SUPPLIER SELECTION MODEL BASED ON DISCRETE CHOICE ANALYSIS AND ITS APPLICATION IN THE APPAREL INDUSTRY OF BANGLADESH

by
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CERTIFICATE OF APPROVAL

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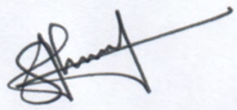

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ABSTRACT

Supplier selection is crucial for the success of any manufacturing organization as it provides the maximum opportunity for cost reduction. This study proposes a market-utility based approach to identify the key supplier selection criteria and rank supplier alternatives based on those criteria. Discrete choice analysis technique is used in this thesis to collect response since it replicates the actual choice of the respondents. The study also investigates the gap between perception and actual choice of the managers. This study is focused towards the apparel industry of Bangladesh. This study identified the key supplier criteria to be cost, responsiveness, lead time, company status, and quality. The study also identified that though the managers perceive quality to be an important criterion, they actually choose suppliers mostly focusing on cost of the product and responsiveness of the supplier. Suppliers for apparel industry of Bangladesh can gain an understanding of the decision-making processes and practices of supplier selection from this study.

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By the grace of the most benevolent and almighty Allah, the thesis titled "SUPPLIER SELECTION MODEL BASED ON DISCRETE CHOICE ANALYSIS AND ITS APPLICATION IN THE APPAREL INDUSTRY OF BANGLADESH" has been completed.

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LIST OF ABBREVIATIONS

RMG	:	Ready Made Garments
GDP	:	Gross Domestic Product
MNL	:	Multinomial Logistic
DCA	:	Discrete Choice Analysis
AHP	:	Analytic Hierarchy Process
ANP	:	Analytic Network Process
ISM	:	Interpretive Structural Model
CBR	:	Case Based Reasoning
ISRMS	:	Intelligent Supplier Selection Relationship Management System
DEA	:	Data Envelopment Analysis
GA	:	Genetic Algorithm
TOPSIS	:	Technique for Order of Preference by Similarity to Ideal Solution
MCDM	:	Multi-Criteria Decision Making
MOP	:	Multi-Objective Programming
GP	:	Goal Programming
LP	:	Linear Programming
PDCA	:	Plan Do Check Act
QFD	:	Quality Function Deployment
CDF	:	Cumulative Distribution Function
PDF	:	Probability Density Function

CHAPTER 1

INTRODUCTION

1.1 Background

In most industries, the cost of raw materials contributes to the majority percentage of the total product cost. This cost, being a variable one, rises and drops with the production level. The performance of the end product is also dependent on the quality of the raw materials. Therefore, selection of the right supplier is crucial and provides the maximum opportunity for cost reduction across the entire supply chain. In the recent years, globalization of trade and availability of information have made supplier selection a challenging and important problem. For a long time, the process of supplier selection was focused simply upon the cost criterion. However, over the course of time it was clear that apart from cost there are other factors also that play an important role in the selection process. Since then, a multi-criteria approach became more relevant to address the problem.

Bangladesh is the 2nd largest exporter of ready-made garments (RMG) in the world [1]. The industry started its operation in 1970 and has become the most significant contributor of the total export and GDP of the country. The industry has not only boosted the economy of the country but also enriched the socio-economic condition by creating a huge number of employment opportunities. However, the industry is facing a number of challenges. Selection of supplier for the procurement of the raw materials is one of the major challenges [1]. Fabric, being the most prominent raw material in the apparel industry is mostly imported from other countries. This increases the production lead time of the products. Local fabric industries are often failing to meet the requirements of the manufacturers. So far there has not been any significant research to identify the key supplier selection criteria for the apparel industry of Bangladesh.

