0.022572
C04	0.008549	0.008465	0.009281	0.008118
C05	0.032169	0.031681	0.03759	0.035791
C06	0.048959	0.031753	0.048838	0.041955
C07	0.012621	0.013161	0.013013	0.011086
C08	0.087278	0.019836	0.04511	0
C09	0.018163	0.025154	0.019068	0.02393
C10	0.005248	0.005039	0.004983	0.004956
C11	0.008357	0.007986	0.007579	0.007177
C12	0.009638	0.009443	0.010342	0.009545
C13	0.001116	0.000954	0.001061	0.000768
C14	0.026767	0.101288	0.016224	0.01958
C15	0.022386	0.022031	0.025213	0.024741
C16	0.009403	0.010076	0.008967	0.007468
C17	0.028563	0.036765	0.030114	0.031597
C18	0.004926	0.005581	0.004791	0.005468
Average (cluster center)	0.028873	0.023606	0.020606	0.023564

Table 5.10: Criteria and cluster centers

To support the results of Table 5.10, we used another method of ranking clusters namely VIKOR. To prepare the data, we used VIKOR normalization formula of equation (4.1) on data presented in Table A.1-A.2 and performed clustering. The four clusters (Table 5.9) were evaluated against the 18 sub-criteria using VIKOR and the results are presented in table 5.11. It can be seen that the result was similar to the one set out in table 5.10 and cluster 1 emerges as the best cluster.

	Cluster 1	**Cluster 2**	**Cluster 3**	**Cluster 4**
C01	0.264	0.811	0.852	0.255
C02	0.503	0.515	0.494	0.532
C03	0.462	0.477	0.513	0.527
C04	0.526	0.530	0.483	0.550
C05	0.538	0.545	0.449	0.486
C06	0.474	0.659	0.479	0.550
C07	0.477	0.455	0.449	0.541
C08	0	0.773	0.494	1
C09	0.508	0.318	0.483	0.351
C10	0.385	0.409	0.427	0.419
C11	0.310	0.341	0.378	0.408
C12	0.497	0.508	0.457	0.502
C13	0.608	0.636	0.607	0.682
C14	0.534	0.052	0.601	0.583
C15	0.527	0.536	0.485	0.487
C16	0.409	0.437	0.419	0.459
C17	0.476	0.389	0.454	0.446
C18	0.358	0.306	0.313	0.358

Criteria centers (using VIKOR normalization)

Rank	**Q**		**S**		**R**	
1	0	Cluster 1	0.409	Cluster 1	0.068	Cluster 1
2	0.435	Cluster 4	0.504	Cluster 4	0.087	Cluster 4
3	0.829	Cluster 2	0.518	Cluster 2	0.146	Cluster 2
4	1	Cluster 3	0.555	Cluster 3	0.153	Cluster 3

Table 5.11: VIKOR results for clusters center

4.2.3 Third Stage: VIKOR Method

Now that the best cluster has been found, it can be seen that only a few data will be dealt with instead of many for supplier quality evaluation. Cluster 1 groups the best 65 suppliers from 250. Evaluating 65 suppliers is much easier than evaluating 250 suppliers.

To use the VIKOR technique, the data from these 65 suppliers must be acquired. The data are listed in Appendix A, Table A.4. These data have been normalized by way of the normalization method that was suggested by the founders of the method (section 4.4.1). Table 5.12 presents the results for the first 15 suppliers ranked by the VIKOR method. These results have been computed by using Excel Spreadsheet. For all results, the reader may refer to Table A.5 in Appendix A.

	Main Criteria Weights					
	Quality=0.55, Performance=0.154, Cost=0.235, Risk=0.043					
	Q		**S**		**R**	
1	0.027	S230	0.232	S014	0.059	S085
2	0.090	S085	0.236	S230	0.062	S094
3	0.106	S058	0.256	S058	0.062	S230
4	0.126	S094	0.298	S085	0.064	S007
5	0.145	S014	0.303	S026	0.069	S072
6	0.183	S007	0.309	S094	0.069	S181
7	0.207	S072	0.311	S173	0.069	S058
8	0.223	S181	0.315	S044	0.070	S133
9	0.271	S026	0.332	S072	0.070	S200
10	0.274	S077	0.337	S040	0.071	S012
11	0.281	S012	0.340	S007	0.076	S077
12	0.282	S129	0.343	S181	0.076	S106
13	0.285	S133	0.345	S077	0.076	S129
14	0.300	S068	0.345	S161	0.076	S241
15	0.306	S062	0.348	S068	0.076	S249

Table 5.12: Top 15 suppliers from VIKOR method

In this calculation v is assumed to be 0.5, and since there are 65 suppliers, $1/(J-1) = 1/(65-1) = 0.0156 \leq Q(a'') - Q(a') = 0.090 - 0.027 = 0.063$. According to this, condition one is satisfied. However, condition two is not satisfied because supplier 230 is not ranked first in S and/or R. Consequently, a compromise solution should be considered. Such a compromise would be to select both supplier 230 and supplier 85. Note that the rectangle under column R means that all the suppliers have the same value. These results were obtained by using the weights assigned to the sub-criteria in Table 5.8. However, what happens if the weights of the main criteria have been changed? This will be discussed in the next section.

5.3 Sensitivity Analysis

In this section, several analyses will be done to check what will happen to the ranked suppliers results when the weights of the main criteria are changed. The analysis will be limited to the top 15 suppliers. In the first evaluation, all four criteria are assumed to have the same weight$\left(w_{Cj} = 0.25\right)$ and $v = 0.5$, see table 5.13. In this case, condition one was found not to be satisfied (0.0153 ≤ 0.0156), but the order of suppliers has been changed. The compromise solution for this case will include the first three suppliers (S161, S094 and S230). Note that two of them are global suppliers and one is a national supplier. Moreover, supplier 230 is still within the compromise solution under these assumed weights, while supplier 85 is moved to choice number 15.

	Main Criteria Weights					
	Quality=Performance=Cost=Risk=0.25					
	Q		**S**		**R**	
1	0	S161	0.2538	S161	0.0435	S161
2	0.0153	S094	0.2585	S094	0.0449	S094
3	0.0808	S230	0.2781	S230	0.0512	S230
4	0.1949	S072	0.2783	S013	0.0553	S207
5	0.2262	S133	0.2872	S014	0.0561	S210
6	0.2408	S233	0.3017	S072	0.0583	S233
7	0.2454	S174	0.3019	S058	0.0597	S056
8	0.2477	S012	0.3110	S044	0.0604	S131
9	0.2553	S143	0.3125	S012	0.0617	S085
10	0.2611	S014	0.3328	S026	0.0617	S133
11	0.2761	S013	0.3365	S106	0.0617	S174
12	0.2937	S131	0.3375	S133	0.0644	S072
13	0.3040	S075	0.3405	S062	0.0648	S075
14	0.3056	S210	0.3447	S143	0.0648	S143
15	0.3255	S085	0.3517	S174	0.0648	S148

Table 5.13: Top 15 suppliers evaluated under same weights

Now we will evaluate what happens if all the weight is given to only one of the main criteria. The results are shown in Tables 5.14, 5.15, 5.16 and 5.17 respectively. The results of testing this assumption show that all the main criteria did encounter any problems under either condition one or two. This means that the solution is the first-ranked supplier in each specific evaluation. In both of the cases in which the weight of quality and the weight of cost was equal to 1, suppliers 230 and 85 appeared within the first 15 suppliers. However, this was not the case when the weight for either performance or risk equaled 1. Therefore, S230 and S085 have better attributes for quality and cost criteria than for performance and risk criteria. On the other hand, global suppliers have better performance than local and national suppliers. That result appears clearly from a review to the top 15 suppliers under this criterion.

	Main Criteria Weights					
	Quality=1, Performance=Cost=Risk=0					
	Q		**S**		**R**	
1	0.000	S014	0.136	S014	0.067	S014
2	0.099	S043	0.161	S173	0.067	S043
3	0.162	S085	0.180	S085	0.108	S085
4	0.217	S230	0.212	S044	0.109	S007
5	0.222	S036	0.222	S230	0.109	S026
6	0.238	S026	0.241	S036	0.109	S036
7	0.242	S129	0.244	S043	0.113	S094
8	0.284	S058	0.249	S129	0.113	S129
9	0.294	S181	0.254	S058	0.113	S230
10	0.300	S007	0.259	S026	0.126	S058
11	0.307	S173	0.266	S181	0.126	S072
12	0.342	S077	0.299	S068	0.126	S181
13	0.343	S072	0.313	S077	0.127	S012
14	0.345	S241	0.317	S241	0.127	S077
15	0.352	S249	0.318	S072	0.127	106

Table 5.14: Top 15 suppliers evaluated under quality criterion (highest)

	Main Criteria Weights					
	Cost=1, Quality=Performance=Risk=0					
	Q		**S**		**R**	
1	0.000	S040	0.011	S040	0.011	S040
2	0.051	S058	0.044	S058	0.044	S058
3	0.064	S032	0.052	S032	0.052	S032
4	0.139	S026	0.104	S013	0.082	S004
5	0.145	S013	0.114	S094	0.082	S026
6	0.151	S004	0.134	S026	0.082	S062
7	0.151	S094	0.156	S004	0.104	S013
8	0.162	S062	0.166	S012	0.104	S094
9	0.212	S117	0.178	S062	0.104	S117
10	0.214	S233	0.185	S230	0.120	S233
11	0.232	S012	0.202	S233	0.152	S210
12	0.272	S230	0.218	S131	0.155	S012
13	0.275	S072	0.229	S117	0.155	S072
14	0.276	S210	0.249	S072	0.155	S235
15	0.284	S235	0.256	S210	0.164	S014

Table 5.15: Top 15 suppliers evaluated under cost criterion (highest)

	Main Criteria Weights					
	Performance=1, Quality=Cost=Risk=0					
	Q		S		R	
1	0.000	S220	0.067	S220	0.037	S220
2	0.053	S226	0.100	S226	0.049	S226
3	0.070	S181	0.113	S181	0.052	S181
4	0.099	S155	0.129	S236	0.052	S174
5	0.101	S174	0.135	S155	0.056	S155
6	0.127	S224	0.144	S174	0.060	S224
7	0.143	S236	0.151	S202	0.088	S236
8	0.176	S202	0.156	S224	0.092	S161
9	0.189	S161	0.169	S161	0.095	S202
10	0.255	S235	0.192	S235	0.109	S156
11	0.295	S156	0.214	S068	0.115	S150
12	0.329	S172	0.226	S024	0.118	S172
13	0.337	S150	0.234	S077	0.119	S235
14	0.344	S233	0.242	S233	0.121	S200
15	0.349	S200	0.243	S062	0.137	S245

Table 5.16: Top 15 suppliers evaluated under performance criterion (highest)

	Main Criteria Weights					
	Risk=1, Quality=Cost=Performance=0					
	Q		**S**		**R**	
1	0	S044	0.047	S044	0.047	S044
2	0.026	S106	0.081	S161	0.047	S106
3	0.065	S161	0.087	S106	0.074	S013
4	0.082	S013	0.120	S013	0.081	S161
5	0.095	S240	0.127	S240	0.081	S240
6	0.115	S075	0.134	S075	0.093	S072
7	0.141	S202	0.174	S202	0.093	S075
8	0.163	S072	0.207	S072	0.093	S095
9	0.163	S072	0.207	S072	0.093	S133
10	0.163	S072	0.207	S072	0.093	S200
11	0.189	S200	0.228	S226	0.093	S202
12	0.245	S226	0.248	S200	0.140	S094
13	0.252	S094	0.254	S094	0.148	S129
14	0.275	S224	0.267	S143	0.148	S210
15	0.305	S241	0.268	S012	0.148	S224

Table 5.17: Top 15 suppliers evaluated under risk criterion (highest)

One more assumption will be tested on the weights, but this time for the sub-criteria. What would happen if all the sub-criteria had the same weight? $(w_j = 0.055)$. In this assumption, $R_j = w_j$, so the second term or part of the Q_j formula that involves R_j has to be eliminated in order that the numerator in the equation is not divided by zero. The results of this calculation are shown in Table 5.18.

	Weights					
	Sub-Criteria Weights=0.055					
	Q		**S**		**R**	
1	0	S044	0.243	S044	0.055	C01-C18=.055
2	0.035	S014	0.271	S014	0.055	
3	0.078	S094	0.306	S094	0.055	
4	0.085	S007	0.312	S007	0.055	
5	0.093	S058	0.318	S058	0.055	
6	0.104	S230	0.327	S230	0.055	
7	0.105	S129	0.328	S129	0.055	
8	0.111	S106	0.333	S106	0.055	
9	0.126	S068	0.345	S068	0.055	
10	0.126	S062	0.345	S062	0.055	
11	0.128	S012	0.347	S012	0.055	
12	0.129	S040	0.347	S040	0.055	
13	0.130	S013	0.349	S013	0.055	
14	0.132	S026	0.350	S026	0.055	
15	0.137	S038	0.354	S038	0.055	

Table 5.18: Top 15 suppliers evaluated under all sub-criteria (equal weights)

In this case, condition one and two are satisfied. That means that supplier 44 is the best choice under this assumption. Note that nearly half of the 15 top suppliers are local suppliers. Moreover, supplier 230 is ranked in 6th place while supplier 85 is no longer within the top 15.

The final test will be the effect of weight on the strategy of maximum group utility (v). The stability of this strategy will be evaluated using the weights that were obtained from the application of the AHP technique. It was found that v satisfies condition one when it is in the interval $0.275 \leq v \leq 0.896$: see Table 5.19. S and R remain in the same order in this interval. However, the ranking of Q_j has undergone a small change during this interval. Supplier 230 is within the compromise solution when v is chosen to be within this interval. However, supplier 85 remains one of the compromise solutions when $0.275 \leq v \leq 0.55$. Supplier 58 takes its place when v is in the interval $0.56 \leq v \leq 0.68$. Supplier 58 surrenders its place to supplier 14 within the interval $0.69 \leq v \leq 0.896$. In conclusion, v is stable in the above-noted interval and in this interval, and one of the compromise solutions is supplier 230, while the other is one of three suppliers – 85, 58 or 14 – depending on v value.

	≤ v ≤									
	0.275			0.5			0.896			
Rank	**Q**	**S**	**R**	**Q**	**S**	**R**	**Q**	**S**	**R**	
1	S230	S014	S085	S230	S014	S085	S230	S014	S085	
2	S085	S230	S094	S085	S230	S094	S014	S230	S094	
3	S094	S058	S230	S058	S058	S230	S058	S058	S230	
4	S058	S085	S007	S094	S085	S007	S085	S085	S007	
5	S007	S026	S072	S014	S026	S072	S094	S026	S072	
6	S072	S094	S181	S007	S094	S181	S026	S094	S181	
7	S181	S173	S058	S072	S173	S058	S173	S173	S058	
8	S014	S044	S133	S181	S044	S133	S044	S044	S133	
9	S133	S072	S200	S026	S072	S200	S072	S072	S200	
10	S012	S040	S012	S077	S040	S012	S007	S040	S012	$1/(J-1)$
$Q(a'') - Q(a')$	**0.01577571**			**0.063470057**			**0.015792301**			**0.015625**

Table 5.19: Top 10 suppliers evaluated under stability of v

5.4 Validating the Model

Duckstein and Opricovic (1980) solved a problem related to ranking and choosing from five-alternative systems for Tisza River Basin in Hungary. The problem they solved was by compromise programming. The same problem has been solved before in two papers of other authors using two different approaches. The first paper, by David and Duckstein (1976), presents a solution using the ELECTRE method, composed of System I (S.I) and System II (S.II). The paper's analysis of these two systems concludes that S.II is the preferred system. The second paper, by Keeney and Wood (1977), solves the problem by using multi-attribute utility theory, and concludes that S.I is slightly better than S.II in terms of utilities. Duckstein and Opricovic (1980) suggested that S.I could be chosen if agencies of some criteria accept the regrets, otherwise the problem should be revised again. The data from these five systems and their criteria are listed in Table 5.20. However, the weights given to the criteria have been obtained from Keeney and Wood (1977), and have been modified so that their sum equals 1. The weights of the criteria are listed in Table 5.21 with the modified weights.

	System					
	I	II	III	IV	V	Objective
C01	99.6	85.7	101.1	95.1	101.8	Min
C02	4	19	50	50	50	Min
C03	4	3	1	4	2	Max
C04	0.7	0.5	0.01	0.1	0.01	Max
C05	4	3	2	1	1	Max
C06	1	0.5	1.5	0.5	2	Min
C07	90	80	80	60	70	Min
C08	3	3	2	1	1	Max
C09	4	3	1	3	2	Max
C10	4	3	2	1	2	Max
C11	4	3	2	1	2	Max
C12	3	3	1	2	1	Max

Table 5.20: River basin systems' data (Duckstein and Opricovic, 1980)

	Weight	w_i/Total
w_1	0.15	0.091
w_2	0.243	0.147
w_3	0.189	0.115
w_4	0.09	0.055
w_5	0.132	0.080
w_6	0.2	0.121
w_7	0.09	0.055
w_8	0.165	0.100
w_9	0.132	0.080
w_{10}	0.189	0.115
w_{11}	0.034	0.021
w_{12}	0.034	0.021
Total	1.648	

Table 5.21: Keeney and Wood (1977) weights for basin systems criteria with the modified weights

These data will now be tested by the proposed model where the results will be compared to the previous solutions. First, the data will be normalized. Then, these data will be multiplied to their corresponding weights. After this, stage two can proceed, wherein the dendrogram shows that the possible number of clusters is 3. The results of *k*-mean clustering are shown in Table 5.22. Cluster 1 has the best alternatives with two members (S.I & S.II).

Cluster	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	Average
1	0.052	0.123	0.096	0.047	0.067	0.101	0.009	0.100	0.067	0.096	0.017	0.021	0.066
2	0.038	0	0.115	0.007	0	0.121	0.055	0	0.053	0	0	0.010	0.033
3	0.002	0	0.019	0	0.013	0.020	0.027	0.025	0.013	0.038	0.007	0	0.014

Cluster 1 membership		Cluster 2 membership	Cluster 3 membership	
S.I	S.II	S.IV	S.III	S.V

Table 5.22: The center of clusters with cluster memberships'

The results of the second stage show that S.I and S.II are the best alternatives, followed by S.IV and then members of cluster 3. Since the result of the best cluster consists of two alternatives, the third stage can be ignored and a simple analysis can be performed for these two alternatives in order to determine the better one. However, the solution to the problem using the VIKOR method is shown in Table 5.23.

	System	
	I	II
C01	0.078582	0
C02	0	0.048082
C03	0	0.038228
C04	0	0.015829
C05	0	0.026699
C06	0.040453	0
C07	0.054612	0.036408
C08	0	0
C09	0	0.026699
C10	0	0.038228
C11	0	0.006877
C12	0	0
S	0.173647	0.237051
R	0.078582	0.048082
Q	0.5	0.5

Table 5.23: VIKOR results of river basin systems problem

The result shows that the compromise solution consists of S.I and S.II. However, further analysis reveals that S.I is the best choice since it is dominant on most criteria, except 3 out of the 12. The S function or solution in the VIKOR method provides the maximum group utility, which represents this domination.

This solution of the proposed model matches that of Keeney and Wood (1977) and of Duckstein and Opricovic (1980). This demonstrates that this model has the ability to deal with large and small numbers of data, as demonstrated in the numerical example and in the river basin system example. Table 5.24 summarizes the solutions that were given to the river basin system problem.

	David and Duckstein (1976)	Keeney and Wood (1977)	Duckstein and Opricovic (1980)	Proposed Model
Method	ELECTRE	MAUT	CP	AHP+CA+VIKOR
Solution	S.II	S.I	S.I	S.I

Table 5.24: Choosing river basin system solution from different authors and methods

As another example of the importance of integrating weights with the data, Holt (1996) applied clustering techniques to 40 suppliers with 21 criteria but without considering the integration of weights with the suppliers' rates. The result of his first clustering's best set of suppliers was 26 out of 40. He did not pursue the analysis to find the best supplier. Instead, he suggested that in order to find the best supplier, these 26 suppliers should be clustered in the same manner until the best supplier falls into a cluster alone. If Holt's procedure is continued, the best supplier will be number 30. However, if partial averaging techniques are applied to the whole data set, supplier number 33 emerges as the best (See Table A.6 for original data and Table A.7 for the partial averaging technique). Nevertheless, if criteria weights (the weights have been taken from his previous paper (Holt *et al*., 1994) and have been normalized as seen in table A.8) are applied to his data, the best supplier is again found to be number 33. After the clustering techniques have been performed two times, the first results consist of three clusters. The best one has 9 suppliers and from these 9 suppliers four clusters have been generated, the best cluster of which occurred alone in a cluster (supplier number 33). Moreover, a comparison of Holt's results of 26 best suppliers with the first outcome's best cluster that considered the weights shows that 4 suppliers out of 9 are missing from his 26 best suppliers. The 26 best suppliers and the 9 suppliers contained in the best cluster are listed in Table 5.25.

Holt's first best cluster			First best cluster with considering the weights
Cr1	Cr13	Cr27	Cr1
Cr2	Cr16	Cr28	Cr8
Cr5	Cr17	Cr30	Cr18
Cr6	Cr18	Cr31	Cr20
Cr7	Cr19	Cr33	Cr24
Cr8	Cr21	Cr36	Cr25
Cr9	Cr22	Cr39	Cr29
Cr10	Cr23	Cr40	Cr33
Cr12	Cr24		Cr35

Table 5.25: Weights effect on cluster results

In addition, by continuing Holt's procedure, these 26 suppliers will fall into three clusters with 7 suppliers in the best cluster. The result of the second round of clustering along with its partial averaging results and the result of the first round of clustering considering weights along with its partial averaging results are all listed in Table 5.26. Notice that the first round of clustering considering weights confirms the accuracy of the results, since the top 9 suppliers are ranked as the top 9 in the partial averaging results. On the other hand, the top 7 suppliers produced in the second round of Holt's clustering procedure are not ranked in the top 7 of the partial averaging results. There are 4 out of the 7 that are ranked within the top 7 suppliers. This comparison shows the importance of considering weights during the clustering procedure before conducting the clustering technique.

	Considering the Weights		Not Considering the Weights	
Rank	**Partial Average**	**Cluster Results**	**Partial Average**	**Cluster Results**
1	S33	Cr33	S33	Cr33
2	S18	Cr18	S08	
3	S24	Cr24	S01	
4	S29	Cr29	S35	
5	S08	Cr8	S18	Cr18
6	S01	Cr1	S24	Cr24
7	S25	Cr25	S30	Cr30
8	S35	Cr35	S13	
9	S20	Cr20	S36	
10	S13		S39	
11	S36		S29	
12	S34		S19	
13	S03		S06	
14	S26		S28	
15	S30		S12	
16	S06		S25	
17	S15		S20	
18	S27		S21	
19	S28		S07	
20	S38		S04	
21	S31		S31	
22	S12		S09	
23	S11		S16	
24	S32		S10	
25	S05		S34	
26	S04		S05	Cr5
27	S23		S23	Cr23
28	S39		S40	
29	S07		S02	Cr2
30	S09		S03	
31	S02		S26	
32	S10		S17	
33	S19		S37	
34	S16		S22	
35	S14		S11	
36	S17		S15	
37	S40		S27	
38	S21		S14	
39	S37		S32	
40	S22		S38	

Table 5. 26: Comparison between partial averaging results and cluster results

Chapter 6:

Conclusions and Future Works

6.1 Conclusions

Choosing the right supplier plays an important role in making organizations profitable and keeping them focused on their potential strengths. Therefore, evaluating the quality of suppliers carefully is vital for any company. The purpose of supplier quality evaluation, however, can differ from one company to another. Some companies might have a large set of suppliers and consequently might want to reduce the number of suppliers so that they can manage them more efficiently and focus on building long-term relationships with only preferred suppliers. On the other hand, some companies might be looking for new suppliers to deal with, therefore, they may use different rationale for supplier quality evaluation.

In this thesis, we propose a three-stage model for supplier quality evaluation. The first stage focuses on selecting evaluation criteria and assigning weight to each criterion. This stage is an essential step in the evaluation of supplier quality.

The second stage addresses the challenge of handling large supplier datasets and reducing complexity by conducting clustering. In this stage, the weights assigned in the first stage are integrated with suppliers' ratings. This step is important for the formation of the right clusters, and the determination of which cluster should have the best suppliers. Considering the weights in the clustering process ensures that similar suppliers are grouped together, since clustering suppliers without considering criteria weights will not consider the trade-offs between criteria.

In the third and the last stage, outranking technique VIKOR is applied to select the best supplier(s) in the supplier cluster obtained from stage 2. The purpose of selecting suppliers is not always to find the best supplier; sometimes its purpose is to reduce the number of suppliers or to choose a specific number of suppliers. By ranking the results, the user can have a clearer appreciation of each supplier and its relative position. Thus, this method enables customers to evaluate suppliers much more easily than before, and will save time and effort in evaluation of large data sets of suppliers.

The proposed model enables one to deal with suppliers' large data sets and simplifies the MCDM problem to the point of dealing with a reduced number of suppliers with a variety of variables (qualitative, quantitative). To assure customers about the quality of the supplier, a careful, efficient and reliable evaluation must be performed. The proposed model offers such an evaluation, since it identifies the best group of suppliers as dominant over the others, and its last stage gives buyers the chance to choose the number of suppliers they need and keep a list of others for future references or as a backup.

This research has some limitations, as some of the data was generated by Excel which does not reflect the real data. Therefore, there is still scope for verifying and validating model results by considering real data.

6.2 Future Works

The proposed model concentrates on evaluating suppliers' quality. This model can be extended by using fuzzy set theory to handle uncertainty and imprecise data. Moreover, clustering techniques have not been given a great deal of attention in the area of supplier quality evaluation and there is an opportunity to integrate this methodology in this domain.

Moreover, the period after selecting the supplier can be considered as an area for future work as well, since supplier performance can change over time giving rise to following questions:

- Which supplier and which criteria should be monitored?

- When and how often this could be done?

Finally, the work should be coupled with supplier development approaches to build long-term relationships for mutual benefits of the buyer organization and the suppliers involved.

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APPENDIX A

	Qualitative Criteria													Quantitative Criteria				
	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14	C15	C16	C17	C18
S001	M	H	VH	L	YES	VH	YES	NO	YES	YES	H	VL	LOCAL	4	1037	4	345	0
S002	ML	VL	L	L	YES	MH	NO	YES	NO	NO	H	ML	LOCAL	2	1125	2	329	0
S003	L	L	VL	M	NO	MH	YES	NO	NO	NO	H	M	LOCAL	12	1561	3	346	0
S004	MH	H	H	H	YES	L	NO	YES	NO	NO	H	M	LOCAL	8	1357	4	324	0
S005	H	L	MH	M	YES	H	NO	NO	YES	YES	H	ML	LOCAL	10	1386	2	305	0
S006	VH	M	VL	L	NO	VL	YES	NO	NO	NO	H	VH	LOCAL	10	1494	2	269	0
S007	MH	L	VH	VL	YES	H	YES	YES	NO	YES	H	L	LOCAL	7	1188	2	276	0
S008	VL	M	H	ML	NO	ML	YES	YES	YES	YES	H	L	LOCAL	14	1417	3	271	0
S009	VL	MH	H	L	NO	VL	YES	YES	YES	NO	H	M	LOCAL	15	1264	4	272	0
S010	L	L	M	VL	NO	VH	NO	NO	NO	NO	H	M	LOCAL	14	1671	3	294	0
S011	ML	L	VL	VL	NO	MH	YES	YES	YES	YES	H	MH	LOCAL	12	1154	4	288	0
S012	H	VH	M	VL	NO	H	YES	YES	NO	YES	H	M	LOCAL	9	1317	3	296	0
S013	VH	VH	MH	MH	NO	MH	NO	YES	NO	YES	H	H	LOCAL	11	1299	2	329	0
S014	VH	MH	MH	VL	YES	VH	YES	YES	NO	YES	H	ML	LOCAL	4	1258	3	317	0
S015	VL	MH	VH	MH	NO	VL	NO	YES	YES	YES	H	ML	LOCAL	12	1011	2	250	0
S016	VH	VL	VH	ML	NO	L	YES	NO	YES	YES	H	VH	LOCAL	5	1071	4	260	0
S017	M	L	ML	H	YES	VL	YES	YES	NO	NO	H	VL	LOCAL	14	1313	4	264	0
S018	H	M	ML	VL	YES	VH	YES	NO	YES	NO	H	ML	LOCAL	10	1421	2	314	0
S019	VL	VH	L	MH	YES	L	YES	YES	YES	YES	H	VH	LOCAL	11	1571	2	317	0
S020	M	MH	H	L	NO	MH	YES	NO	NO	NO	H	ML	LOCAL	2	1020	2	285	0
S021	VL	VH	M	VH	YES	L	YES	NO	YES	NO	H	H	LOCAL	13	1299	4	326	0
S022	VH	H	MH	L	YES	L	NO	NO	YES	NO	H	VH	LOCAL	7	1000	2	258	0
S023	H	M	VH	L	YES	M	YES	YES	NO	YES	H	VL	LOCAL	10	1694	4	339	0
S024	M	ML	H	H	NO	M	NO	YES	YES	NO	H	H	LOCAL	15	1023	4	252	0
S025	VH	VH	H	H	NO	L	NO	NO	NO	YES	H	H	LOCAL	5	1645	4	344	0
S026	MH	H	H	MH	YES	H	NO	YES	NO	NO	H	M	LOCAL	2	1467	2	328	0
S027	VL	H	VH	M	NO	M	YES	YES	NO	YES	H	ML	LOCAL	6	1217	2	315	0
S028	M	M	VH	MH	NO	H	NO	YES	NO	NO	H	L	LOCAL	11	1426	3	273	0
S029	VL	ML	H	M	YES	L	NO	YES	YES	YES	H	L	LOCAL	6	1742	4	264	0
S030	VL	MH	VL	MH	NO	ML	YES	NO	YES	NO	H	L	LOCAL	7	1743	2	328	0
S031	L	ML	ML	H	YES	MH	NO	NO	NO	YES	H	L	LOCAL	8	1134	4	318	0
S032	M	VH	H	MH	YES	ML	NO	YES	NO	YES	H	L	LOCAL	14	1319	2	290	0
S033	L	ML	H	ML	YES	L	YES	NO	NO	NO	H	VL	LOCAL	4	1395	2	307	0
S034	L	VH	MH	M	NO	H	YES	YES	YES	YES	H	MH	LOCAL	15	1334	4	332	0
S035	VL	VL	H	VH	NO	L	YES	NO	YES	YES	H	L	LOCAL	14	1089	2	343	0
S036	MH	VL	ML	ML	YES	MH	YES	YES	YES	NO	H	M	LOCAL	5	1461	4	329	0
S037	VL	MH	M	H	NO	L	NO	NO	YES	YES	H	ML	LOCAL	4	1675	3	283	0
S038	H	M	MH	VL	NO	L	YES	YES	YES	YES	H	M	LOCAL	4	1551	4	335	0
S039	VH	MH	MH	VL	NO	ML	YES	NO	YES	YES	H	M	LOCAL	9	1049	4	337	0
S040	VH	VH	VH	L	YES	VL	YES	YES	YES	NO	H	VL	LOCAL	9	1658	3	310	0
S041	L	L	VL	H	YES	M	NO	NO	NO	NO	H	H	LOCAL	9	1188	2	333	0
S042	VL	L	M	L	YES	M	YES	YES	NO	YES	H	ML	LOCAL	12	1559	4	279	0
S043	H	ML	M	ML	YES	MH	NO	YES	NO	YES	H	VL	LOCAL	2	1706	4	323	0
S044	VH	ML	ML	ML	YES	H	YES	YES	YES	YES	H	VH	LOCAL	11	1289	2	350	0
S045	L	M	ML	L	YES	VH	NO	YES	NO	NO	H	ML	LOCAL	5	1294	3	275	0
S046	ML	VH	VH	MH	YES	ML	YES	YES	NO	NO	H	ML	LOCAL	11	1723	2	309	0
S047	ML	VL	VL	VH	YES	VH	YES	NO	NO	YES	H	MH	LOCAL	14	1182	2	308	0
S048	M	H	L	L	NO	H	NO	NO	YES	YES	H	H	LOCAL	7	1393	4	286	0
S049	VH	VH	MH	VH	YES	M	NO	NO	YES	YES	H	VL	NATIONAL	14	1678	4	302	0
S050	H	ML	MH	ML	NO	MH	YES	NO	YES	YES	M	ML	NATIONAL	13	1630	3	252	0
S051	MH	H	M	M	YES	VL	YES	NO	NO	NO	MH	M	NATIONAL	13	1109	6	266	0
S052	M	VH	VH	L	NO	ML	YES	NO	NO	YES	M	VH	NATIONAL	15	1585	6	275	0
S053	ML	ML	H	VL	YES	MH	YES	NO	NO	YES	H	ML	NATIONAL	6	1682	7	229	0
S054	L	MH	ML	H	YES	VL	YES	YES	YES	YES	H	M	NATIONAL	4	1219	7	269	0
S055	L	MH	MH	VH	YES	L	YES	YES	NO	NO	MH	M	NATIONAL	6	1465	6	258	0
S056	VH	MH	M	MH	NO	H	NO	YES	NO	NO	M	MH	NATIONAL	13	1680	4	266	0
S057	VL	VL	M	VH	YES	M	NO	YES	NO	NO	MH	VH	NATIONAL	9	1257	3	232	0
S058	VH	VH	VH	VL	YES	H	YES	YES	NO	YES	MH	VL	NATIONAL	9	1195	6	290	0
S059	ML	MH	VL	H	YES	M	NO	NO	NO	NO	MH	ML	NATIONAL	14	1093	4	236	0
S060	L	L	L	L	NO	VL	YES	NO	YES	YES	H	ML	NATIONAL	13	1635	3	261	0
S061	MH	VH	ML	MH	YES	M	NO	NO	YES	NO	M	VH	NATIONAL	7	1692	4	261	0
S062	VH	H	H	L	NO	L	YES	YES	YES	YES	MH	L	NATIONAL	10	1204	6	225	0
S063	VL	VH	ML	VL	YES	H	YES	NO	YES	YES	H	VH	NATIONAL	14	1358	4	227	0
S064	L	VL	MH	VL	YES	M	NO	NO	YES	YES	M	VL	NATIONAL	4	1014	4	229	0
S065	ML	VH	VL	H	NO	L	NO	NO	YES	YES	MH	VH	NATIONAL	2	1380	3	254	0
S066	M	H	M	H	NO	VH	YES	NO	NO	NO	M	VL	NATIONAL	11	1352	4	202	0
S067	L	H	M	MH	YES	L	NO	YES	NO	YES	M	M	NATIONAL	9	1377	6	292	0
S068	H	VL	ML	M	YES	M	YES	YES	YES	NO	M	VH	NATIONAL	10	1133	5	220	0
S069	MH	VL	VL	VH	NO	L	YES	NO	NO	YES	M	ML	NATIONAL	3	1641	6	278	0
S070	L	MH	L	M	YES	M	YES	YES	NO	YES	MH	M	NATIONAL	7	1389	6	235	0
S071	MH	H	MH	MH	YES	MH	NO	NO	YES	YES	MH	H	NATIONAL	8	1220	6	290	0
S072	H	H	M	L	YES	VH	NO	YES	NO	YES	MH	H	NATIONAL	9	1562	3	279	0
S073	VH	VL	L	MH	NO	H	YES	NO	YES	NO	M	M	NATIONAL	7	1590	3	270	0
S074	VL	L	VH	L	NO	H	YES	YES	NO	NO	M	H	NATIONAL	4	1214	7	254	0
S075	MH	VH	L	ML	NO	VL	NO	YES	NO	YES	MH	VH	NATIONAL	8	1633	5	278	0
S076	MH	ML	ML	M	YES	MH	YES	NO	YES	YES	MH	MH	NATIONAL	3	1615	3	300	0
S077	H	VL	VH	ML	NO	MH	YES	YES	YES	NO	M	VL	NATIONAL	5	1254	3	208	0
S078	H	VH	M	M	NO	ML	NO	NO	NO	NO	MH	VL	NATIONAL	10	1339	3	266	0
S079	ML	VL	H	H	YES	VL	YES	YES	YES	YES	H	VH	NATIONAL	3	1573	5	200	0
S080	ML	MH	H	H	NO	ML	NO	YES	YES	YES	H	MH	NATIONAL	6	1153	3	246	0
S081	M	M	MH	M	YES	VL	NO	NO	NO	YES	M	M	NATIONAL	7	1521	5	243	0
S082	VL	H	L	H	YES	M	NO	NO	YES	YES	MH	MH	NATIONAL	2	1431	3	207	0
S083	MH	ML	ML	L	YES	M	NO	NO	YES	NO	H	ML	NATIONAL	13	1409	4	259	0
S084	VH	ML	MH	M	NO	M	NO	YES	NO	YES	H	VL	NATIONAL	14	1079	4	256	0
S085	VH	M	ML	VH	YES	H	NO	YES	YES	NO	M	M	NATIONAL	8	1701	3	228	0
S086	VH	VH	H	MH	NO	ML	NO	NO	YES	NO	M	VL	NATIONAL	12	1035	6	251	0
S087	M	VL	ML	ML	YES	ML	NO	NO	YES	YES	MH	ML	NATIONAL	8	1125	3	288	0
S088	VL	VL	ML	L	NO	M	YES	NO	NO	NO	MH	VL	NATIONAL	3	1526	3	214	0
S089	H	H	L	M	YES	MH	YES	NO	YES	NO	H	MH	NATIONAL	11	1075	3	260	0
S090	MH	L	VL	L	YES	H	NO	NO	NO	YES	M	H	NATIONAL	13	1637	7	236	0
S091	MH	VH	VL	H	NO	M	NO	YES	NO	YES	M	M	NATIONAL	14	1617	3	266	0
S092	ML	H	M	M	YES	M	YES	YES	NO	YES	H	VH	NATIONAL	14	1613	3	236	0
S093	H	H	M	L	NO	VH	YES	NO	NO	NO	H	ML	NATIONAL	14	1171	4	297	0
S094	MH	VH	MH	ML	YES	ML	NO	YES	YES	YES	M	H	NATIONAL	7	1348	3	225	0
S095	VH	M	VL	ML	YES	MH	NO	YES	NO	YES	MH	H	NATIONAL	14	1166	6	252	0
S096	VL	VL	ML	H	YES	VH	YES	NO	YES	YES	M	ML	NATIONAL	6	1123	6	206	0
S097	ML	H	VL	ML	YES	H	NO	YES	YES	NO	MH	M	NATIONAL	12	1557	7	244	0
S098	H	M	M	VL	NO	ML	NO	NO	YES	NO	M	MH	NATIONAL	12	1114	7	283	0
S099	VL	MH	M	MH	NO	ML	NO	NO	NO	NO	MH	ML	NATIONAL	5	1595	5	250	0
S100	VL	L	VH	ML	NO	M	NO	NO	NO	NO	MH	H	NATIONAL	11	1424	5	254	0
S101	MH	MH	L	VL	NO	VL	NO	NO	YES	NO	H	L	NATIONAL	14	1314	5	289	0
S102	M	ML	MH	MH	YES	VL	NO	YES	YES	YES	MH	VL	NATIONAL	10	1372	4	224	0
S103	MH	VL	M	ML	YES	VL	NO	NO	YES	YES	MH	VL	NATIONAL	14	1749	6	255	0
S104	VL	ML	VL	H	NO	VL	NO	NO	YES	YES	H	L	NATIONAL	10	1651	5	224	0
S105	VH	H	ML	M	YES	H	YES	NO	NO	YES	MH	VL	NATIONAL	6	1166	4	250	0
S106	MH	VL	H	MH	NO	MH	YES	YES	NO	YES	H	VH	NATIONAL	2	1500	3	223	0
S107	VL	ML	M	VL	YES	L	YES	NO	YES	YES	MH	L	NATIONAL	2	1728	4	256	0
S108	M	L	MH	L	NO	M	NO	NO	YES	NO	H	MH	NATIONAL	12	1561	4	281	0
S109	VL	ML	ML	M	NO	ML	NO	YES	NO	YES	MH	M	NATIONAL	15	1026	4	224	0
S110	VH	H	ML	MH	NO	MH	NO	NO	NO	NO	MH	H	NATIONAL	14	1589	7	211	0
S111	VL	L	VH	MH	YES	H	NO	NO	NO	NO	M	L	NATIONAL	6	1673	7	217	0
S112	H	L	H	ML	YES	VH	NO	NO	YES	YES	MH	VH	NATIONAL	7	1656	5	263	0
S113	L	M	VH	VL	NO	MH	YES	YES	YES	NO	M	VL	NATIONAL	5	1354	6	226	0
S114	VL	H	MH	VH	YES	VL	YES	NO	YES	NO	M	VH	NATIONAL	2	1561	7	233	0
S115	ML	M	ML	H	NO	M	YES	NO	YES	YES	H	H	NATIONAL	15	1055	3	265	0
S116	VH	VL	M	ML	NO	L	YES	YES	YES	YES	H	L	NATIONAL	7	1420	3	234	0
S117	VH	H	MH	VL	NO	H	YES	YES	YES	YES	MH	VL	NATIONAL	13	1387	6	258	0
S118	VL	H	H	L	YES	L	YES	YES	YES	NO	MH	L	NATIONAL	9	1368	7	260	0
S119	L	M	H	MH	NO	H	YES	NO	NO	YES	H	MH	NATIONAL	7	1350	4	203	0
S120	ML	ML	VL	H	YES	VH	YES	YES	YES	NO	M	M	NATIONAL	14	1239	6	265	0
S121	VH	VL	L	M	YES	L	NO	NO	YES	YES	H	ML	NATIONAL	5	1333	5	218	0
S122	L	H	M	ML	YES	VH	NO	YES	YES	YES	H	VL	NATIONAL	3	1283	5	244	0
S123	VH	VL	VL	L	YES	VL	YES	NO	YES	YES	MH	ML	NATIONAL	13	1490	7	246	0
S124	ML	VL	H	VL	NO	ML	YES	YES	NO	NO	H	H	NATIONAL	5	1093	4	233	0