Although there has been a considerable amount of research for supplier selection, the process of selecting the supplier of key raw materials is still challenging in a number of industries. The process of selecting a supplier involves evaluating the characteristics of a particular supplier based on the key criteria and then comparing them with that of other suppliers. Most of the previous researches in this area are based on rating of the perceived importance, which requires verbal qualitative response regarding the criteria from the experts [2]. However, the verbal qualitative responses of the supplier criteria may differ from the actual choice of suppliers in an experimental setting. Very few previous methods have considered such market utility-based approach and none of them has constructed a complete framework for ranking and selecting the available alternatives. Also, no work was published regarding the influencing criteria for supplier selection for the apparel industries of Bangladesh, which may change across industries. Therefore, developing a supplier selection model based on discrete choice analysis targeted towards the apparel industries of Bangladesh is still an open problem and thereby yields the scope of the proposed thesis.

1.2 Objectives with Specific Aims

The specific objectives of this research are:

- **(i)** To identify the criteria that play a vital role for supplier selection in the apparel industry of Bangladesh and rank those criteria according to their importance.
- **(ii)** To rank the supplier alternatives by assessing their performance according to those criteria and select the most suitable ones.
- **(iii)** To evaluate whether the perception of the respondents regarding the relative importance of the criteria matches with their actual practices.

1.3 Outline of Methodologies Used

The proposed research methodology is outlined below:

(i) Influencing criteria for supplier selection are identified by collecting information from the relevant experts of the apparel industries of Bangladesh.

(ii) Appropriate levels of each of the criteria for experimental design are specified.

(iii) The experiment is designed and presented to the respondents for collecting categorical choice from the respondents.

(iv) Relative importance of the criteria and the interrelationships between them are calculated by analyzing the categorical responses through a Multinomial Logistic Regression (MNL) analysis.

(v) Available suppliers are ranked by assessing their scores against relative importance of the criteria.

(vi) Results obtained from this model are compared with the verbal qualitative responses collected from the respondents regarding the relative importance of the criteria.

1.4 Organization of the Thesis

This thesis has been organized in the following manner:

The first chapter contains the necessary background of the thesis, clearly defined objectives, and summary of the developed methodology. Chapter 2 presents the literature review of all the relevant topics of the thesis. Chapter 3 provides necessary theoretical background required to understand discrete choice analysis and multinomial logistic regression model. The detailed methodology for supplier selection using discrete choice analysis is described in Chapter 4. The process of comparison between the results obtained using discrete choice analysis and verbal response is also described in Chapter 4. A case study is formulated that illustrates the proposed methodology for supplier selection using discrete choice analysis for the apparel industry of Bangladesh in Chapter 5. Finally, the thesis paper is concluded along with recommendations for future work

CHAPTER 2
LITERATURE REVIEW

2.1 Literature on Supplier Selection Process

Supplier selection problem was first addressed and brought into the attention of researchers by Dickson [3]. After that, enormous amount of effort and research work has been done to address the problem of supplier selection. The research in this direction was summarized by many authors including Weber et al. [4], Degraeve et al. [5], De Boer et al. [6], and Ho et al. [7]. The literature on supplier selection deals with identifying supplier criteria, selection of models and evaluation of suppliers.

There are a number of single model approaches that have been proposed by various researchers for supplier selection. Acar and Burhan [8] proposed an analytic hierarchy process (AHP) approach for supplier selection. Bayazit [9] proposed a model having dependency and interaction between several supplier criteria and indicated that analytic network process (ANP) is a more appropriate method. In case of total cost of ownership methodology, the ability of AHP to deal with multiple criteria in case of supplier selection was dealt with Bhutta and Huq [10]. A model for interactive supplier selection based on AHP was proposed by Chan [11]. With a view to investigate the interactions among various supplier selection criteria Govindan et al. [12] proposed a supplier selection model based on interpretive structural model (ISM). Similar methodology was used by Govindan et al. [13] to identify the relationship among attributes.