Table A. 1: Generated data

	Qualitative Criteria													Quantitative Criteria				
	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14	C15	C16	C17	C18
S125	VL	VL	H	H	NO	H	NO	YES	NO	YES	M	MH	NATIONAL	5	1656	7	213	0
S126	H	ML	ML	MH	NO	ML	YES	NO	YES	YES	MH	L	NATIONAL	5	1283	5	285	0
S127	VL	H	L	M	YES	MH	YES	NO	NO	YES	MH	MH	NATIONAL	12	1230	6	248	0
S128	VL	MH	MH	H	NO	M	YES	NO	NO	YES	MH	ML	NATIONAL	6	1412	4	209	0
S129	MH	VL	VH	L	YES	ML	YES	YES	YES	YES	M	MH	NATIONAL	2	1705	5	274	0
S130	L	VL	VL	MH	NO	M	YES	NO	NO	YES	M	VH	NATIONAL	2	1093	7	204	0
S131	M	VH	ML	H	NO	M	NO	YES	YES	NO	H	MH	NATIONAL	14	1140	3	268	0
S132	ML	ML	L	M	NO	VH	NO	NO	YES	NO	H	M	NATIONAL	13	1391	5	249	0
S133	MH	M	M	L	NO	ML	NO	YES	YES	YES	MH	H	NATIONAL	3	1396	5	202	0
S134	ML	H	MH	M	YES	M	NO	YES	NO	NO	H	ML	NATIONAL	15	1292	4	248	0
S135	M	MH	H	VH	NO	L	NO	NO	YES	NO	M	VH	NATIONAL	7	1291	7	293	0
S136	VL	VH	VH	M	YES	H	NO	YES	YES	YES	MH	H	NATIONAL	5	1304	5	249	0
S137	VL	VH	MH	MH	YES	L	NO	YES	YES	YES	ML	MH	GLOBAL	7	1507	6	126	12.6
S138	L	VH	H	L	YES	VH	NO	YES	YES	NO	M	M	GLOBAL	14	1141	5	186	18.6
S139	VL	MH	L	VL	NO	M	NO	NO	YES	NO	VH	L	GLOBAL	4	1652	19	121	12.1
S140	ML	VH	ML	H	YES	ML	NO	YES	YES	YES	M	ML	GLOBAL	4	1288	20	156	15.6
S141	VL	MH	M	ML	YES	ML	YES	NO	YES	NO	ML	VH	GLOBAL	12	1190	19	174	17.4
S142	M	VL	VH	L	YES	VH	YES	NO	NO	YES	H	M	GLOBAL	10	1696	20	136	13.6
S143	H	VH	L	H	NO	L	YES	YES	YES	YES	ML	VH	GLOBAL	10	1552	14	127	12.7
S144	M	MH	VL	H	NO	VH	YES	NO	YES	NO	VH	M	GLOBAL	4	1428	17	170	17
S145	ML	ML	VH	H	NO	M	YES	NO	YES	NO	VH	MH	GLOBAL	5	1167	18	159	15.9
S146	ML	VL	VL	L	YES	H	NO	YES	NO	YES	L	VH	GLOBAL	8	1590	20	141	14.1
S147	VL	M	VH	VH	NO	VH	YES	NO	NO	NO	H	VH	GLOBAL	7	1732	17	148	14.8
S148	H	MH	L	MH	NO	VH	NO	YES	NO	NO	VH	H	GLOBAL	14	1733	13	156	15.6
S149	MH	VL	VH	L	NO	H	NO	NO	YES	YES	ML	VH	GLOBAL	8	1461	12	128	12.8
S150	M	H	ML	VH	YES	VH	NO	YES	NO	YES	ML	L	GLOBAL	13	1346	14	180	18
S151	VL	VL	MH	MH	NO	H	NO	NO	NO	NO	MH	H	GLOBAL	9	1150	17	160	16
S152	VL	VL	VL	ML	YES	H	NO	NO	NO	YES	VH	M	GLOBAL	9	1250	20	194	19.4
S153	VH	M	ML	VH	NO	L	YES	NO	YES	NO	VL	H	GLOBAL	15	1190	15	155	15.5
S154	VL	M	M	VH	NO	L	NO	YES	NO	NO	MH	M	GLOBAL	3	1361	16	105	10.5
S155	VH	ML	VH	M	NO	VL	NO	YES	YES	NO	H	L	GLOBAL	4	1113	13	139	13.9
S156	M	L	M	ML	NO	L	NO	YES	YES	NO	MH	MH	GLOBAL	6	1265	14	176	17.6
S157	ML	MH	VL	VH	NO	MH	NO	NO	YES	YES	H	MH	GLOBAL	11	1098	20	113	11.3
S158	VL	H	VH	ML	NO	VL	YES	NO	NO	YES	VH	H	GLOBAL	2	1219	20	162	16.2
S159	MH	M	ML	M	YES	VH	YES	NO	NO	YES	L	H	GLOBAL	12	1487	16	167	16.7
S160	L	H	L	H	NO	MH	YES	NO	NO	YES	VL	VL	GLOBAL	13	1164	15	136	13.6
S161	H	H	H	ML	NO	VL	YES	YES	NO	YES	VH	VH	GLOBAL	3	1080	18	164	16.4
S162	ML	ML	VH	MH	YES	M	NO	YES	YES	YES	VL	ML	GLOBAL	5	1066	12	146	14.6
S163	M	L	M	H	YES	VL	NO	NO	YES	NO	MH	H	GLOBAL	7	1371	14	193	19.3
S164	VL	MH	MH	L	YES	MH	YES	NO	NO	NO	H	ML	GLOBAL	14	1382	20	127	12.7
S165	VH	L	VL	L	YES	L	NO	NO	YES	YES	L	MH	GLOBAL	7	1527	20	119	11.9
S166	M	L	MH	H	NO	M	NO	NO	NO	NO	ML	MH	GLOBAL	8	1118	15	104	10.4
S167	ML	M	H	ML	NO	VL	YES	NO	YES	NO	M	VH	GLOBAL	2	1523	20	110	11
S168	L	VL	VH	MH	NO	M	NO	YES	NO	YES	L	ML	GLOBAL	15	1631	12	119	11.9
S169	M	L	H	MH	NO	ML	NO	NO	YES	YES	L	L	GLOBAL	13	1356	20	136	13.6
S170	H	MH	ML	H	YES	MH	NO	NO	NO	NO	VH	L	GLOBAL	15	1150	12	164	16.4
S171	VL	VH	VH	L	NO	MH	NO	YES	YES	YES	L	VL	GLOBAL	2	1419	13	130	13
S172	M	VL	M	L	NO	VH	YES	YES	NO	NO	L	ML	GLOBAL	15	1296	17	182	18.2
S173	VH	ML	L	VH	YES	VH	YES	YES	YES	YES	VL	MH	GLOBAL	11	1437	16	199	19.9
S174	M	M	MH	M	YES	M	YES	YES	YES	NO	H	VH	GLOBAL	14	1158	12	136	13.6
S175	ML	L	H	VL	NO	VH	NO	NO	YES	NO	VH	M	GLOBAL	15	1242	17	137	13.7
S176	L	ML	VL	ML	YES	VL	NO	NO	NO	YES	VL	M	GLOBAL	15	1108	20	137	13.7
S177	VL	M	VL	H	YES	MH	NO	NO	NO	NO	VH	MH	GLOBAL	9	1671	17	169	16.9
S178	VL	MH	VH	H	NO	ML	YES	NO	YES	YES	H	H	GLOBAL	4	1459	20	118	11.8
S179	M	VL	VL	VL	YES	L	NO	NO	NO	YES	ML	ML	GLOBAL	5	1516	12	126	12.6
S180	L	M	M	M	YES	VH	YES	NO	NO	YES	L	VH	GLOBAL	12	1395	16	112	11.2
S181	VH	L	L	M	YES	MH	YES	YES	NO	NO	MH	VL	GLOBAL	9	1166	20	117	11.7
S182	VL	L	VH	M	NO	M	NO	NO	NO	YES	H	ML	GLOBAL	14	1372	20	140	14
S183	MH	ML	M	M	NO	ML	NO	NO	YES	YES	H	VH	GLOBAL	2	1284	18	186	18.6
S184	L	M	VL	ML	NO	ML	YES	NO	YES	NO	ML	H	GLOBAL	9	1673	19	150	15
S185	M	L	VL	VL	YES	M	NO	NO	YES	NO	VH	M	GLOBAL	11	1648	15	152	15.2
S186	H	MH	MH	ML	NO	M	NO	YES	NO	YES	VH	ML	GLOBAL	10	1723	13	183	18.3
S187	ML	M	M	L	YES	M	YES	NO	YES	YES	M	ML	GLOBAL	4	1695	16	120	12
S188	M	ML	M	VH	YES	M	NO	NO	NO	YES	L	MH	GLOBAL	9	1027	17	149	14.9
S189	M	L	H	VL	YES	L	YES	NO	YES	YES	M	ML	GLOBAL	10	1345	20	171	17.1
S190	ML	VH	ML	L	YES	M	YES	YES	YES	YES	H	ML	GLOBAL	5	1745	13	111	11.1
S191	ML	MH	VH	VH	NO	M	NO	NO	YES	YES	ML	H	GLOBAL	15	1044	15	129	12.9
S192	H	MH	VH	VH	NO	MH	NO	NO	YES	NO	VL	ML	GLOBAL	13	1316	20	145	14.5
S193	VL	MH	ML	VH	NO	MH	YES	YES	YES	YES	M	L	GLOBAL	13	1714	19	167	16.7
S194	ML	MH	ML	ML	YES	H	YES	YES	YES	YES	VL	VH	GLOBAL	6	1219	13	143	14.3
S195	L	H	M	L	NO	H	YES	YES	YES	NO	MH	M	GLOBAL	8	1058	16	109	10.9
S196	VL	VL	MH	VL	NO	H	NO	YES	NO	NO	VL	ML	GLOBAL	5	1490	17	196	19.6
S197	MH	L	VH	MH	NO	L	NO	NO	YES	NO	VH	MH	GLOBAL	15	1409	12	130	13
S198	VL	M	M	MH	NO	ML	YES	NO	YES	YES	VH	M	GLOBAL	7	1082	17	130	13
S199	MH	M	ML	ML	NO	M	YES	YES	NO	YES	VL	H	GLOBAL	12	1693	13	159	15.9
S200	H	L	L	MH	NO	M	YES	YES	NO	YES	MH	H	GLOBAL	5	1389	19	174	17.4
S201	M	ML	ML	MH	YES	L	YES	NO	YES	YES	MH	VH	GLOBAL	15	1213	15	180	18
S202	M	VL	MH	ML	YES	L	YES	YES	YES	YES	MH	VH	GLOBAL	7	1306	13	114	11.4
S203	MH	H	ML	L	NO	VL	YES	NO	YES	YES	ML	L	GLOBAL	12	1355	15	178	17.8
S204	H	M	MH	L	YES	VH	YES	NO	YES	YES	H	MH	GLOBAL	14	1625	18	119	11.9
S205	ML	L	VL	L	YES	VL	YES	YES	NO	NO	VL	VH	GLOBAL	13	1331	15	167	16.7
S206	VH	VL	M	ML	YES	ML	YES	NO	NO	YES	M	ML	GLOBAL	13	1151	17	124	12.4
S207	M	H	ML	VH	NO	MH	NO	YES	YES	NO	VH	M	GLOBAL	11	1444	19	183	18.3
S208	VH	MH	VL	VH	NO	MH	YES	NO	YES	YES	VH	VL	GLOBAL	15	1311	13	168	16.8
S209	M	VL	H	MH	NO	VH	NO	NO	NO	YES	ML	MH	GLOBAL	11	1057	18	106	10.6
S210	M	VH	MH	VL	NO	L	YES	YES	NO	YES	M	MH	GLOBAL	10	1721	16	177	17.7
S211	L	MH	VL	M	YES	VL	YES	YES	YES	NO	M	H	GLOBAL	5	1338	19	129	12.9
S212	M	VL	M	H	NO	VL	NO	YES	NO	YES	H	VL	GLOBAL	8	1642	16	137	13.7
S213	H	MH	H	VH	YES	ML	NO	NO	YES	NO	VL	MH	GLOBAL	5	1421	17	183	18.3
S214	ML	ML	VL	VL	YES	VL	NO	NO	NO	YES	M	MH	GLOBAL	12	1562	13	176	17.6
S215	M	M	VL	L	YES	L	NO	NO	NO	YES	M	M	GLOBAL	8	1005	20	172	17.2
S216	ML	ML	M	ML	NO	VL	NO	YES	YES	YES	VL	MH	GLOBAL	8	1264	18	134	13.4
S217	VH	L	VL	L	NO	H	YES	NO	YES	NO	ML	M	GLOBAL	2	1102	19	162	16.2
S218	H	M	M	M	NO	L	NO	NO	YES	NO	M	MH	GLOBAL	4	1722	16	157	15.7
S219	M	H	ML	ML	YES	MH	NO	YES	YES	NO	M	ML	GLOBAL	2	1225	12	126	12.6
S220	MH	L	VL	M	YES	VH	YES	YES	NO	NO	H	L	GLOBAL	10	1017	20	117	11.7
S221	M	H	M	M	NO	ML	YES	NO	YES	NO	MH	L	GLOBAL	13	1234	14	127	12.7
S222	L	MH	ML	M	YES	H	NO	YES	NO	YES	L	M	GLOBAL	13	1552	13	145	14.5
S223	H	VH	H	M	YES	L	NO	NO	NO	YES	ML	VL	GLOBAL	5	1289	17	137	13.7
S224	MH	ML	VL	ML	YES	MH	NO	YES	YES	YES	H	MH	GLOBAL	11	1162	18	142	14.2
S225	ML	L	L	H	YES	ML	YES	NO	YES	YES	L	VL	GLOBAL	2	1468	18	163	16.3
S226	M	L	ML	H	NO	VH	YES	YES	YES	YES	VH	MH	GLOBAL	7	1029	20	134	13.4
S227	VH	MH	H	L	NO	L	YES	NO	NO	YES	MH	H	GLOBAL	3	1266	18	153	15.3
S228	VL	H	MH	L	YES	L	YES	NO	YES	NO	VL	M	GLOBAL	14	1296	20	108	10.8
S229	M	H	ML	VH	YES	H	NO	NO	YES	YES	H	MH	GLOBAL	7	1354	20	119	11.9
S230	MH	VH	VH	VH	YES	ML	YES	YES	YES	NO	MH	H	GLOBAL	2	1658	19	114	11.4
S231	MH	M	L	VL	NO	VL	YES	NO	NO	NO	M	ML	GLOBAL	15	1212	18	175	17.5
S232	MH	MH	L	L	YES	M	NO	NO	YES	NO	VH	VL	GLOBAL	14	1519	16	134	13.4
S233	MH	H	VH	M	NO	M	YES	YES	YES	YES	M	M	GLOBAL	15	1463	13	138	13.8
S234	M	ML	M	VH	NO	VH	NO	YES	YES	YES	ML	VL	GLOBAL	3	1495	18	157	15.7
S235	MH	VH	M	M	NO	L	NO	YES	YES	NO	L	ML	GLOBAL	9	1049	12	183	18.3
S236	H	M	L	ML	YES	ML	NO	YES	NO	YES	H	M	GLOBAL	11	1284	20	105	10.5
S237	L	MH	MH	VL	YES	M	YES	NO	YES	YES	VH	M	GLOBAL	12	1086	15	173	17.3
S238	H	M	M	VL	NO	VL	NO	NO	NO	YES	L	VH	GLOBAL	3	1253	16	100	10
S239	VH	ML	ML	L	NO	M	YES	NO	YES	YES	L	ML	GLOBAL	10	1194	13	112	11.2
S240	MH	VL	VL	L	NO	VL	YES	YES	NO	YES	H	VH	GLOBAL	11	1545	15	177	17.7
S241	H	VL	M	VL	NO	M	YES	YES	YES	YES	MH	MH	GLOBAL	3	1495	17	186	18.6
S242	H	VL	MH	VH	YES	L	YES	NO	NO	YES	M	L	GLOBAL	15	1668	15	187	18.7
S243	M	ML	H	VH	YES	MH	NO	YES	NO	NO	VH	VL	GLOBAL	14	1539	14	142	14.2
S244	ML	H	L	M	YES	H	NO	NO	NO	YES	MH	M	GLOBAL	12	1374	15	122	12.2
S245	M	L	M	H	YES	H	NO	YES	YES	NO	L	H	GLOBAL	10	1344	17	195	19.5
S246	VH	ML	L	ML	YES	ML	YES	NO	YES	YES	L	VL	GLOBAL	5	1528	17	133	13.3
S247	L	ML	ML	M	YES	VL	YES	YES	YES	YES	VL	L	GLOBAL	5	1706	19	174	17.4
S248	ML	L	MH	MH	NO	VL	YES	NO	YES	YES	H	MH	GLOBAL	7	1452	20	169	16.9
S249	H	VL	VL	VL	NO	MH	YES	YES	YES	NO	VH	H	GLOBAL	5	1685	16	138	13.8
S250	ML	MH	L	VH	NO	H	NO	YES	YES	NO	VL	VH	GLOBAL	15	1082	19	135	13.5

Table A.1: Generated data Cont’d

	Qualitative Criteria													Quantitative Criteria				
	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14	C15	C16	C17	C18
S001	4	6	7	2	1	7	1	0	1	1	6	1	1	4	1037	4	345	0
S002	3	1	2	2	1	5	0	1	0	0	6	3	1	2	1125	2	329	0
S003	2	2	1	4	0	5	1	0	0	0	6	4	1	12	1561	3	346	0
S004	5	6	6	6	1	2	0	1	0	0	6	4	1	8	1357	4	324	0
S005	6	2	5	4	1	6	0	0	1	1	6	3	1	10	1386	2	305	0
S006	7	4	1	2	0	1	1	0	0	0	6	7	1	10	1494	2	269	0
S007	5	2	7	1	1	6	1	1	0	1	6	2	1	7	1188	2	276	0
S008	1	4	6	3	0	3	1	1	1	1	6	2	1	14	1417	3	271	0
S009	1	5	6	2	0	1	1	1	1	0	6	4	1	15	1264	4	272	0
S010	2	2	4	1	0	7	0	0	0	0	6	4	1	14	1671	3	294	0
S011	3	2	1	1	0	5	1	1	1	1	6	5	1	12	1154	4	288	0
S012	6	7	4	1	0	6	1	1	0	1	6	4	1	9	1317	3	296	0
S013	7	7	5	5	0	5	0	1	0	1	6	6	1	11	1299	2	329	0
S014	7	5	5	1	1	7	1	1	0	1	6	3	1	4	1258	3	317	0
S015	1	5	7	5	0	1	0	1	1	1	6	3	1	12	1011	2	250	0
S016	7	1	7	3	0	2	1	0	1	1	6	7	1	5	1071	4	260	0
S017	4	2	3	6	1	1	1	1	0	0	6	1	1	14	1313	4	264	0
S018	6	4	3	1	1	7	1	0	1	0	6	3	1	10	1421	2	314	0
S019	1	7	2	5	1	2	1	1	1	1	6	7	1	11	1571	2	317	0
S020	4	5	6	2	0	5	1	0	0	0	6	3	1	2	1020	2	285	0
S021	1	7	4	7	1	2	1	0	1	0	6	6	1	13	1299	4	326	0
S022	7	6	5	2	1	2	0	0	1	0	6	7	1	7	1000	2	258	0
S023	6	4	7	2	1	4	1	1	0	1	6	1	1	10	1694	4	339	0
S024	4	3	6	6	0	4	0	1	1	0	6	6	1	15	1023	4	252	0
S025	7	7	6	6	0	2	0	0	0	1	6	6	1	5	1645	4	344	0
S026	5	6	6	5	1	6	0	1	0	0	6	4	1	2	1467	2	328	0
S027	1	6	7	4	0	4	1	1	0	1	6	3	1	6	1217	2	315	0
S028	4	4	7	5	0	6	0	1	0	0	6	2	1	11	1426	3	273	0
S029	1	3	6	4	1	2	0	1	1	1	6	2	1	6	1742	4	264	0
S030	1	5	1	5	0	3	1	0	1	0	6	2	1	7	1743	2	328	0
S031	2	3	3	6	1	5	0	0	0	1	6	2	1	8	1134	4	318	0
S032	4	7	6	5	1	3	0	1	0	1	6	2	1	14	1319	2	290	0
S033	2	3	6	3	1	2	1	0	0	0	6	1	1	4	1395	2	307	0
S034	2	7	5	4	0	6	1	1	1	1	6	5	1	15	1334	4	332	0
S035	1	1	6	7	0	2	1	0	1	1	6	2	1	14	1089	2	343	0
S036	5	1	3	3	1	5	1	1	1	0	6	4	1	5	1461	4	329	0
S037	1	5	4	6	0	2	0	0	1	1	6	3	1	4	1675	3	283	0
S038	6	4	5	1	0	2	1	1	1	1	6	4	1	4	1551	4	335	0
S039	7	5	5	1	0	3	1	0	1	1	6	4	1	9	1049	4	337	0
S040	7	7	7	2	1	1	1	1	1	0	6	1	1	9	1658	3	310	0
S041	2	2	1	6	1	4	0	0	0	0	6	6	1	9	1188	2	333	0
S042	1	2	4	2	1	4	1	1	0	1	6	3	1	12	1559	4	279	0
S043	6	3	4	3	1	5	0	1	0	1	6	1	1	2	1706	4	323	0
S044	7	3	3	3	1	6	1	1	1	1	6	7	1	11	1289	2	350	0
S045	2	4	3	2	1	7	0	1	0	0	6	3	1	5	1294	3	275	0
S046	3	7	7	5	1	3	1	1	0	0	6	3	1	11	1723	2	309	0
S047	3	1	1	7	1	7	1	0	0	1	6	5	1	14	1182	2	308	0
S048	4	6	2	2	0	6	0	0	1	1	6	6	1	7	1393	4	286	0
S049	7	7	5	7	1	4	0	0	1	1	6	1	2	14	1678	4	302	0
S050	6	3	5	3	0	5	1	0	1	1	4	3	2	13	1630	3	252	0
S051	5	6	4	4	1	1	1	0	0	0	5	4	2	13	1109	6	266	0
S052	4	7	7	2	0	3	1	0	0	1	4	7	2	15	1585	6	275	0
S053	3	3	6	1	1	5	1	0	0	1	6	3	2	6	1682	7	229	0
S054	2	5	3	6	1	1	1	1	1	1	6	4	2	4	1219	7	269	0
S055	2	5	5	7	1	2	1	1	0	0	5	4	2	6	1465	6	258	0
S056	7	5	4	5	0	6	0	1	0	0	4	5	2	13	1680	4	266	0
S057	1	1	4	7	1	4	0	1	0	0	5	7	2	9	1257	3	232	0
S058	7	7	7	1	1	6	1	1	0	1	5	1	2	9	1195	6	290	0
S059	3	5	1	6	1	4	0	0	0	0	5	3	2	14	1093	4	236	0
S060	2	2	2	2	0	1	1	0	1	1	6	3	2	13	1635	3	261	0
S061	5	7	3	5	1	4	0	0	1	0	4	7	2	7	1692	4	261	0
S062	7	6	6	2	0	2	1	1	1	1	5	2	2	10	1204	6	225	0

	Qualitative Criteria													Quantitative Criteria				
	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14	C15	C16	C17	C18
S063	1	7	3	1	1	6	1	0	1	1	6	7	2	14	1358	4	227	0
S064	2	1	5	1	1	4	0	0	1	1	4	1	2	4	1014	4	229	0
S065	3	7	1	6	0	2	0	0	1	1	5	7	2	2	1380	3	254	0
S066	4	6	4	6	0	7	1	0	0	0	4	1	2	11	1352	4	202	0
S067	2	6	4	5	1	2	0	1	0	1	4	4	2	9	1377	6	292	0
S068	6	1	3	4	1	4	1	1	1	0	4	7	2	10	1133	5	220	0
S069	5	1	1	7	0	2	1	0	0	1	4	3	2	3	1641	6	278	0
S070	2	5	2	4	1	4	1	1	0	1	5	4	2	7	1389	6	235	0
S071	5	6	5	5	1	5	0	0	1	1	5	6	2	8	1220	6	290	0
S072	6	6	4	2	1	7	0	1	0	1	5	6	2	9	1562	3	279	0
S073	7	1	2	5	0	6	1	0	1	0	4	4	2	7	1590	3	270	0
S074	1	2	7	2	0	6	1	1	0	0	4	6	2	4	1214	7	254	0
S075	5	7	2	3	0	1	0	1	0	1	5	7	2	8	1633	5	278	0
S076	5	3	3	4	1	5	1	0	1	1	5	5	2	3	1615	3	300	0
S077	6	1	7	3	0	5	1	1	1	0	4	1	2	5	1254	3	208	0
S078	6	7	4	4	0	3	0	0	0	0	5	1	2	10	1339	3	266	0
S079	3	1	6	6	1	1	1	1	1	1	6	7	2	3	1573	5	200	0
S080	3	5	6	6	0	3	0	1	1	1	6	5	2	6	1153	3	246	0
S081	4	4	5	4	1	1	0	0	0	1	4	4	2	7	1521	5	243	0
S082	1	6	2	6	1	4	0	0	1	1	5	5	2	2	1431	3	207	0
S083	5	3	3	2	1	4	0	0	1	0	6	3	2	13	1409	4	259	0
S084	7	3	5	4	0	4	0	1	0	1	6	1	2	14	1079	4	256	0
S085	7	4	3	7	1	6	0	1	1	0	4	4	2	8	1701	3	228	0
S086	7	7	6	5	0	3	0	0	1	0	4	1	2	12	1035	6	251	0
S087	4	1	3	3	1	3	0	0	1	1	5	3	2	8	1125	3	288	0
S088	1	1	3	2	0	4	1	0	0	0	5	1	2	3	1526	3	214	0
S089	6	6	2	4	1	5	1	0	1	0	6	5	2	11	1075	3	260	0
S090	5	2	1	2	1	6	0	0	0	1	4	6	2	13	1637	7	236	0
S091	5	7	1	6	0	4	0	1	0	1	4	4	2	14	1617	3	266	0
S092	3	6	4	4	1	4	1	1	0	1	6	7	2	14	1613	3	236	0
S093	6	6	4	2	0	7	1	0	0	0	6	3	2	14	1171	4	297	0
S094	5	7	5	3	1	3	0	1	1	1	4	6	2	7	1348	3	225	0
S095	7	4	1	3	1	5	0	1	0	1	5	6	2	14	1166	6	252	0
S096	1	1	3	6	1	7	1	0	1	1	4	3	2	6	1123	6	206	0
S097	3	6	1	3	1	6	0	1	1	0	5	4	2	12	1557	7	244	0
S098	6	4	4	1	0	3	0	0	1	0	4	5	2	12	1114	7	283	0
S099	1	5	4	5	0	3	0	0	0	0	5	3	2	5	1595	5	250	0
S100	1	2	7	3	0	4	0	0	0	0	5	6	2	11	1424	5	254	0
S101	5	5	2	1	0	1	0	0	1	0	6	2	2	14	1314	5	289	0
S102	4	3	5	5	1	1	0	1	1	1	5	1	2	10	1372	4	224	0
S103	5	1	4	3	1	1	0	0	1	1	5	1	2	14	1749	6	255	0
S104	1	3	1	6	0	1	0	0	1	1	6	2	2	10	1651	5	224	0
S105	7	6	3	4	1	6	1	0	0	1	5	1	2	6	1166	4	250	0
S106	5	1	6	5	0	5	1	1	0	1	6	7	2	2	1500	3	223	0
S107	1	3	4	1	1	2	1	0	1	1	5	2	2	2	1728	4	256	0
S108	4	2	5	2	0	4	0	0	1	0	6	5	2	12	1561	4	281	0
S109	1	3	3	4	0	3	0	1	0	1	5	4	2	15	1026	4	224	0
S110	7	6	3	5	0	5	0	0	0	0	5	6	2	14	1589	7	211	0
S111	1	2	7	5	1	6	0	0	0	0	4	2	2	6	1673	7	217	0
S112	6	2	6	3	1	7	0	0	1	1	5	7	2	7	1656	5	263	0
S113	2	4	7	1	0	5	1	1	1	0	4	1	2	5	1354	6	226	0
S114	1	6	5	7	1	1	1	0	1	0	4	7	2	2	1561	7	233	0
S115	3	4	3	6	0	4	1	0	1	1	6	6	2	15	1055	3	265	0
S116	7	1	4	3	0	2	1	1	1	1	6	2	2	7	1420	3	234	0
S117	7	6	5	1	0	6	1	1	1	1	5	1	2	13	1387	6	258	0
S118	1	6	6	2	1	2	1	1	1	0	5	2	2	9	1368	7	260	0
S119	2	4	6	5	0	6	1	0	0	1	6	5	2	7	1350	4	203	0
S120	3	3	1	6	1	7	1	1	1	0	4	4	2	14	1239	6	265	0
S121	7	1	2	4	1	2	0	0	1	1	6	3	2	5	1333	5	218	0
S122	2	6	4	3	1	7	0	1	1	1	6	1	2	3	1283	5	244	0
S123	7	1	1	2	1	1	1	0	1	1	5	3	2	13	1490	7	246	0
S124	3	1	6	1	0	3	1	1	0	0	6	6	2	5	1093	4	233	0

Table A. 2: Quantitative data (Transformed)

	Qualitative Criteria													Quantitative Criteria				
	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14	C15	C16	C17	C18
S125	1	1	6	6	0	6	0	1	0	1	4	5	2	5	1656	7	213	0
S126	6	3	3	5	0	3	1	0	1	1	5	2	2	5	1283	5	285	0
S127	1	6	2	4	1	5	1	0	0	1	5	5	2	12	1230	6	248	0
S128	1	5	5	6	0	4	1	0	0	1	5	3	2	6	1412	4	209	0
S129	5	1	7	2	1	3	1	1	1	1	4	5	2	2	1705	5	274	0
S130	2	1	1	5	0	4	1	0	0	1	4	7	2	2	1093	7	204	0
S131	4	7	3	6	0	4	0	1	1	0	6	5	2	14	1140	3	268	0
S132	3	3	2	4	0	7	0	0	1	0	6	4	2	13	1391	5	249	0
S133	5	4	4	2	0	3	0	1	1	1	5	6	2	3	1396	5	202	0
S134	3	6	5	4	1	4	0	1	0	0	6	3	2	15	1292	4	248	0
S135	4	5	6	7	0	2	0	0	1	0	4	7	2	7	1291	7	293	0
S136	1	7	7	4	1	6	0	1	1	1	5	6	2	5	1304	5	249	0
S137	1	7	5	5	1	2	0	1	1	1	3	5	3	7	1507	6	126	12.6
S138	2	7	6	2	1	7	0	1	1	0	4	4	3	14	1141	5	186	18.6
S139	1	5	2	1	0	4	0	0	1	0	7	2	3	4	1652	19	121	12.1
S140	3	7	3	6	1	3	0	1	1	1	4	3	3	4	1288	20	156	15.6
S141	1	5	4	3	1	3	1	0	1	0	3	7	3	12	1190	19	174	17.4
S142	4	1	7	2	1	7	1	0	0	1	6	4	3	10	1696	20	136	13.6
S143	6	7	2	6	0	2	1	1	1	1	3	7	3	10	1552	14	127	12.7
S144	4	5	1	6	0	7	1	0	1	0	7	4	3	4	1428	17	170	17
S145	3	3	7	6	0	4	1	0	1	0	7	5	3	5	1167	18	159	15.9
S146	3	1	1	2	1	6	0	1	0	1	2	7	3	8	1590	20	141	14.1
S147	1	4	7	7	0	7	1	0	0	0	6	7	3	7	1732	17	148	14.8
S148	6	5	2	5	0	7	0	1	0	0	7	6	3	14	1733	13	156	15.6
S149	5	1	7	2	0	6	0	0	1	1	3	7	3	8	1461	12	128	12.8
S150	4	6	3	7	1	7	0	1	0	1	3	2	3	13	1346	14	180	18
S151	1	1	5	5	0	6	0	0	0	0	5	6	3	9	1150	17	160	16
S152	1	1	1	3	1	6	0	0	0	1	7	4	3	9	1250	20	194	19.4
S153	7	4	3	7	0	2	1	0	1	0	1	6	3	15	1190	15	155	15.5
S154	1	4	4	7	0	2	0	1	0	0	5	4	3	3	1361	16	105	10.5
S155	7	3	7	4	0	1	0	1	1	0	6	2	3	4	1113	13	139	13.9
S156	4	2	4	3	0	2	0	1	1	0	5	5	3	6	1265	14	176	17.6
S157	3	5	1	7	0	5	0	0	1	1	6	5	3	11	1098	20	113	11.3
S158	1	6	7	3	0	1	1	0	0	1	7	6	3	2	1219	20	162	16.2
S159	5	4	3	4	1	7	1	0	0	1	2	6	3	12	1487	16	167	16.7
S160	2	6	2	6	0	5	1	0	0	1	1	1	3	13	1164	15	136	13.6
S161	6	6	6	3	0	1	1	1	0	1	7	7	3	3	1080	18	164	16.4
S162	3	3	7	5	1	4	0	1	1	1	1	3	3	5	1066	12	146	14.6
S163	4	2	4	6	1	1	0	0	1	0	5	6	3	7	1371	14	193	19.3
S164	1	5	5	2	1	5	1	0	0	0	6	3	3	14	1382	20	127	12.7
S165	7	2	1	2	1	2	0	0	1	1	2	5	3	7	1527	20	119	11.9
S166	4	2	5	6	0	4	0	0	0	0	3	5	3	8	1118	15	104	10.4
S167	3	4	6	3	0	1	1	0	1	0	4	7	3	2	1523	20	110	11
S168	2	1	7	5	0	4	0	1	0	1	2	3	3	15	1631	12	119	11.9
S169	4	2	6	5	0	3	0	0	1	1	2	2	3	13	1356	20	136	13.6
S170	6	5	3	6	1	5	0	0	0	0	7	2	3	15	1150	12	164	16.4
S171	1	7	7	2	0	5	0	1	1	1	2	1	3	2	1419	13	130	13
S172	4	1	4	2	0	7	1	1	0	0	2	3	3	15	1296	17	182	18.2
S173	7	3	2	7	1	7	1	1	1	1	1	5	3	11	1437	16	199	19.9
S174	4	4	5	4	1	4	1	1	1	0	6	7	3	14	1158	12	136	13.6
S175	3	2	6	1	0	7	0	0	1	0	7	4	3	15	1242	17	137	13.7
S176	2	3	1	3	1	1	0	0	0	1	1	4	3	15	1108	20	137	13.7
S177	1	4	1	6	1	5	0	0	0	0	7	5	3	9	1671	17	169	16.9
S178	1	5	7	6	0	3	1	0	1	1	6	6	3	4	1459	20	118	11.8
S179	4	1	1	1	1	2	0	0	0	1	3	3	3	5	1516	12	126	12.6
S180	2	4	4	4	1	7	1	0	0	1	2	7	3	12	1395	16	112	11.2
S181	7	2	2	4	1	5	1	1	0	0	5	1	3	9	1166	20	117	11.7
S182	1	2	7	4	0	4	0	0	0	1	6	3	3	14	1372	20	140	14
S183	5	3	4	4	0	3	0	0	1	1	6	7	3	2	1284	18	186	18.6
S184	2	4	1	3	0	3	1	0	1	0	3	6	3	9	1673	19	150	15
S185	4	2	1	1	1	4	0	0	1	0	7	4	3	11	1648	15	152	15.2
S186	6	5	5	3	0	4	0	1	0	1	7	3	3	10	1723	13	183	18.3
S187	3	4	4	2	1	4	1	0	1	1	4	3	3	4	1695	16	120	12