Environmental factors in a supplier selection process were considered in a case-based reasoning (CBR) supplier selection model by Humphreys et al. [14]. Choy et al. [15] used artificial neural network to build a hybrid case-based reasoning (CBR) model for intelligent supplier selection relationship management system (ISRMS) to rate and select the most suitable supplier. Performance of the suppliers as a whole was evaluated by using data envelopment analysis (DEA) in a manufacturing farm by Liu et al. [16]. Wu et al. [17] proposed an approach that included three stages. Firstly, DEA and CCR models are used to calculate pair-wise efficiency and a cross- evaluation DEA model is proposed. Secondly, the pair-wise efficiency scores were then utilized to construct the consistent fuzzy preference relation. Thirdly, the row wise summation technique was used [17]. Ding et al. [18] proposed the use of genetic algorithm (GA) for supplier selection. Intuitionistic fuzzy TOPSIS and other multi-criteria decision making (MCDM) methods [19-20] were proposed to deal with different conflicting supplier selection criteria. Expert opinions are often taken to collect data of ratings and weights. Fuzzy numbers are often used to translate expert opinions into numerical values. To address the supplier selection problem, a group multi-criteria decision making (MCDM) model is applied in case of third party reverse logistic provider by Kannan et al. [21]. Later, a model for third party reverse logistic provider in case of fuzzy environment for battery industry was proposed by Kannan and Murugesan [22]. The use of linear weighted model was proposed by Ng [23]. A number of other approaches such as multi-objective programming (MOP), goal programming (GP) were also used to address supplier selection problem by a number of researchers [24-26]. A mixed integer model was proposed by Hong et al. [27], where the objective was to find optimal supplier for maximizing revenue with the customer needs being satisfied.

Discrete Choice Analysis (DCA) offers an effective approach for incorporating customer preferences into operating decisions. It had been used in various service industries such as healthcare, hospitality, financial services, marketing and so on for collecting consumer preference as suggested by Verma and Thompson [34]. Van der Rhee et al. [2] proposed the use of discrete choice analysis (DCA) for analyzing trade-offs between criteria in the supplier selection process.

There are a number of mixed supplier selection model where AHP is linked with other methods as evident from the review work of various researchers [6-7]. AHP and LP were linked together by Ghodsypour and O'Brien [28] to identify the best supplier by considering tangible and intangible criteria in order to maximize the total value of purchasing. Deng et al. [29] extended the existing AHP methodology by D numbers to account for uncertainty. To deal with uncertainty Zhang et al. [30] and Zhang et al. [31] proposed methods by combining analytic network process with fuzzy and Dempster–Shafer evidence theory. Pi and Low [32] proposed a supplier evaluation and selection model by linking Taguchi Loss Function and AHP. AHP was linked with data envelopment analysis (DEA) by Sevkli et al. [33] to identify the most suitable supplier for a TV company.

2.2 Literature on Apparel Industry of Bangladesh

In spite of being highest revenue export earner, the apparel industry of Bangladesh is not vastly explored by the researchers. Very few works have been done to enhance the overall performance and productivity of the industry. Mottaleb and Sonobe [35] inquired the major reasons for the rapid growth of apparel industry in Bangladesh. Tahiduzzaman et al. published a work to minimize the sewing defects in the apparel industry of Bangladesh with 5S and Plan Do Check Act (PDCA) cycle [36]. Halder et al. [37] proposed a fuzzy AHP based approach to evaluate the factors affecting the productivity of Ready Made Garments (RMG) industry in Bangladesh. Chowdhury and Quaddus [38] identified the major supply chain vulnerabilities and proposed a multiple objective optimization based QFD approach to build a resilient RMG supply chain in Bangladesh. Huq et al. [39] addressed social sustainability issues prevailing in the supply chain of RMG industry in Bangladesh. Ali and Habib [40] projected an overall view of the supply chain of textile industry in Bangladesh in their work. The work primarily focused on various supply chain constraints such as ineffective communication, longer lead time, etc. Work related to supplier selection in apparel industry of Bangladesh is really numbered. Considering suppler selection, a multi criteria decision making (MCDM) problem, Marufuzzaman and Ahsan [41] proposed an AHP based approach for supplier evaluation. Kaes and Azeem [42] proposed an AHP based approach for supplier selection and demand forecasting of incoming materials in RMG industry.

Most of the methods discussed above such as AHP, ANP, LP etc. require verbal responses from the respondents for evaluating supplier alternatives. Very few previous methods have considered such market utility-based approach and none of them has constructed a complete framework for ranking and selecting the available alternatives. The importance of the supplier attributes varies across industries and geographical regions. No study was published regarding supplier selection using a market utility-based approach for the apparel industries of Bangladesh. Therefore, developing a supplier selection model based on discrete choice analysis targeted towards the apparel industries of Bangladesh is still an open problem and thereby yields the scope of the proposed thesis.