	Qualitative Criteria													Quantitative Criteria				
	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14	C15	C16	C17	C18
S188	4	3	4	7	1	4	0	0	0	1	2	5	3	9	1027	17	149	14.9
S189	4	2	6	1	1	2	1	0	1	1	4	3	3	10	1345	20	171	17.1
S190	3	7	3	2	1	4	1	1	1	1	6	3	3	5	1745	13	111	11.1
S191	3	5	7	7	0	4	0	0	1	1	3	6	3	15	1044	15	129	12.9
S192	6	5	7	7	0	5	0	0	1	0	1	3	3	13	1316	20	145	14.5
S193	1	5	3	7	0	5	1	1	1	1	4	2	3	13	1714	19	167	16.7
S194	3	5	3	3	1	6	1	1	1	1	1	7	3	6	1219	13	143	14.3
S195	2	6	4	2	0	6	1	1	1	0	5	4	3	8	1058	16	109	10.9
S196	1	1	5	1	0	6	0	1	0	0	1	3	3	5	1490	17	196	19.6
S197	5	2	7	5	0	2	0	0	1	0	7	5	3	15	1409	12	130	13
S198	1	4	4	5	0	3	1	0	1	1	7	4	3	7	1082	17	130	13
S199	5	4	3	3	0	4	1	1	0	1	1	6	3	12	1693	13	159	15.9
S200	6	2	2	5	0	4	1	1	0	1	5	6	3	5	1389	19	174	17.4
S201	4	3	3	5	1	2	1	0	1	1	5	7	3	15	1213	15	180	18
S202	4	1	5	3	1	2	1	1	1	1	5	7	3	7	1306	13	114	11.4
S203	5	6	3	2	0	1	1	0	1	1	3	2	3	12	1355	15	178	17.8
S204	6	4	5	2	1	7	1	0	1	1	6	5	3	14	1625	18	119	11.9
S205	3	2	1	2	1	1	1	1	0	0	1	7	3	13	1331	15	167	16.7
S206	7	1	4	3	1	3	1	0	0	1	4	3	3	13	1151	17	124	12.4
S207	4	6	3	7	0	5	0	1	1	0	7	4	3	11	1444	19	183	18.3
S208	7	5	1	7	0	5	1	0	1	1	7	1	3	15	1311	13	168	16.8
S209	4	1	6	5	0	7	0	0	0	1	3	5	3	11	1057	18	106	10.6
S210	4	7	5	1	0	2	1	1	0	1	4	5	3	10	1721	16	177	17.7
S211	2	5	1	4	1	1	1	1	1	0	4	6	3	5	1338	19	129	12.9
S212	4	1	4	6	0	1	0	1	0	1	6	1	3	8	1642	16	137	13.7
S213	6	5	6	7	1	3	0	0	1	0	1	5	3	5	1421	17	183	18.3
S214	3	3	1	1	1	1	0	0	0	1	4	5	3	12	1562	13	176	17.6
S215	4	4	1	2	1	2	0	0	0	1	4	4	3	8	1005	20	172	17.2
S216	3	3	4	3	0	1	0	1	1	1	1	5	3	8	1264	18	134	13.4
S217	7	2	1	2	0	6	1	0	1	0	3	4	3	2	1102	19	162	16.2
S218	6	4	4	4	0	2	0	0	1	0	4	5	3	4	1722	16	157	15.7
S219	4	6	3	3	1	5	0	1	1	0	4	3	3	2	1225	12	126	12.6
S220	5	2	1	4	1	7	1	1	0	0	6	2	3	10	1017	20	117	11.7
S221	4	6	4	4	0	3	1	0	1	0	5	2	3	13	1234	14	127	12.7
S222	2	5	3	4	1	6	0	1	0	1	2	4	3	13	1552	13	145	14.5
S223	6	7	6	4	1	2	0	0	0	1	3	1	3	5	1289	17	137	13.7
S224	5	3	1	3	1	5	0	1	1	1	6	5	3	11	1162	18	142	14.2
S225	3	2	2	6	1	3	1	0	1	1	2	1	3	2	1468	18	163	16.3
S226	4	2	3	6	0	7	1	1	1	1	7	5	3	7	1029	20	134	13.4
S227	7	5	6	2	0	2	1	0	0	1	5	6	3	3	1266	18	153	15.3
S228	1	6	5	2	1	2	1	0	1	0	1	4	3	14	1296	20	108	10.8
S229	4	6	3	7	1	6	0	0	1	1	6	5	3	7	1354	20	119	11.9
S230	5	7	7	7	1	3	1	1	1	0	5	6	3	2	1658	19	114	11.4
S231	5	4	2	1	0	1	1	0	0	0	4	3	3	15	1212	18	175	17.5
S232	5	5	2	2	1	4	0	0	1	0	7	1	3	14	1519	16	134	13.4
S233	5	6	7	4	0	4	1	1	1	1	4	4	3	15	1463	13	138	13.8
S234	4	3	4	7	0	7	0	1	1	1	3	1	3	3	1495	18	157	15.7
S235	5	7	4	4	0	2	0	1	1	0	2	3	3	9	1049	12	183	18.3
S236	6	4	2	3	1	3	0	1	0	1	6	4	3	11	1284	20	105	10.5
S237	2	5	5	1	1	4	1	0	1	1	7	4	3	12	1086	15	173	17.3
S238	6	4	4	1	0	1	0	0	0	1	2	7	3	3	1253	16	100	10
S239	7	3	3	2	0	4	1	0	1	1	2	3	3	10	1194	13	112	11.2
S240	5	1	1	2	0	1	1	1	0	1	6	7	3	11	1545	15	177	17.7
S241	6	1	4	1	0	4	1	1	1	1	5	5	3	3	1495	17	186	18.6
S242	6	1	5	7	1	2	1	0	0	1	4	2	3	15	1668	15	187	18.7
S243	4	3	6	7	1	5	0	1	0	0	7	1	3	14	1539	14	142	14.2
S244	3	6	2	4	1	6	0	0	0	1	5	4	3	12	1374	15	122	12.2
S245	4	2	4	6	1	6	0	1	1	0	2	6	3	10	1344	17	195	19.5
S246	7	3	2	3	1	3	1	0	1	1	2	1	3	5	1528	17	133	13.3
S247	2	3	3	4	1	1	1	1	1	1	1	2	3	5	1706	19	174	17.4
S248	3	2	5	5	0	1	1	0	1	1	6	5	3	7	1452	20	169	16.9
S249	6	1	1	1	0	5	1	1	1	0	7	6	3	5	1685	16	138	13.8
S250	3	5	2	7	0	6	0	1	1	0	1	7	3	15	1082	19	135	13.5

Table A.2: Quantitative data (Transformed) Cont'd

	Qualitative Criteria													Quantitative Criteria				
	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14	C15	C16	C17	C18
S001	0.5	0.83	1	0.17	1	1	1	0	1	1	0.83	0	1	0.42	0.9167	0.44	0.01	0
S002	0.33	0	0.17	0.17	1	0.67	0	1	0	0	0.83	0.33	1	1	0.7405	1	0.03	0
S003	0.17	0.17	0	0.5	0	0.67	1	0	0	0	0.83	0.5	1	0.04	0.1608	0.63	0	0
S004	0.67	0.83	0.83	0.83	1	0.17	0	1	0	0	0.83	0.5	1	0.13	0.3857	0.44	0.03	0
S005	0.83	0.17	0.67	0.5	1	0.83	0	0	1	1	0.83	0.33	1	0.08	0.3497	1	0.06	0
S006	1	0.5	0	0.17	0	0	1	0	0	0	0.83	1	1	0.08	0.2279	1	0.12	0
S007	0.67	0.17	1	0	1	0.83	1	1	0	1	0.83	0.17	1	0.18	0.6305	1	0.11	0
S008	0	0.5	0.83	0.33	0	0.33	1	1	1	1	0.83	0.17	1	0.01	0.3128	0.63	0.12	0
S009	0	0.67	0.83	0.17	0	0	1	1	1	0	0.83	0.5	1	0	0.5123	0.44	0.11	0
S010	0.17	0.17	0.5	0	0	1	0	0	0	0	0.83	0.5	1	0.01	0.0623	0.63	0.08	0
S011	0.33	0.17	0	0	0	0.67	1	1	1	1	0.83	0.67	1	0.04	0.6884	0.44	0.09	0
S012	0.83	1	0.5	0	0	0.83	1	1	0	1	0.83	0.5	1	0.1	0.4379	0.63	0.07	0
S013	1	1	0.67	0.67	0	0.67	0	1	0	1	0.83	0.83	1	0.06	0.4625	1	0.03	0
S014	1	0.67	0.67	0	1	1	1	1	0	1	0.83	0.33	1	0.42	0.5211	0.63	0.04	0
S015	0	0.67	1	0.67	0	0	0	1	1	1	0.83	0.33	1	0.04	0.9746	1	0.16	0
S016	1	0	1	0.33	0	0.17	1	0	1	1	0.83	1	1	0.31	0.8452	0.44	0.14	0
S017	0.5	0.17	0.33	0.83	1	0	1	1	0	0	0.83	0	1	0.01	0.4433	0.44	0.13	0
S018	0.83	0.5	0.33	0	1	1	1	0	1	0	0.83	0.33	1	0.08	0.3082	1	0.05	0
S019	0	1	0.17	0.67	1	0.17	1	1	1	1	0.83	1	1	0.06	0.1513	1	0.04	0
S020	0.5	0.67	0.83	0.17	0	0.67	1	0	0	0	0.83	0.33	1	1	0.9542	1	0.09	0
S021	0	1	0.5	1	1	0.17	1	0	1	0	0.83	0.83	1	0.02	0.4625	0.44	0.03	0
S022	1	0.83	0.67	0.17	1	0.17	0	0	1	0	0.83	1	1	0.18	1	1	0.14	0
S023	0.83	0.5	1	0.17	1	0.5	1	1	0	1	0.83	0	1	0.08	0.0433	0.44	0.01	0
S024	0.5	0.33	0.83	0.83	0	0.5	0	1	1	0	0.83	0.83	1	0	0.9475	0.44	0.16	0
S025	1	1	0.83	0.83	0	0.17	0	0	0	1	0.83	0.83	1	0.31	0.0844	0.44	0.01	0
S026	0.67	0.83	0.83	0.67	1	0.83	0	1	0	0	0.83	0.5	1	1	0.2566	1	0.03	0
S027	0	0.83	1	0.5	0	0.5	1	1	0	1	0.83	0.33	1	0.23	0.5836	1	0.04	0
S028	0.5	0.5	1	0.67	0	0.83	0	1	0	0	0.83	0.17	1	0.06	0.3024	0.63	0.11	0
S029	0	0.33	0.83	0.5	1	0.17	0	1	1	1	0.83	0.17	1	0.23	0.0054	0.44	0.13	0
S030	0	0.67	0	0.67	0	0.33	1	0	1	0	0.83	0.17	1	0.18	0.0046	1	0.03	0
S031	0.17	0.33	0.33	0.83	1	0.67	0	0	0	1	0.83	0.17	1	0.13	0.7241	0.44	0.04	0
S032	0.5	1	0.83	0.67	1	0.33	0	1	0	1	0.83	0.17	1	0.01	0.4353	1	0.08	0
S033	0.17	0.33	0.83	0.33	1	0.17	1	0	0	0	0.83	0	1	0.42	0.3388	1	0.06	0
S034	0.17	1	0.67	0.5	0	0.83	1	1	1	1	0.83	0.67	1	0	0.4153	0.44	0.02	0
S035	0	0	0.83	1	0	0.17	1	0	1	1	0.83	0.17	1	0.01	0.8092	1	0.01	0
S036	0.67	0	0.33	0.33	1	0.67	1	1	1	0	0.83	0.5	1	0.31	0.2632	0.44	0.03	0
S037	0	0.67	0.5	0.83	0	0.17	0	0	1	1	0.83	0.33	1	0.42	0.059	0.63	0.09	0
S038	0.83	0.5	0.67	0	0	0.17	1	1	1	1	0.83	0.5	1	0.42	0.1704	0.44	0.02	0
S039	1	0.67	0.67	0	0	0.33	1	0	1	1	0.83	0.5	1	0.1	0.8909	0.44	0.02	0
S040	1	1	1	0.17	1	0	1	1	1	0	0.83	0	1	0.1	0.0733	0.63	0.05	0
S041	0.17	0.17	0	0.83	1	0.5	0	0	0	0	0.83	0.83	1	0.1	0.6305	1	0.02	0
S042	0	0.17	0.5	0.17	1	0.5	1	1	0	1	0.83	0.33	1	0.04	0.1627	0.44	0.1	0
S043	0.83	0.33	0.5	0.33	1	0.67	0	1	0	1	0.83	0	1	1	0.0337	0.44	0.03	0
S044	1	0.33	0.33	0.33	1	0.83	1	1	1	1	0.83	1	1	0.06	0.4765	1	0	0
S045	0.17	0.5	0.33	0.17	1	1	0	1	0	0	0.83	0.33	1	0.31	0.4695	0.63	0.11	0
S046	0.33	1	1	0.67	1	0.33	1	1	0	0	0.83	0.33	1	0.06	0.0201	1	0.05	0
S047	0.33	0	0	1	1	1	1	0	0	1	0.83	0.67	1	0.01	0.6404	1	0.05	0
S048	0.5	0.83	0.17	0.17	0	0.83	0	0	1	1	0.83	0.83	1	0.18	0.3412	0.44	0.09	0
S049	1	1	0.67	1	1	0.5	0	0	1	1	0.83	0	0.25	0.01	0.0565	0.44	0.06	0
S050	0.83	0.33	0.67	0.33	0	0.67	1	0	1	1	0.5	0.33	0.25	0.02	0.0975	0.63	0.16	0
S051	0.67	0.83	0.5	0.5	1	0	1	0	0	0	0.67	0.5	0.25	0.02	0.7705	0.26	0.13	0
S052	0.5	1	1	0.17	0	0.33	1	0	0	1	0.5	1	0.25	0	0.1381	0.26	0.11	0
S053	0.33	0.33	0.83	0	1	0.67	1	0	0	1	0.83	0.33	0.25	0.23	0.0532	0.21	0.21	0
S054	0.17	0.67	0.33	0.83	1	0	1	1	1	1	0.83	0.5	0.25	0.42	0.5805	0.21	0.12	0
S055	0.17	0.67	0.67	1	1	0.17	1	1	0	0	0.67	0.5	0.25	0.23	0.2588	0.26	0.14	0
S056	1	0.67	0.5	0.67	0	0.83	0	1	0	0	0.5	0.67	0.25	0.02	0.0548	0.44	0.13	0
S057	0	0	0.5	1	1	0.5	0	1	0	0	0.67	1	0.25	0.1	0.5226	0.63	0.2	0
S058	1	1	1	0	1	0.83	1	1	0	1	0.67	0	0.25	0.1	0.619	0.26	0.08	0
S059	0.33	0.67	0	0.83	1	0.5	0	0	0	0	0.67	0.33	0.25	0.01	0.8013	0.44	0.19	0
S060	0.17	0.17	0.17	0.17	0	0	1	0	1	1	0.83	0.33	0.25	0.02	0.0931	0.63	0.14	0
S061	0.67	1	0.33	0.67	1	0.5	0	0	1	0	0.5	1	0.25	0.18	0.045	0.44	0.14	0
S062	1	0.83	0.83	0.17	0	0.17	1	1	1	1	0.67	0.17	0.25	0.08	0.6043	0.26	0.22	0
S063	0	1	0.33	0	1	0.83	1	0	1	1	0.83	1	0.25	0.01	0.3844	0.44	0.22	0
S064	0.17	0	0.67	0	1	0.5	0	0	1	1	0.5	0	0.25	0.42	0.9678	0.44	0.21	0
S065	0.33	1	0	0.83	0	0.17	0	0	1	1	0.67	1	0.25	1	0.357	0.63	0.15	0
S066	0.5	0.83	0.5	0.83	0	1	1	0	0	0	0.5	0	0.25	0.06	0.392	0.44	0.29	0
S067	0.17	0.83	0.5	0.67	1	0.17	0	1	0	1	0.5	0.5	0.25	0.1	0.3607	0.26	0.08	0
S068	0.83	0	0.33	0.5	1	0.5	1	1	1	0	0.5	1	0.25	0.08	0.7259	0.33	0.24	0
S069	0.67	0	0	1	0	0.17	1	0	0	1	0.5	0.33	0.25	0.62	0.0879	0.26	0.1	0
S070	0.17	0.67	0.17	0.5	1	0.5	1	1	0	1	0.67	0.5	0.25	0.18	0.346	0.26	0.2	0
S071	0.67	0.83	0.67	0.67	1	0.67	0	0	1	1	0.67	0.83	0.25	0.13	0.5789	0.26	0.08	0
S072	0.83	0.83	0.5	0.17	1	1	0	1	0	1	0.67	0.83	0.25	0.1	0.1598	0.63	0.1	0
S073	1	0	0.17	0.67	0	0.83	1	0	1	0	0.5	0.5	0.25	0.18	0.1335	0.63	0.12	0
S074	0	0.17	1	0.17	0	0.83	1	1	0	0	0.5	0.83	0.25	0.42	0.5884	0.21	0.15	0
S075	0.67	1	0.17	0.33	0	0	0	1	0	1	0.67	1	0.25	0.13	0.0948	0.33	0.1	0
S076	0.67	0.33	0.33	0.5	1	0.67	1	0	1	1	0.67	0.67	0.25	0.62	0.1108	0.63	0.07	0
S077	0.83	0	1	0.33	0	0.67	1	1	1	0	0.5	0	0.25	0.31	0.527	0.63	0.27	0
S078	0.83	1	0.5	0.5	0	0.33	0	0	0	0	0.67	0	0.25	0.08	0.4088	0.63	0.13	0
S079	0.33	0	0.83	0.83	1	0	1	1	1	1	0.83	1	0.25	0.62	0.1494	0.33	0.3	0
S080	0.33	0.67	0.83	0.83	0	0.33	0	1	1	1	0.83	0.67	0.25	0.23	0.6901	0.63	0.17	0
S081	0.5	0.5	0.67	0.5	1	0	0	0	0	1	0.5	0.5	0.25	0.18	0.2001	0.33	0.18	0
S082	0	0.83	0.17	0.83	1	0.5	0	0	1	1	0.67	0.67	0.25	1	0.2967	0.63	0.28	0
S083	0.67	0.33	0.33	0.17	1	0.5	0	0	1	0	0.83	0.33	0.25	0.02	0.3222	0.44	0.14	0
S084	1	0.33	0.67	0.5	0	0.5	0	1	0	1	0.83	0	0.25	0.01	0.829	0.44	0.15	0
S085	1	0.5	0.33	1	1	0.83	0	1	1	0	0.5	0.5	0.25	0.13	0.0377	0.63	0.21	0
S086	1	1	0.83	0.67	0	0.33	0	0	1	0	0.5	0	0.25	0.04	0.921	0.26	0.16	0
S087	0.5	0	0.33	0.33	1	0.33	0	0	1	1	0.67	0.33	0.25	0.13	0.7405	0.63	0.09	0
S088	0	0	0.33	0.17	0	0.5	1	0	0	0	0.67	0	0.25	0.62	0.1951	0.63	0.25	0
S089	0.83	0.83	0.17	0.5	1	0.67	1	0	1	0	0.83	0.67	0.25	0.06	0.8371	0.63	0.14	0
S090	0.67	0.17	0	0.17	1	0.83	0	0	0	1	0.5	0.83	0.25	0.02	0.0913	0.21	0.19	0
S091	0.67	1	0	0.83	0	0.5	0	1	0	1	0.5	0.5	0.25	0.01	0.109	0.63	0.13	0
S092	0.33	0.83	0.5	0.5	1	0.5	1	1	0	1	0.83	1	0.25	0.01	0.1126	0.63	0.19	0
S093	0.83	0.83	0.5	0.17	0	1	1	0	0	0	0.83	0.33	0.25	0.01	0.659	0.44	0.07	0
S094	0.67	1	0.67	0.33	1	0.33	0	1	1	1	0.5	0.83	0.25	0.18	0.3972	0.63	0.22	0
S095	1	0.5	0	0.33	1	0.67	0	1	0	1	0.67	0.83	0.25	0.01	0.6676	0.26	0.16	0
S096	0	0	0.33	0.83	1	1	1	0	1	1	0.5	0.33	0.25	0.23	0.7442	0.26	0.28	0
S097	0.33	0.83	0	0.33	1	0.83	0	1	1	0	0.67	0.5	0.25	0.04	0.1646	0.21	0.17	0
S098	0.83	0.5	0.5	0	0	0.33	0	0	1	0	0.5	0.67	0.25	0.04	0.761	0.21	0.09	0
S099	0	0.67	0.5	0.67	0	0.33	0	0	0	0	0.67	0.33	0.25	0.31	0.1289	0.33	0.16	0
S100	0	0.17	1	0.33	0	0.5	0	0	0	0	0.67	0.83	0.25	0.06	0.3047	0.33	0.15	0
S101	0.67	0.67	0.17	0	0	0	0	0	1	0	0.83	0.17	0.25	0.01	0.442	0.33	0.08	0
S102	0.5	0.33	0.67	0.67	1	0	0	1	1	1	0.67	0	0.25	0.08	0.3669	0.44	0.23	0
S103	0.67	0	0.5	0.33	1	0	0	0	1	1	0.67	0	0.25	0.01	0	0.26	0.15	0
S104	0	0.33	0	0.83	0	0	0	0	1	1	0.83	0.17	0.25	0.08	0.0792	0.33	0.23	0
S105	1	0.83	0.33	0.5	1	0.83	1	0	0	1	0.67	0	0.25	0.23	0.6676	0.44	0.16	0
S106	0.67	0	0.83	0.67	0	0.67	1	1	0	1	0.83	1	0.25	1	0.2216	0.63	0.23	0
S107	0	0.33	0.5	0	1	0.17	1	0	1	1	0.67	0.17	0.25	1	0.0162	0.44	0.15	0
S108	0.5	0.17	0.67	0.17	0	0.5	0	0	1	0	0.83	0.67	0.25	0.04	0.1608	0.44	0.1	0
S109	0	0.33	0.33	0.5	0	0.33	0	1	0	1	0.67	0.5	0.25	0	0.9408	0.44	0.23	0
S110	1	0.83	0.33	0.67	0	0.67	0	0	0	0	0.67	0.83	0.25	0.01	0.1344	0.21	0.26	0
S111	0	0.17	1	0.67	1	0.83	0	0	0	0	0.5	0.17	0.25	0.23	0.0607	0.21	0.25	0
S112	0.83	0.17	0.83	0.33	1	1	0	0	1	1	0.67	1	0.25	0.18	0.075	0.33	0.13	0
S113	0.17	0.5	1	0	0	0.67	1	1	1	0	0.5	0	0.25	0.31	0.3895	0.26	0.22	0
S114	0	0.83	0.67	1	1	0	1	0	1	0	0.5	1	0.25	1	0.1608	0.21	0.2	0
S115	0.33	0.5	0.33	0.83	0	0.5	1	0	1	1	0.83	0.83	0.25	0	0.8783	0.63	0.13	0
S116	1	0	0.5	0.33	0	0.17	1	1	1	1	0.83	0.17	0.25	0.18	0.3093	0.63	0.2	0
S117	1	0.83	0.67	0	0	0.83	1	1	1	1	0.67	0	0.25	0.02	0.3485	0.26	0.14	0
S118	0	0.83	0.83	0.17	1	0.17	1	1	1	0	0.67	0.17	0.25	0.1	0.3718	0.21	0.14	0
S119	0.17	0.5	0.83	0.67	0	0.83	1	0	0	1	0.83	0.67	0.25	0.18	0.3946	0.44	0.29	0
S120	0.33	0.33	0	0.83	1	1	1	1	1	0	0.5	0.5	0.25	0.01	0.5496	0.26	0.13	0
S121	1	0	0.17	0.5	1	0.17	0	0	1	1	0.83	0.33	0.25	0.31	0.4167	0.33	0.24	0
S122	0.17	0.83	0.5	0.33	1	1	0	1	1	1	0.83	0	0.25	0.62	0.4849	0.33	0.17	0
S123	1	0	0	0.17	1	0	1	0	1	1	0.67	0.33	0.25	0.02	0.2321	0.21	0.17	0
S124	0.33	0	0.83	0	0	0.33	1	1	0	0	0.83	0.83	0.25	0.31	0.8013	0.44	0.2	0

Table A. 3: Normalized data

	Qualitative Criteria													Quantitative Criteria				
	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14	C15	C16	C17	C18
S125	0	0	0.83	0.83	0	0.83	0	1	0	1	0.5	0.67	0.25	0.31	0.075	0.21	0.26	0
S126	0.83	0.33	0.33	0.67	0	0.33	1	0	1	1	0.67	0.17	0.25	0.31	0.4849	0.33	0.09	0
S127	0	0.83	0.17	0.5	1	0.67	1	0	0	1	0.67	0.67	0.25	0.04	0.5634	0.26	0.16	0
S128	0	0.67	0.67	0.83	0	0.5	1	0	0	1	0.67	0.33	0.25	0.23	0.3186	0.44	0.27	0
S129	0.67	0	1	0.17	1	0.33	1	1	1	1	0.5	0.67	0.25	1	0.0345	0.33	0.11	0
S130	0.17	0	0	0.67	0	0.5	1	0	0	1	0.5	1	0.25	1	0.8013	0.21	0.29	0
S131	0.5	1	0.33	0.83	0	0.5	0	1	1	0	0.83	0.67	0.25	0.01	0.7132	0.63	0.12	0
S132	0.33	0.33	0.17	0.5	0	1	0	0	1	0	0.83	0.5	0.25	0.02	0.3436	0.33	0.16	0
S133	0.67	0.5	0.5	0.17	0	0.33	0	1	1	1	0.67	0.83	0.25	0.62	0.3376	0.33	0.29	0
S134	0.33	0.83	0.67	0.5	1	0.5	0	1	0	0	0.83	0.33	0.25	0	0.4722	0.44	0.16	0
S135	0.5	0.67	0.83	1	0	0.17	0	0	1	0	0.5	1	0.25	0.18	0.4736	0.21	0.08	0
S136	0	1	1	0.5	1	0.83	0	1	1	1	0.67	0.83	0.25	0.31	0.4556	0.33	0.16	0
S137	0	1	0.67	0.67	1	0.17	0	1	1	1	0.33	0.67	0	0.18	0.2144	0.26	0.71	0.79
S138	0.17	1	0.83	0.17	1	1	0	1	1	0	0.5	0.5	0	0.01	0.7114	0.33	0.35	0.54
S139	0	0.67	0.17	0	0	0.5	0	0	1	0	1	0.17	0	0.42	0.0784	0.01	0.76	0.83
S140	0.33	1	0.33	0.83	1	0.33	0	1	1	1	0.5	0.33	0	0.42	0.4779	0	0.5	0.64
S141	0	0.67	0.5	0.33	1	0.33	1	0	1	0	0.33	1	0	0.04	0.6272	0.01	0.4	0.57
S142	0.5	0	1	0.17	1	1	1	0	0	1	0.83	0.5	0	0.08	0.0417	0	0.63	0.74
S143	0.83	1	0.17	0.83	0	0.17	1	1	1	1	0.33	1	0	0.08	0.1695	0.05	0.7	0.79
S144	0.5	0.67	0	0.83	0	1	1	0	1	0	1	0.5	0	0.42	0.3001	0.02	0.42	0.59
S145	0.33	0.33	1	0.83	0	0.5	1	0	1	0	1	0.67	0	0.31	0.6658	0.01	0.48	0.63
S146	0.33	0	0	0.17	1	0.83	0	1	0	1	0.17	1	0	0.13	0.1335	0	0.59	0.71
S147	0	0.5	1	1	0	1	1	0	0	0	0.83	1	0	0.18	0.0131	0.02	0.55	0.68
S148	0.83	0.67	0.17	0.67	0	1	0	1	0	0	1	0.83	0	0.01	0.0123	0.06	0.5	0.64
S149	0.67	0	1	0.17	0	0.83	0	0	1	1	0.33	1	0	0.13	0.2632	0.07	0.69	0.78
S150	0.5	0.83	0.33	1	1	1	0	1	0	1	0.33	0.17	0	0.02	0.3997	0.05	0.38	0.56
S151	0	0	0.67	0.67	0	0.83	0	0	0	0	0.67	0.83	0	0.1	0.6954	0.02	0.48	0.63
S152	0	0	0	0.33	1	0.83	0	0	0	1	1	0.5	0	0.1	0.533	0	0.32	0.52
S153	1	0.5	0.33	1	0	0.17	1	0	1	0	0	0.83	0	0	0.6272	0.04	0.5	0.65
S154	0	0.5	0.5	1	0	0.17	0	1	0	0	0.67	0.5	0	0.62	0.3806	0.03	0.93	0.95
S155	1	0.33	1	0.5	0	0	0	1	1	0	0.83	0.17	0	0.42	0.7629	0.06	0.61	0.72
S156	0.5	0.17	0.5	0.33	0	0.17	0	1	1	0	0.67	0.67	0	0.23	0.5108	0.05	0.4	0.57
S157	0.33	0.67	0	1	0	0.67	0	0	1	1	0.83	0.67	0	0.06	0.7916	0	0.84	0.88
S158	0	0.83	1	0.33	0	0	1	0	0	1	1	0.83	0	1	0.5805	0	0.46	0.62
S159	0.67	0.5	0.33	0.5	1	1	1	0	0	1	0.17	0.83	0	0.04	0.2352	0.03	0.44	0.6
S160	0.17	0.83	0.17	0.83	0	0.67	1	0	0	1	0	0	0	0.02	0.671	0.04	0.63	0.74
S161	0.83	0.83	0.83	0.33	0	0	1	1	0	1	1	1	0	0.62	0.827	0.01	0.45	0.61
S162	0.33	0.33	1	0.67	1	0.5	0	1	1	1	0	0.33	0	0.31	0.8554	0.07	0.56	0.68
S163	0.5	0.17	0.5	0.83	1	0	0	0	1	0	0.67	0.83	0	0.18	0.3681	0.05	0.33	0.52
S164	0	0.67	0.67	0.17	1	0.67	1	0	0	0	0.83	0.33	0	0.01	0.3545	0	0.7	0.79
S165	1	0.17	0	0.17	1	0.17	0	0	1	1	0.17	0.67	0	0.18	0.1941	0	0.78	0.84
S166	0.5	0.17	0.67	0.83	0	0.5	0	0	0	0	0.33	0.67	0	0.13	0.7535	0.04	0.95	0.96
S167	0.33	0.5	0.83	0.33	0	0	1	0	1	0	0.5	1	0	1	0.1981	0	0.87	0.91
S168	0.17	0	1	0.67	0	0.5	0	1	0	1	0.17	0.33	0	0	0.0966	0.07	0.78	0.84
S169	0.5	0.17	0.83	0.67	0	0.33	0	0	1	1	0.17	0.17	0	0.02	0.3869	0	0.63	0.74
S170	0.83	0.67	0.33	0.83	1	0.67	0	0	0	0	1	0.17	0	0	0.6954	0.07	0.45	0.61
S171	0	1	1	0.17	0	0.67	0	1	1	1	0.17	0	0	1	0.3105	0.06	0.68	0.77
S172	0.5	0	0.5	0.17	0	1	1	1	0	0	0.17	0.33	0	0	0.4667	0.02	0.37	0.55
S173	1	0.33	0.17	1	1	1	1	1	1	1	0	0.67	0	0.06	0.2899	0.03	0.3	0.5
S174	0.5	0.5	0.67	0.5	1	0.5	1	1	1	0	0.83	1	0	0.01	0.6814	0.07	0.63	0.74
S175	0.33	0.17	0.83	0	0	1	0	0	1	0	1	0.5	0	0	0.545	0.02	0.62	0.73
S176	0.17	0.33	0	0.33	1	0	0	0	0	1	0	0.5	0	0	0.7724	0	0.62	0.73
S177	0	0.5	0	0.83	1	0.67	0	0	0	0	1	0.67	0	0.1	0.0623	0.02	0.43	0.59
S178	0	0.67	1	0.83	0	0.33	1	0	1	1	0.83	0.83	0	0.42	0.2654	0	0.79	0.85
S179	0.5	0	0	0	1	0.17	0	0	0	1	0.33	0.33	0	0.31	0.2052	0.07	0.71	0.79
S180	0.17	0.5	0.5	0.5	1	1	1	0	0	1	0.17	1	0	0.04	0.3388	0.03	0.85	0.89
S181	1	0.17	0.17	0.5	1	0.67	1	1	0	0	0.67	0	0	0.1	0.6676	0	0.8	0.85
S182	0	0.17	1	0.5	0	0.5	0	0	0	1	0.83	0.33	0	0.01	0.3669	0	0.6	0.71
S183	0.67	0.33	0.5	0.5	0	0.33	0	0	1	1	0.83	1	0	1	0.4835	0.01	0.35	0.54
S184	0.17	0.5	0	0.33	0	0.33	1	0	1	0	0.33	0.83	0	0.1	0.0607	0.01	0.53	0.67
S185	0.5	0.17	0	0	1	0.5	0	0	1	0	1	0.5	0	0.06	0.0818	0.04	0.52	0.66
S186	0.83	0.67	0.67	0.33	0	0.5	0	1	0	1	1	0.33	0	0.08	0.0201	0.06	0.37	0.55
S187	0.33	0.5	0.5	0.17	1	0.5	1	0	1	1	0.5	0.33	0	0.42	0.0425	0.03	0.77	0.83
S188	0.5	0.33	0.5	1	1	0.5	0	0	0	1	0.17	0.67	0	0.1	0.9386	0.02	0.54	0.67
S189	0.5	0.17	0.83	0	1	0.17	1	0	1	1	0.5	0.33	0	0.08	0.401	0	0.42	0.58
S190	0.33	1	0.33	0.17	1	0.5	1	1	1	1	0.83	0.33	0	0.31	0.0031	0.06	0.86	0.9
S191	0.33	0.67	1	1	0	0.5	0	0	1	1	0.33	0.83	0	0	0.9016	0.04	0.69	0.78
S192	0.83	0.67	1	1	0	0.67	0	0	1	0	0	0.33	0	0.02	0.4393	0	0.57	0.69
S193	0	0.67	0.33	1	0	0.67	1	1	1	1	0.5	0.17	0	0.02	0.0273	0.01	0.44	0.6
S194	0.33	0.67	0.33	0.33	1	0.83	1	1	1	1	0	1	0	0.23	0.5805	0.06	0.58	0.7
S195	0.17	0.83	0.5	0.17	0	0.83	1	1	1	0	0.67	0.5	0	0.13	0.872	0.03	0.88	0.92
S196	0	0	0.67	0	0	0.83	0	1	0	0	0	0.33	0	0.31	0.2321	0.02	0.31	0.51
S197	0.67	0.17	1	0.67	0	0.17	0	0	1	0	1	0.67	0	0	0.3222	0.07	0.68	0.77
S198	0	0.5	0.5	0.67	0	0.33	1	0	1	1	1	0.5	0	0.18	0.823	0.02	0.68	0.77
S199	0.67	0.5	0.33	0.33	0	0.5	1	1	0	1	0	0.83	0	0.04	0.0442	0.06	0.48	0.63
S200	0.83	0.17	0.17	0.67	0	0.5	1	1	0	1	0.67	0.83	0	0.31	0.346	0.01	0.4	0.57
S201	0.5	0.33	0.33	0.67	1	0.17	1	0	1	1	0.67	1	0	0	0.59	0.04	0.38	0.56
S202	0.5	0	0.67	0.33	1	0.17	1	1	1	1	0.67	1	0	0.18	0.4529	0.06	0.83	0.88
S203	0.67	0.83	0.33	0.17	0	0	1	0	1	1	0.33	0.17	0	0.04	0.3882	0.04	0.39	0.56
S204	0.83	0.5	0.67	0.17	1	1	1	0	1	1	0.83	0.67	0	0.01	0.1019	0.01	0.78	0.84
S205	0.33	0.17	0	0.17	1	0	1	1	0	0	0	1	0	0.02	0.4193	0.04	0.44	0.6
S206	1	0	0.5	0.33	1	0.33	1	0	0	1	0.5	0.33	0	0.02	0.6937	0.02	0.73	0.81
S207	0.5	0.83	0.33	1	0	0.67	0	1	1	0	1	0.5	0	0.06	0.282	0.01	0.37	0.55
S208	1	0.67	0	1	0	0.67	1	0	1	1	1	0	0	0	0.4461	0.06	0.43	0.6
S209	0.5	0	0.83	0.67	0	1	0	0	0	1	0.33	0.67	0	0.06	0.8741	0.01	0.92	0.94
S210	0.5	1	0.67	0	0	0.17	1	1	0	1	0.5	0.67	0	0.08	0.0217	0.03	0.39	0.56
S211	0.17	0.67	0	0.5	1	0	1	1	1	0	0.5	0.83	0	0.31	0.4101	0.01	0.69	0.78
S212	0.5	0	0.5	0.83	0	0	0	1	0	1	0.83	0	0	0.13	0.087	0.03	0.62	0.73
S213	0.83	0.67	0.83	1	1	0.33	0	0	1	0	0	0.67	0	0.31	0.3082	0.02	0.37	0.55
S214	0.33	0.33	0	0	1	0	0	0	0	1	0.5	0.67	0	0.04	0.1598	0.06	0.4	0.57
S215	0.5	0.5	0	0.17	1	0.17	0	0	0	1	0.5	0.5	0	0.13	0.9884	0	0.41	0.58
S216	0.33	0.33	0.5	0.33	0	0	0	1	1	1	0	0.67	0	0.13	0.5123	0.01	0.64	0.75
S217	1	0.17	0	0.17	0	0.83	1	0	1	0	0.33	0.5	0	1	0.7839	0.01	0.46	0.62
S218	0.83	0.5	0.5	0.5	0	0.17	0	0	1	0	0.5	0.67	0	0.42	0.0209	0.03	0.49	0.64
S219	0.5	0.83	0.33	0.33	1	0.67	0	1	1	0	0.5	0.33	0	1	0.5711	0.07	0.71	0.79
S220	0.67	0.17	0	0.5	1	1	1	1	0	0	0.83	0.17	0	0.08	0.961	0	0.8	0.85
S221	0.5	0.83	0.5	0.5	0	0.33	1	0	1	0	0.67	0.17	0	0.02	0.5572	0.05	0.7	0.79
S222	0.17	0.67	0.33	0.5	1	0.83	0	1	0	1	0.17	0.5	0	0.02	0.1695	0.06	0.57	0.69
S223	0.83	1	0.83	0.5	1	0.17	0	0	0	1	0.33	0	0	0.31	0.4765	0.02	0.62	0.73
S224	0.67	0.33	0	0.33	1	0.67	0	1	1	1	0.83	0.67	0	0.06	0.6745	0.01	0.59	0.7
S225	0.33	0.17	0.17	0.83	1	0.33	1	0	1	1	0.17	0	0	1	0.2556	0.01	0.46	0.61
S226	0.5	0.17	0.33	0.83	0	1	1	1	1	1	1	0.67	0	0.18	0.9342	0	0.64	0.75
S227	1	0.67	0.83	0.17	0	0.17	1	0	0	1	0.67	0.83	0	0.62	0.5094	0.01	0.52	0.65
S228	0	0.83	0.67	0.17	1	0.17	1	0	1	0	0	0.5	0	0.01	0.4667	0	0.9	0.93
S229	0.5	0.83	0.33	1	1	0.83	0	0	1	1	0.83	0.67	0	0.18	0.3895	0	0.78	0.84
S230	0.67	1	1	1	1	0.33	1	1	1	0	0.67	0.83	0	1	0.0733	0.01	0.83	0.88
S231	0.67	0.5	0.17	0	0	0	1	0	0	0	0.5	0.33	0	0	0.5915	0.01	0.4	0.57
S232	0.67	0.67	0.17	0.17	1	0.5	0	0	1	0	1	0	0	0.01	0.2022	0.03	0.64	0.75
S233	0.67	0.83	1	0.5	0	0.5	1	1	1	1	0.5	0.5	0	0	0.261	0.06	0.61	0.72
S234	0.5	0.33	0.5	1	0	1	0	1	1	1	0.33	0	0	0.62	0.2268	0.01	0.49	0.64
S235	0.67	1	0.5	0.5	0	0.17	0	1	1	0	0.17	0.33	0	0.1	0.8909	0.07	0.37	0.55
S236	0.83	0.5	0.17	0.33	1	0.33	0	1	0	1	0.83	0.5	0	0.06	0.4835	0	0.93	0.95
S237	0.17	0.67	0.67	0	1	0.5	1	0	1	1	1	0.5	0	0.04	0.8151	0.04	0.41	0.58
S238	0.83	0.5	0.5	0	0	0	0	0	0	1	0.17	1	0	0.62	0.5285	0.03	1	1
S239	1	0.33	0.33	0.17	0	0.5	1	0	1	1	0.17	0.33	0	0.08	0.6206	0.06	0.85	0.89
S240	0.67	0	0	0.17	0	0	1	1	0	1	0.83	1	0	0.06	0.1763	0.04	0.39	0.56
S241	0.83	0	0.5	0	0	0.5	1	1	1	1	0.67	0.67	0	0.62	0.2268	0.02	0.35	0.54
S242	0.83	0	0.67	1	1	0.17	1	0	0	1	0.5	0.17	0	0	0.0648	0.04	0.35	0.53
S243	0.5	0.33	0.83	1	1	0.67	0	1	0	0	1	0	0	0.01	0.1822	0.05	0.59	0.7
S244	0.33	0.83	0.17	0.5	1	0.83	0	0	0	1	0.67	0.5	0	0.04	0.3644	0.04	0.75	0.82
S245	0.5	0.17	0.5	0.83	1	0.83	0	1	1	0	0.17	0.83	0	0.08	0.4023	0.02	0.32	0.51
S246	1	0.33	0.17	0.33	1	0.33	1	0	1	1	0.17	0	0	0.31	0.1931	0.02	0.65	0.75
S247	0.17	0.33	0.33	0.5	1	0	1	1	1	1	0	0.17	0	0.31	0.0337	0.01	0.4	0.57
S248	0.33	0.17	0.67	0.67	0	0	1	0	1	1	0.83	0.67	0	0.18	0.2731	0	0.43	0.59
S249	0.83	0	0	0	0	0.67	1	1	1	0	1	0.83	0	0.31	0.0507	0.03	0.61	0.72
S250	0.33	0.67	0.17	1	0	0.83	0	1	1	0	0	1	0	0	0.823	0.01	0.64	0.74