CHAPTER 3

THEORETICAL BACKGROUND

3.1 Discrete Choice Analysis

Discrete choice models have been largely used in various disciplines of social science such as marketing, psychology, economics, etc. to model consumer choice behaviors. Here, a decision maker is modeled to be selecting an alternative with the highest benefit or utility amongst the ones presented at that time. Discrete choice analysis solves the problem of modeling consumer behavior from a set of mutually exclusive and collectively exhaustive alternatives. This model contains utility functions consisting of independent variables and unknown parameters. The decision maker is presented with a set of alternatives and the values of those unknown parameters are estimated from the choices made by the decision maker. It is uncertain that a model will always be successful in predicting the choice pattern by an individual decision maker. Therefore, the concept of random utility is used, which was first utilized by Thurston in psychology [43]. McFadden [44] wrote a review of the existing applications of discrete choice model. The following section provides a brief overview of the general framework of discrete choice model. Multinomial logit (MNL) model will be discussed in detail as it is used in the formulation of the thesis work.

3.2 Assumption and Derivation of Multinomial Logit Model

The primary assumption of discrete choice model is that each individual chooses the option that results in maximum random utility. Here, the term “random utility” does not necessarily mean that each individual’s behavior needs to be stochastic. It is natural for each individual to be consistent in making choices.

In discrete choice model, it is also assumed that an individual has a utility u_i for an alternative i, which is a combination of a deterministic component v_i and a random component ε_i [45]. Although the deterministic component can be estimated from preference of individuals, the random component can be estimated as follows:

$$u_i = v_i + \varepsilon_i \tag{3.1}$$

Thus, the probability of choosing an alternative i from a set of J alternatives can be expressed by

$P_i = P(u_i \geq u_j, j = 1,........,J)$ or,

$$P_i = P(\varepsilon_j \leq v_i - v_j + \varepsilon_i, j = 1,........,J) \tag{3.2}$$

Let us assume that an individual chooses the first alternative. Then the choice probability can be expressed as

$$P_1 = P(\varepsilon_2 \leq v_1 - v_2 + \varepsilon_1, \varepsilon_3 \leq v_1 - v_3 + \varepsilon_1, ..., \varepsilon_J \leq v_1 - v_J + \varepsilon_1) \tag{3.3}$$

For any given outcome ε_1^* of ε_1 the first alternative will be chosen with the probability

$$P_1 = \int_{-\infty}^{v_1 - v_2 + \varepsilon_1^*} \cdots \int_{-\infty}^{v_1 - v_J + \varepsilon_1^*} f(\varepsilon_1^*, \varepsilon_2, ..., \varepsilon_J) d\varepsilon_J ... d\varepsilon_2 \tag{3.4}$$

where, the probability density function is denoted by f. For all other possible outcomes

$$P_1 = \int_{-\infty}^{\infty} \int_{-\infty}^{v_1 - v_2 + \varepsilon_1} \cdots \int_{-\infty}^{v_1 - v_J + \varepsilon_1} f(\varepsilon_1, \varepsilon_2, ..., \varepsilon_J) d\varepsilon_J ... d\varepsilon_1 \tag{3.5}$$

This derivation is true for all probabilistic choice models. The only difference in various other choice models lies in the assumption of underlying error distribution. Ideally one would assume the error term would follow multivariate normal distribution but then the choice probabilities could not be expressed in an analytical closed form. However, assuming the error distribution to follow Gumbel distribution enables the closed form of choice probabilities and also replicates normal distribution. When the random error terms in Equation (3.1) are assumed to be independent and identically distributed Gumbel distributions, then it results in MNL model.