Table A.3: Normalized data Cont’d

		Cluster 1																	
		C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14	C15	C16	C17	C18
1	S004	0.333	0.167	0.167	0.167	0	0.833	1	0	1	1	0.167	0.500	0	0.462	0.477	0.111	0.896	0
2	S007	0.333	0.833	0.000	1.000	0	0.167	0	0	1	0	0.167	0.833	0	0.385	0.251	0.000	0.704	0
3	S012	0.167	0.000	0.500	1.000	1	0.167	0	0	1	0	0.167	0.500	0	0.538	0.423	0.056	0.784	0
4	S013	0.000	0.000	0.333	0.333	1	0.333	1	0	1	0	0.167	0.167	0	0.692	0.399	0.000	0.916	0
5	S014	0.000	0.333	0.333	1.000	0	0.000	0	0	1	0	0.167	0.667	0	0.154	0.344	0.056	0.868	0
6	S017	0.500	0.833	0.667	0.167	0	1.000	0	0	1	1	0.167	1.000	0	0.923	0.418	0.111	0.656	0
7	S023	0.167	0.500	0.000	0.833	0	0.500	0	0	1	0	0.167	1.000	0	0.615	0.927	0.111	0.956	0
8	S024	0.500	0.667	0.167	0.167	1	0.500	1	0	0	1	0.167	0.167	0	1.000	0.031	0.111	0.608	0
9	S026	0.333	0.167	0.167	0.333	0	0.167	1	0	1	1	0.167	0.500	0	0.000	0.623	0.000	0.912	0
10	S028	0.500	0.500	0.000	0.333	1	0.167	1	0	1	1	0.167	0.833	0	0.692	0.569	0.056	0.692	0
11	S032	0.500	0.000	0.167	0.333	0	0.667	1	0	1	0	0.167	0.833	0	0.923	0.426	0.000	0.760	0
12	S036	0.333	1.000	0.667	0.667	0	0.333	0	0	0	1	0.167	0.500	0	0.231	0.615	0.111	0.916	0
13	S038	0.167	0.500	0.333	1.000	1	0.833	0	0	0	0	0.167	0.500	0	0.154	0.736	0.111	0.940	0
14	S040	0.000	0.000	0.000	0.833	0	1.000	0	0	0	1	0.167	1.000	0	0.538	0.879	0.056	0.840	0
15	S043	0.167	0.667	0.500	0.667	0	0.333	1	0	1	0	0.167	1.000	0	0.000	0.943	0.111	0.892	0
16	S044	0.000	0.667	0.667	0.667	0	0.167	0	0	0	0	0.167	0.000	0	0.692	0.386	0.000	1.000	0
17	S056	0.000	0.333	0.500	0.333	1	0.167	1	0	1	1	0.500	0.333	0.5	0.846	0.908	0.111	0.664	0
18	S058	0.000	0.000	0.000	1.000	0	0.167	0	0	1	0	0.333	1.000	0.5	0.538	0.260	0.222	0.760	0
19	S062	0.000	0.167	0.167	0.833	1	0.833	0	0	0	0	0.333	0.833	0.5	0.615	0.272	0.222	0.500	0
20	S068	0.167	1.000	0.667	0.500	0	0.500	0	0	0	1	0.500	0.000	0.5	0.615	0.178	0.167	0.480	0
21	S072	0.167	0.167	0.500	0.833	0	0.000	1	0	1	0	0.333	0.167	0.5	0.538	0.750	0.056	0.716	0
22	S075	0.333	0.000	0.833	0.667	1	1.000	1	0	1	0	0.333	0.000	0.5	0.462	0.845	0.167	0.712	0
23	S077	0.167	1.000	0.000	0.667	1	0.333	0	0	0	1	0.500	1.000	0.5	0.231	0.339	0.056	0.432	0
24	S084	0.000	0.667	0.333	0.500	1	0.500	1	0	1	0	0.167	1.000	0.5	0.923	0.105	0.111	0.624	0
25	S085	0.000	0.500	0.667	0.000	0	0.167	1	0	0	1	0.500	0.500	0.5	0.462	0.936	0.056	0.512	0
26	S091	0.333	0.000	1.000	0.167	1	0.500	1	0	1	0	0.500	0.500	0.5	0.923	0.824	0.056	0.664	0
27	S094	0.333	0.000	0.333	0.667	0	0.667	1	0	0	0	0.500	0.167	0.5	0.385	0.465	0.056	0.500	0
28	S095	0.000	0.500	1.000	0.667	0	0.333	1	0	1	0	0.333	0.167	0.5	0.923	0.222	0.222	0.608	0
29	S102	0.500	0.667	0.333	0.333	0	1.000	1	0	0	0	0.333	1.000	0.5	0.615	0.497	0.111	0.496	0
30	S106	0.333	1.000	0.167	0.333	1	0.333	0	0	1	0	0.167	0.000	0.5	0.000	0.668	0.056	0.492	0
31	S116	0.000	1.000	0.500	0.667	1	0.833	0	0	0	0	0.167	0.833	0.5	0.385	0.561	0.056	0.536	0
32	S117	0.000	0.167	0.333	1.000	1	0.167	0	0	0	0	0.333	1.000	0.5	0.846	0.517	0.222	0.632	0
33	S129	0.333	1.000	0.000	0.833	0	0.667	0	0	0	0	0.500	0.333	0.5	0.000	0.941	0.167	0.696	0
34	S131	0.500	0.000	0.667	0.167	1	0.500	1	0	0	1	0.167	0.333	0.5	0.923	0.187	0.056	0.672	0
35	S133	0.333	0.500	0.500	0.833	1	0.667	1	0	0	0	0.333	0.167	0.5	0.077	0.529	0.167	0.408	0
36	S143	0.167	0.000	0.833	0.167	1	0.833	0	0	0	0	0.667	0.000	1	0.615	0.737	0.667	0.108	0.638191
37	S148	0.167	0.333	0.833	0.333	1	0.000	1	0	1	1	0.000	0.167	1	0.923	0.979	0.611	0.224	0.78392
38	S150	0.500	0.167	0.667	0.000	0	0.000	1	0	1	0	0.667	0.833	1	0.846	0.462	0.667	0.320	0.904523
39	S155	0.000	0.667	0.000	0.500	1	1.000	1	0	0	1	0.167	0.833	1	0.154	0.151	0.611	0.156	0.698492
40	S156	0.500	0.833	0.500	0.667	1	0.833	1	0	0	1	0.333	0.333	1	0.308	0.354	0.667	0.304	0.884422
41	S161	0.167	0.167	0.167	0.667	1	1.000	0	0	1	0	0.000	0.000	1	0.077	0.107	0.889	0.256	0.824121
42	S172	0.500	1.000	0.500	0.833	1	0.000	0	0	1	1	0.833	0.667	1	1.000	0.395	0.833	0.328	0.914573
43	S173	0.000	0.667	0.833	0.000	0	0.000	0	0	0	0	1.000	0.333	1	0.692	0.583	0.778	0.396	1
44	S174	0.500	0.500	0.333	0.500	0	0.500	0	0	0	1	0.167	0.000	1	0.923	0.211	0.556	0.144	0.683417
45	S181	0.000	0.833	0.833	0.500	0	0.333	0	0	1	1	0.333	1.000	1	0.538	0.222	1.000	0.068	0.58794
46	S186	0.167	0.333	0.333	0.667	1	0.500	1	0	1	0	0.000	0.667	1	0.615	0.965	0.611	0.332	0.919598
47	S199	0.333	0.500	0.667	0.667	1	0.500	0	0	1	0	1.000	0.167	1	0.769	0.925	0.611	0.236	0.798995
48	S200	0.167	0.833	0.833	0.333	1	0.500	0	0	1	0	0.333	0.167	1	0.231	0.519	0.944	0.296	0.874372
49	S202	0.500	1.000	0.333	0.667	0	0.833	0	0	0	0	0.333	0.000	1	0.385	0.409	0.611	0.056	0.572864
50	S207	0.500	0.167	0.667	0.000	1	0.333	1	0	0	1	0.000	0.500	1	0.692	0.593	0.944	0.332	0.919598
51	S210	0.500	0.000	0.333	1.000	1	0.833	0	0	1	0	0.500	0.333	1	0.615	0.963	0.778	0.308	0.889447
52	S212	0.500	1.000	0.500	0.167	1	1.000	1	0	1	0	0.167	1.000	1	0.462	0.857	0.778	0.148	0.688442
53	S220	0.333	0.833	1.000	0.500	0	0.000	0	0	1	1	0.167	0.833	1	0.615	0.023	1.000	0.068	0.58794
54	S224	0.333	0.667	1.000	0.667	0	0.333	1	0	0	0	0.167	0.333	1	0.692	0.216	0.889	0.168	0.713568
55	S226	0.500	0.833	0.667	0.167	1	0.000	0	0	0	0	0.000	0.333	1	0.385	0.039	1.000	0.136	0.673367
56	S230	0.333	0.000	0.000	0.000	0	0.667	0	0	0	1	0.333	0.167	1	0.000	0.879	0.944	0.056	0.572864
57	S233	0.333	0.167	0.000	0.500	1	0.500	0	0	0	0	0.500	0.500	1	1.000	0.618	0.611	0.152	0.693467
58	S234	0.500	0.667	0.500	0.000	1	0.000	1	0	0	0	0.667	1.000	1	0.077	0.661	0.889	0.228	0.788945
59	S235	0.333	0.000	0.500	0.500	1	0.833	1	0	0	1	0.833	0.667	1	0.538	0.065	0.556	0.332	0.919598
60	S236	0.167	0.500	0.833	0.667	0	0.667	1	0	1	0	0.167	0.500	1	0.692	0.379	1.000	0.020	0.527638
61	S240	0.333	1.000	1.000	0.833	1	1.000	0	0	1	0	0.167	0.000	1	0.692	0.728	0.722	0.308	0.889447
62	S241	0.167	1.000	0.500	1.000	1	0.500	0	0	0	0	0.333	0.333	1	0.077	0.661	0.833	0.344	0.934673
63	S243	0.500	0.667	0.167	0.000	0	0.333	1	0	1	1	0.000	1.000	1	0.923	0.720	0.667	0.168	0.713568
64	S245	0.500	0.833	0.500	0.167	0	0.167	1	0	0	1	0.833	0.167	1	0.615	0.459	0.833	0.380	0.979899
65	S249	0.167	1.000	1.000	1.000	1	0.333	0	0	0	1	0.000	0.167	1	0.231	0.915	0.778	0.152	0.693467
Cluster Center		0.264	0.503	0.462	0.526	0.538	0.474	0.477	0	0.508	0.385	0.310	0.497	0.608	0.534	0.527	0.409	0.476	0.358

Table A. 4: The best cluster data

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	S004	S007	S012	S013	S014	S017	S023	S024	S026	S028	S032	S036	S038	S040	S043	S044
C01	0.333	0.333	0.167	0.000	0.000	0.500	0.167	0.500	0.333	0.500	0.500	0.333	0.167	0.000	0.167	0.000
C02	0.167	0.833	0.000	0.000	0.333	0.833	0.500	0.667	0.167	0.500	0.000	1.000	0.500	0.000	0.667	0.667
C03	0.167	0.000	0.500	0.333	0.333	0.667	0.000	0.167	0.167	0.000	0.167	0.667	0.333	0.000	0.500	0.667
C04	0.167	1.000	1.000	0.333	1.000	0.167	0.833	0.167	0.333	0.333	0.333	0.667	1.000	0.833	0.667	0.667
C05	0	0	1	1	0	0	0	1	0	1	0	0	1	0	0	0
C06	0.833	0.167	0.167	0.333	0.000	1.000	0.500	0.500	0.167	0.167	0.667	0.333	0.833	1.000	0.333	0.167
C07	1	0	0	1	0	0	0	1	1	1	1	0	0	0	1	0
C08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C09	1	1	1	1	1	1	1	0	1	1	1	0	0	0	1	0
C10	1	0	0	0	0	1	0	1	1	1	0	1	0	1	0	0
C11	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167	0.167
C12	0.500	0.833	0.500	0.167	0.667	1.000	1.000	0.167	0.500	0.833	0.833	0.500	0.500	1.000	1.000	0.000
C13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C14	0.462	0.385	0.538	0.692	0.154	0.923	0.615	1.000	0.000	0.692	0.923	0.231	0.154	0.538	0.000	0.692
C15	0.477	0.251	0.423	0.399	0.344	0.418	0.927	0.031	0.623	0.569	0.426	0.615	0.736	0.879	0.943	0.386
C16	0.111	0.000	0.056	0.000	0.056	0.111	0.111	0.111	0.000	0.056	0.000	0.111	0.111	0.056	0.111	0.000
C17	0.896	0.704	0.784	0.916	0.868	0.656	0.956	0.608	0.912	0.692	0.760	0.916	0.940	0.840	0.892	1.000
C18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	S056	S058	S062	S068	S072	S075	S077	S084	S085	S091	S094	S095	S102	S106	S116	S117	S129
C01	0.000	0.000	0.000	0.167	0.167	0.333	0.167	0.000	0.000	0.333	0.333	0.000	0.500	0.333	0.000	0.000	0.333
C02	0.333	0.000	0.167	1.000	0.167	0.000	1.000	0.667	0.500	0.000	0.000	0.500	0.667	1.000	1.000	0.167	1.000
C03	0.500	0.000	0.167	0.667	0.500	0.833	0.000	0.333	0.667	1.000	0.333	1.000	0.333	0.167	0.500	0.333	0.000
C04	0.333	1.000	0.833	0.500	0.833	0.667	0.667	0.500	0.000	0.167	0.667	0.667	0.333	0.333	0.667	1.000	0.833
C05	1	0	1	0	0	1	1	1	0	1	0	0	0	1	1	1	0
C06	0.167	0.167	0.833	0.500	0.000	1.000	0.333	0.500	0.167	0.500	0.667	0.333	1.000	0.333	0.833	0.167	0.667
C07	1	0	0	0	1	1	0	1	1	1	1	1	1	0	0	0	0
C08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C09	1	1	0	0	1	1	0	1	0	1	0	1	0	1	0	0	0
C10	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0
C11	0.500	0.333	0.333	0.500	0.333	0.333	0.500	0.167	0.500	0.500	0.500	0.333	0.333	0.167	0.167	0.333	0.500
C12	0.333	1.000	0.833	0.000	0.167	0.000	1.000	1.000	0.500	0.500	0.167	0.167	1.000	0.000	0.833	1.000	0.333
C13	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
C14	0.846	0.538	0.615	0.615	0.538	0.462	0.231	0.923	0.462	0.923	0.385	0.923	0.615	0.000	0.385	0.846	0.000
C15	0.908	0.260	0.272	0.178	0.750	0.845	0.339	0.105	0.936	0.824	0.465	0.222	0.497	0.668	0.561	0.517	0.941
C16	0.111	0.222	0.222	0.167	0.056	0.167	0.056	0.111	0.056	0.056	0.056	0.222	0.111	0.056	0.056	0.222	0.167
C17	0.664	0.760	0.500	0.480	0.716	0.712	0.432	0.624	0.512	0.664	0.500	0.608	0.496	0.492	0.536	0.632	0.696
C18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	S004	S007	S012	S013	S014	S017	S023	S024	S026	S028	S032	S036	S038	S040	S043	S044
S	0.415	0.340	0.373	0.385	0.232	0.554	0.412	0.494	0.303	0.494	0.458	0.383	0.413	0.337	0.370	0.315
R	0.082	0.064	0.071	0.089	0.079	0.118	0.087	0.128	0.083	0.090	0.118	0.083	0.086	0.093	0.081	0.091
Q	0.412	0.183	0.281	0.422	0.145	0.866	0.447	0.857	0.271	0.578	0.736	0.383	0.438	0.389	0.348	0.344

	S056	S058	S062	S068	S072	S075	S077	S084	S085	S091	S094	S095	S102	S106	S116	S117	S129
S	0.450	0.256	0.352	0.348	0.332	0.520	0.345	0.460	0.298	0.534	0.309	0.392	0.461	0.377	0.412	0.360	0.351
R	0.108	0.069	0.079	0.079	0.069	0.093	0.076	0.118	0.059	0.118	0.062	0.118	0.093	0.076	0.078	0.108	0.076
Q	0.654	0.106	0.306	0.300	0.207	0.639	0.274	0.740	0.090	0.840	0.126	0.647	0.558	0.318	0.378	0.532	0.282

	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
	S131	S133	S143	S148	S150	S155	S156	S161	S172	S173	S174	S181	S186	S199	S200	S202
C01	0.500	0.333	0.167	0.167	0.500	0.000	0.500	0.167	0.500	0.000	0.500	0.000	0.167	0.333	0.167	0.500
C02	0.000	0.500	0.000	0.333	0.167	0.667	0.833	0.167	1.000	0.667	0.500	0.833	0.333	0.500	0.833	1.000
C03	0.667	0.500	0.833	0.833	0.667	0.000	0.500	0.167	0.500	0.833	0.333	0.833	0.333	0.667	0.833	0.333
C04	0.167	0.833	0.167	0.333	0.000	0.500	0.667	0.667	0.833	0.000	0.500	0.500	0.667	0.667	0.333	0.667
C05	1	1	1	1	0	1	1	1	1	0	0	0	1	1	1	0
C06	0.500	0.667	0.833	0.000	0.000	1.000	0.833	1.000	0.000	0.000	0.500	0.333	0.500	0.500	0.500	0.833
C07	1	1	0	1	1	1	1	0	0	0	0	0	1	0	0	0
C08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C09	0	0	0	1	1	0	0	1	1	0	0	1	1	1	1	0
C10	1	0	0	1	0	1	1	0	1	0	1	1	0	0	0	0
C11	0.167	0.333	0.667	0.000	0.667	0.167	0.333	0.000	0.833	1.000	0.167	0.333	0.000	1.000	0.333	0.333
C12	0.333	0.167	0.000	0.167	0.833	0.833	0.333	0.000	0.667	0.333	0.000	1.000	0.667	0.167	0.167	0.000
C13	0.5	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1
C14	0.923	0.077	0.615	0.923	0.846	0.154	0.308	0.077	1.000	0.692	0.923	0.538	0.615	0.769	0.231	0.385
C15	0.187	0.529	0.737	0.979	0.462	0.151	0.354	0.107	0.395	0.583	0.211	0.222	0.965	0.925	0.519	0.409
C16	0.056	0.167	0.667	0.611	0.667	0.611	0.667	0.889	0.833	0.778	0.556	1.000	0.611	0.611	0.944	0.611
C17	0.672	0.408	0.108	0.224	0.320	0.156	0.304	0.256	0.328	0.396	0.144	0.068	0.332	0.236	0.296	0.056
C18	0	0	0.638	0.784	0.905	0.698	0.884	0.824	0.915	1.000	0.683	0.588	0.920	0.799	0.874	0.573

	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65
	S207	S210	S212	S220	S224	S226	S230	S233	S234	S235	S236	S240	S241	S243	S245	S249
C01	0.500	0.500	0.500	0.333	0.333	0.500	0.333	0.333	0.500	0.333	0.167	0.333	0.167	0.500	0.500	0.167
C02	0.167	0.000	1.000	0.833	0.667	0.833	0.000	0.167	0.667	0.000	0.500	1.000	1.000	0.667	0.833	1.000
C03	0.667	0.333	0.500	1.000	1.000	0.667	0.000	0.000	0.500	0.500	0.833	1.000	0.500	0.167	0.500	1.000
C04	0.000	1.000	0.167	0.500	0.667	0.167	0.000	0.500	0.000	0.500	0.667	0.833	1.000	0.000	0.167	1.000
C05	1	1	1	0	0	1	0	1	1	1	0	1	1	0	0	1
C06	0.333	0.833	1.000	0.000	0.333	0.000	0.667	0.500	0.000	0.833	0.667	1.000	0.500	0.333	0.167	0.333
C07	1	0	1	0	1	0	0	0	1	1	1	0	0	1	1	0
C08	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C09	0	1	1	1	0	0	0	0	0	0	1	1	0	1	0	0
C10	1	0	0	1	0	0	1	0	0	1	0	0	0	1	1	1
C11	0.000	0.500	0.167	0.167	0.167	0.000	0.333	0.500	0.667	0.833	0.167	0.167	0.333	0.000	0.833	0.000
C12	0.500	0.333	1.000	0.833	0.333	0.333	0.167	0.500	1.000	0.667	0.500	0.000	0.333	1.000	0.167	0.167
C13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
C14	0.692	0.615	0.462	0.615	0.692	0.385	0.000	1.000	0.077	0.538	0.692	0.692	0.077	0.923	0.615	0.231
C15	0.593	0.963	0.857	0.023	0.216	0.039	0.879	0.618	0.661	0.065	0.379	0.728	0.661	0.720	0.459	0.915
C16	0.944	0.778	0.778	1.000	0.889	1.000	0.944	0.611	0.889	0.556	1.000	0.722	0.833	0.667	0.833	0.778
C17	0.332	0.308	0.148	0.068	0.168	0.136	0.056	0.152	0.228	0.332	0.020	0.308	0.344	0.168	0.380	0.152
C18	0.920	0.889	0.688	0.588	0.714	0.673	0.573	0.693	0.789	0.920	0.528	0.889	0.935	0.714	0.980	0.693

	S131	S133	S143	S148	S150	S155	S156	S161	S172	S173	S174	S181	S186	S199	S200	S202
S	0.476	0.385	0.394	0.474	0.422	0.349	0.505	0.345	0.567	0.311	0.385	0.343	0.476	0.519	0.432	0.385
R	0.118	0.070	0.079	0.118	0.108	0.093	0.090	0.093	0.128	0.089	0.118	0.069	0.079	0.099	0.070	0.090
Q	0.761	0.285	0.364	0.759	0.616	0.406	0.594	0.400	0.956	0.322	0.637	0.223	0.475	0.677	0.349	0.430

	S207	S210	S212	S220	S224	S226	S230	S233	S234	S235	S236	S240	S241	S243	S245	S249
S	0.478	0.525	0.599	0.373	0.392	0.372	0.236	0.425	0.398	0.434	0.409	0.599	0.398	0.479	0.426	0.419
R	0.090	0.090	0.093	0.079	0.089	0.090	0.062	0.128	0.090	0.078	0.089	0.093	0.076	0.118	0.090	0.076
Q	0.557	0.621	0.745	0.334	0.432	0.413	0.027	0.763	0.448	0.408	0.456	0.746	0.346	0.765	0.486	0.375

Table A. 5: VIKOR results

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15	V16	V17	V18	V19	V20	V21
Cr1	0.75	1	0.46	1	0.92	0.9	1	0	0.13	0.18	0.18	0.01	0.26	0.79	0.1	0.45	0.89	0.69	0.5	0.45	0.63
Cr2	0.22	0	0.33	1	0.94	0.35	0.9	0.13	0.02	0	0.38	0.95	0.88	0.72	0.25	0.26	0.28	0.18	0.09	0.41	0.92
Cr3	0.53	0	0.74	0	0.03	0.89	0.1	0.12	0	0.3	0.66	0.08	0.86	0.22	0.69	0.8	0.28	0.58	0.88	0.76	0.32
Cr4	0.28	1	0.8	0	0.54	0.75	0.85	1	1	0.87	0.33	0.5	0.78	0.12	0.41	0.21	0.03	0.2	0.36	0.07	0.83
Cr5	0.3	0	0.79	1	0.6	0.49	0.8	0.15	0.97	0.79	0.83	0.13	0.46	0.15	0.69	0.51	0.48	0.08	0.67	0.2	0.73
Cr6	0.5	1	0.27	0	0.43	0.52	0.12	0	0	0.25	0.9	0.07	0.26	0	0.6	0.54	0.35	0.23	0.11	0.33	0.06
Cr7	0.25	1	0.6	1	0.01	0.18	0	0.13	1	0.85	0.51	0.59	0.12	1	0.99	0.38	0.22	0.48	0.75	0.51	1
Cr8	0.76	1	0.68	1	0.55	0.87	0	0.14	0	1	0.98	0.19	0.86	0.99	0.01	0.56	0.54	0.93	0.32	0.2	0.82
Cr9	0.25	1	0.5	1	0.26	0.92	0.94	0.03	0.15	1	0.7	0.41	0.95	1	0.83	0.32	0.74	0.48	0.21	0.86	0.42
Cr10	0.16	1	0.7	0	0.46	0.62	0.9	0	0.03	0	0.3	0.68	0.61	1	0.96	0.03	0.83	0.96	0.09	0.86	0.9
Cr11	0.31	0	0.3	0	0.09	0.73	1	1	1	0	0.87	0.3	0.98	0	0.01	1	0.61	0.84	0.07	0.02	0.6
Cr12	0.34	1	0.39	1	0.75	0.94	0.78	0.3	0	0.85	0.94	0.61	0.46	0.3	0.44	0.58	0.34	0.47	0.61	0.11	0.2
Cr13	0.62	1	0.02	1	0.15	0.97	0.15	0.01	0.18	0.92	0.55	0.23	0.12	0.97	0.42	0.87	0.76	0.95	0.15	0.87	0.69
Cr14	0.08	0	0.27	0	0.14	0.42	1	0.91	0	0.82	0.45	0.42	0.81	1	0.29	0.54	0.38	0.15	0.92	0.95	0.68
Cr15	0.49	0	0.98	0	0.52	0.68	0	0.24	0.06	0	0.52	0.84	0.05	0.76	0.71	0.4	0.26	0.52	0.78	0.63	0.42
Cr16	0.1	1	0.32	1	0.67	0.21	1	0.85	0.16	0.29	0.49	0.41	0.29	0.27	0.18	0.79	0.21	0.19	0.18	0.78	0.85
Cr17	0.08	0	0.19	1	0.24	0.87	0	0.72	0.26	1	0.84	0.99	0.64	0.04	0.61	0.38	0.8	0.07	0.35	0.51	0.92
Cr18	0.86	0	0.28	1	0.95	0.08	1	0.12	0.2	0	0.4	0.76	0.66	1	0.96	0.99	0.76	0.87	0.98	0.72	0.73
Cr19	0.15	1	0.92	1	0.77	0.63	0	0	0.3	0.22	0.22	0.94	0.93	0.26	0.04	0.11	0.16	0.88	0.6	0.38	0.3
Cr20	0.72	0	0.88	0	0.15	0.93	0.97	1	1	1	0.75	0.64	0.26	1	0.54	0.83	0.34	0.5	0.66	0.97	0.64
Cr21	0.07	1	0.8	1	0.48	0.35	0	1	0.27	0.93	0.52	0.82	0.07	0.71	0.03	0.27	0.61	0.2	0.8	0.79	0.75
Cr22	0.02	1	0.35	0	0.83	0.26	0.04	0	0.78	0.97	0.28	0.19	0.8	0.08	0.69	0.72	0.25	1	0.74	0.25	0.6
Cr23	0.28	0	0.94	1	0.25	0.45	0.73	0.89	0	0.17	0.56	0.08	0.15	0.91	0.28	0.24	0.33	0.8	0.28	0.74	0.96
Cr24	0.82	0	0.83	1	0.08	0.47	0	0.94	0	0.87	0.6	0.52	0.61	0.96	0.38	0	0.55	0.16	0.78	0.56	0.41
Cr25	0.74	0	0.59	0	0.23	0.44	0.04	0.9	0.26	0.09	0.78	0.32	0.58	0	0.45	0.15	0.13	0.57	0.02	0.08	0.01
Cr26	0.53	0	0.28	0	0.39	0.84	0.77	0.25	0.28	0.85	0.77	0.52	0.15	0	0.47	0.58	0.55	0.68	0.81	0.65	0.43
Cr27	0.49	0	0.08	1	0.43	0.07	0.03	0.76	0.9	0	0.79	0.89	0.84	0.01	0.62	0.03	0.01	0.92	0.82	0.58	0.25
Cr28	0.49	1	0.69	0	0.41	0.68	0.23	0	0.75	1	0.33	0.81	0.91	0	0.23	0.99	0.03	0.75	0.47	0.37	0.58
Cr29	0.79	0	0.45	0	0.2	0	0.79	0.96	1	1	0.05	0.38	0.59	1	0.86	0.29	0.16	0.01	0.87	0.9	0.37
Cr30	0.51	1	0.76	1	0.05	0.38	1	0.99	0.82	0.01	0.94	0.83	0.98	0.96	0.13	0.85	0.6	0.15	0.69	0.49	0.42
Cr31	0.41	1	0.18	1	0.68	0.35	0.05	0.78	1	1	0.76	0.17	0.37	0.03	0.99	0.38	0.47	0.32	0.17	0.34	0.91
Cr32	0.31	0	0.91	0	0.17	0.93	0	0.25	0.25	0.73	0.9	0.39	0.67	0	0.95	0.44	0.11	0.53	0.96	0.71	0.85
Cr33	0.98	0	0.3	1	0.9	0.13	0	1	0	0.85	0.25	0.55	0.87	1	0.49	0.57	0.53	0.53	0.53	0.87	0.72
Cr34	0.54	0	0.01	1	0.22	0.96	1	1	0.18	1	0.91	0.01	0.22	0.08	0.99	0.98	0.85	0.99	0.14	0.98	0.37
Cr35	0.73	1	0.7	0	0.7	0.96	0.76	0.82	0.88	0.14	0.12	0.02	0.94	0.75	0.65	0.81	0.2	0.03	0.86	0.1	0.83
Cr36	0.62	1	0.28	1	0.38	0.75	0	1	1	0.19	0.1	0.23	0.86	0	0.91	0.66	0.94	0.57	0.2	0.97	0.99
Cr37	0.05	1	0.22	0	0.67	0.36	0.1	1	0	0	0.73	0.53	0.73	0.84	0.62	0.93	0.2	0.34	0.48	0.03	0.79
Cr38	0.47	0	0.7	0	0.34	0.27	0.74	0.93	0.11	0.17	0.05	0.54	0.46	0.24	0.68	0.45	0.63	0.98	0.34	0.82	0.01
Cr39	0.26	1	0.95	1	0.73	0.68	0.85	0.16	0.76	0.19	0.93	0.22	0.9	0	0.54	0.06	0.15	0.92	0.7	0.36	0.71
Cr40	0.08	1	0.45	0	0.6	0.09	0.87	0.04	0.16	0.19	0.04	0.21	0.19	0.25	0.53	0.47	0.28	0.16	0.04	0.46	0.78

Table A. 6: Holt’s suppliers’ data

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	Score
Cr1	0.75	0.88	0.74	0.80	0.83	0.84	0.86	0.75	0.68	0.63	0.59	0.54	0.52	0.54	0.51	0.51	0.53	0.54	0.54	0.53	0.54	0.88
Cr2	0.22	0.11	0.18	0.39	0.50	0.47	0.53	0.48	0.43	0.39	0.39	0.44	0.47	0.49	0.47	0.46	0.45	0.43	0.41	0.41	0.44	0.53
Cr3	0.53	0.27	0.42	0.32	0.26	0.37	0.33	0.30	0.27	0.27	0.31	0.29	0.33	0.32	0.35	0.38	0.37	0.38	0.41	0.43	0.42	0.53
Cr4	0.28	0.64	0.69	0.52	0.52	0.56	0.60	0.65	0.69	0.71	0.67	0.66	0.67	0.63	0.62	0.59	0.56	0.54	0.53	0.51	0.52	0.71
Cr5	0.30	0.15	0.36	0.52	0.54	0.53	0.57	0.52	0.57	0.59	0.61	0.57	0.56	0.53	0.54	0.54	0.54	0.51	0.52	0.50	0.52	0.61
Cr6	0.50	0.75	0.59	0.44	0.44	0.45	0.41	0.36	0.32	0.31	0.36	0.34	0.33	0.31	0.33	0.34	0.34	0.34	0.32	0.32	0.31	0.75
Cr7	0.25	0.63	0.62	0.71	0.57	0.51	0.43	0.40	0.46	0.50	0.50	0.51	0.48	0.52	0.55	0.54	0.52	0.52	0.53	0.53	0.55	0.71
Cr8	0.76	0.88	0.81	0.86	0.80	0.81	0.69	0.63	0.56	0.60	0.63	0.60	0.62	0.64	0.60	0.60	0.60	0.61	0.60	0.58	0.59	0.88
Cr9	0.25	0.63	0.58	0.69	0.60	0.66	0.70	0.61	0.56	0.61	0.61	0.60	0.62	0.65	0.66	0.64	0.65	0.64	0.62	0.63	0.62	0.70
Cr10	0.16	0.58	0.62	0.47	0.46	0.49	0.55	0.48	0.43	0.39	0.38	0.40	0.42	0.46	0.49	0.47	0.49	0.51	0.49	0.51	0.53	0.62
Cr11	0.31	0.16	0.20	0.15	0.14	0.24	0.35	0.43	0.49	0.44	0.48	0.47	0.51	0.47	0.44	0.47	0.48	0.50	0.48	0.46	0.46	0.51
Cr12	0.34	0.67	0.58	0.68	0.70	0.74	0.74	0.69	0.61	0.64	0.66	0.66	0.64	0.62	0.61	0.61	0.59	0.58	0.58	0.56	0.54	0.74
Cr13	0.62	0.81	0.55	0.66	0.56	0.63	0.56	0.49	0.46	0.50	0.51	0.48	0.46	0.49	0.49	0.51	0.53	0.55	0.53	0.55	0.55	0.81
Cr14	0.08	0.04	0.12	0.09	0.10	0.15	0.27	0.35	0.31	0.36	0.37	0.38	0.41	0.45	0.44	0.45	0.44	0.43	0.45	0.48	0.49	0.49
Cr15	0.49	0.25	0.49	0.37	0.40	0.45	0.38	0.36	0.33	0.30	0.32	0.36	0.34	0.37	0.39	0.39	0.38	0.39	0.41	0.42	0.42	0.49
Cr16	0.10	0.55	0.47	0.61	0.62	0.55	0.61	0.64	0.59	0.56	0.55	0.54	0.52	0.50	0.48	0.50	0.48	0.47	0.45	0.47	0.49	0.64
Cr17	0.08	0.04	0.09	0.32	0.30	0.40	0.34	0.39	0.37	0.44	0.47	0.52	0.53	0.49	0.50	0.49	0.51	0.49	0.48	0.48	0.50	0.53
Cr18	0.86	0.43	0.38	0.54	0.62	0.53	0.60	0.54	0.50	0.45	0.44	0.47	0.49	0.52	0.55	0.58	0.59	0.61	0.62	0.63	0.63	0.86
Cr19	0.15	0.58	0.69	0.77	0.77	0.75	0.64	0.56	0.53	0.50	0.47	0.51	0.54	0.52	0.49	0.47	0.45	0.47	0.48	0.48	0.47	0.77
Cr20	0.72	0.36	0.53	0.40	0.35	0.45	0.52	0.58	0.63	0.67	0.67	0.67	0.64	0.66	0.66	0.67	0.65	0.64	0.64	0.66	0.66	0.72
Cr21	0.07	0.54	0.62	0.72	0.67	0.62	0.53	0.59	0.55	0.59	0.58	0.60	0.56	0.57	0.54	0.52	0.53	0.51	0.52	0.54	0.55	0.72
Cr22	0.02	0.51	0.46	0.34	0.44	0.41	0.36	0.31	0.36	0.43	0.41	0.39	0.42	0.40	0.42	0.44	0.43	0.46	0.47	0.46	0.47	0.51
Cr23	0.28	0.14	0.41	0.56	0.49	0.49	0.52	0.57	0.50	0.47	0.48	0.45	0.42	0.46	0.45	0.43	0.43	0.45	0.44	0.45	0.48	0.57
Cr24	0.82	0.41	0.55	0.66	0.55	0.53	0.46	0.52	0.46	0.50	0.51	0.51	0.52	0.55	0.54	0.51	0.51	0.49	0.50	0.51	0.50	0.82
Cr25	0.74	0.37	0.44	0.33	0.31	0.33	0.29	0.37	0.36	0.33	0.37	0.37	0.38	0.36	0.36	0.35	0.34	0.35	0.33	0.32	0.30	0.74
Cr26	0.53	0.27	0.27	0.20	0.24	0.34	0.40	0.38	0.37	0.42	0.45	0.46	0.43	0.40	0.41	0.42	0.43	0.44	0.46	0.47	0.47	0.53
Cr27	0.49	0.25	0.19	0.39	0.40	0.35	0.30	0.36	0.42	0.38	0.41	0.45	0.48	0.45	0.46	0.43	0.41	0.44	0.46	0.46	0.45	0.49
Cr28	0.49	0.75	0.73	0.55	0.52	0.55	0.50	0.44	0.47	0.53	0.51	0.53	0.56	0.52	0.50	0.53	0.50	0.52	0.51	0.51	0.51	0.75
Cr29	0.79	0.40	0.41	0.31	0.29	0.24	0.32	0.40	0.47	0.52	0.48	0.47	0.48	0.52	0.54	0.52	0.50	0.47	0.49	0.52	0.51	0.79
Cr30	0.51	0.76	0.76	0.82	0.66	0.62	0.67	0.71	0.72	0.65	0.68	0.69	0.71	0.73	0.69	0.70	0.69	0.66	0.67	0.66	0.65	0.82
Cr31	0.41	0.71	0.53	0.65	0.65	0.60	0.52	0.56	0.61	0.65	0.66	0.62	0.60	0.56	0.58	0.57	0.57	0.55	0.53	0.52	0.54	0.71
Cr32	0.31	0.16	0.41	0.31	0.28	0.39	0.33	0.32	0.31	0.36	0.40	0.40	0.42	0.39	0.43	0.43	0.41	0.42	0.45	0.46	0.48	0.48
Cr33	0.98	0.49	0.43	0.57	0.64	0.55	0.47	0.54	0.48	0.52	0.49	0.50	0.53	0.56	0.55	0.56	0.55	0.55	0.55	0.57	0.57	0.98
Cr34	0.54	0.27	0.18	0.39	0.35	0.46	0.53	0.59	0.55	0.59	0.62	0.57	0.54	0.51	0.54	0.57	0.59	0.61	0.58	0.60	0.59	0.62
Cr35	0.73	0.87	0.81	0.61	0.63	0.68	0.69	0.71	0.73	0.67	0.62	0.57	0.60	0.61	0.61	0.62	0.60	0.57	0.58	0.56	0.57	0.87
Cr36	0.62	0.81	0.63	0.73	0.66	0.67	0.58	0.63	0.67	0.62	0.57	0.55	0.57	0.53	0.55	0.56	0.58	0.58	0.56	0.58	0.60	0.81
Cr37	0.05	0.53	0.42	0.32	0.39	0.38	0.34	0.43	0.38	0.34	0.38	0.39	0.41	0.45	0.46	0.49	0.47	0.46	0.46	0.44	0.46	0.53
Cr38	0.47	0.24	0.39	0.29	0.30	0.30	0.36	0.43	0.40	0.37	0.34	0.36	0.37	0.36	0.38	0.38	0.40	0.43	0.43	0.45	0.43	0.47
Cr39	0.26	0.63	0.74	0.80	0.79	0.77	0.78	0.70	0.71	0.66	0.68	0.64	0.66	0.62	0.61	0.58	0.55	0.57	0.58	0.57	0.57	0.80
Cr40	0.08	0.54	0.51	0.38	0.43	0.37	0.44	0.39	0.37	0.35	0.32	0.31	0.30	0.30	0.31	0.32	0.32	0.31	0.30	0.31	0.33	0.54

Table A. 7: Partial Average results to Holts' data

	Weight	Normalized Weight
V01	0.501	0.0379
V02	0.435	0.0329
V03	0.408	0.0308
V04	0.529	0.0400
V05	0.583	0.0441
V06	0.545	0.0412
V07	0.631	0.0477
V08	0.669	0.0506
V09	0.634	0.0479
V10	0.667	0.0504
V11	0.676	0.0511
V12	0.648	0.0490
V13	0.695	0.0525
V14	0.814	0.0615
V15	0.735	0.0555
V16	0.851	0.0643
V17	0.748	0.0565
V18	0.679	0.0513
V19	0.541	0.0409
V20	0.576	0.0435
V21	0.667	0.0504
Total	13.232	

Table A. 8: Holt's Criteria Weights