The CDF and PDF of Gumbel distribution have the forms,

$F(\varepsilon) = e^{-e^{-\mu(\varepsilon - \eta)}}$, μ>0 (3.6) and

$$f(\varepsilon) = \mu e^{-\mu(\varepsilon-\eta)} e^{-e^{-\mu(\varepsilon-\eta)}} \tag{3.7}$$

respectively. Here, the location parameter is represented by η and the positive scale parameter by μ. The common probability density function can be represented as the product of univariate PDF when the error terms in MNL model are independent. It then can be expressed as:

$$P_1 = \int_{-\infty}^{\infty} \int_{-\infty}^{v_1-v_2+\varepsilon_1} \cdots \int_{-\infty}^{v_1-v_J+\varepsilon_1} f(\varepsilon_1) f(\varepsilon_2) \ldots f(\varepsilon_J) d\varepsilon_J \ldots d\varepsilon_1 \tag{3.8}$$

$$= \int_{-\infty}^{\infty} f(\varepsilon_1) \int_{-\infty}^{v_1-v_2+\varepsilon_1} f(\varepsilon_2) \ldots \int_{-\infty}^{v_1-v_J+\varepsilon_1} f(\varepsilon_J) d\varepsilon_J \ldots d\varepsilon_1$$

$$= \int_{-\infty}^{\infty} f(\varepsilon_1) \prod_{j=2}^{J} F(v_1 - v_j + \varepsilon_1) d\varepsilon_1$$

Assuming standard Gumbel (η = 0 and μ = 1) from Equation (3.3) and (3.4) we get,

$$P_1 = \int_{-\infty}^{\infty} e^{-\varepsilon_1} e^{-e^{-\varepsilon_1}} \prod_{j=2}^{J} e^{-e^{(-v_1+v_J-\varepsilon_1)}} d\varepsilon_1 \tag{3.9}$$

$$= \int_{-\infty}^{\infty} e^{-\varepsilon_1} e^{\left(-e^{-\varepsilon_1} \sum_{j=1}^{J} e^{(v_j-v_1)}\right)} d\varepsilon_1$$

Let us define a constant $a = \sum_{j=1}^{J} e^{(v_j-v_1)}$ and make the substitution $z = e^{-\varepsilon_1}$. As, $\varepsilon_1 = -\ln(z)$ and $\frac{d\varepsilon_1}{dz} = -\frac{1}{z}$ we get,

$$P_1 = \int_{\infty}^{0} -ze^{-az} \frac{1}{z} dz = \int_{0}^{\infty} e^{-az} dz = -\frac{1}{a}[e^{-az}]_0^{\infty} = 0 - (-\frac{1}{a}) = \frac{1}{a} \tag{3.10}$$

Finally, resetting the value of *a*, we obtain the MNL model formulation.

$$P_1 = \frac{1}{\sum_{j=1}^{J} e^{(v_j - v_1)}} = \frac{e^{v_1}}{\sum_{j=1}^{J} e^{v_j}} \tag{3.11}$$

In a more general scenario, for alternative i and a choice set n comprising J_n possible choice alternatives, we get the following formulation.

$$P_{in} = \frac{e^{v_{in}}}{\sum_{j=1}^{J_n} e^{v_{jn}}} \tag{3.12}$$

Here, P_{in} represents the probability that an individual selects an alternative and v_{in} represents utility of an alternative i from the nth choice set containing J_n possible choices, respectively. Generally, it is assumed that the deterministic component of a utility function can be expressed by a linear additive combination of the level of criteria and unknown parameters of an alternative. Thus, the additive utility function can be expressed as follows.

$$v_{in} = \sum_{k=1}^{K} \beta_k x_{ikn} \tag{3.13}$$

Here, the level of the criteria k of alternative i in the nth choice set is represented by x_{ikn}. The utility of a particular criteria k is represented by β_k. Although, there are a number of ways to estimate the β parameter, maximum likelihood estimation technique is used most. If the total number of respondents is M, the likelihood function is calculated as follows.

$$L(\beta) = \prod_{i=1}^{I} \prod_{m=1}^{M} \prod_{n=1}^{N} \left[P_{in}(\beta) \right]^{Y_{imn}} \tag{3.14}$$

Here, $Y_{imn} = 1$ if the respondent m selects alternative i in the nth choice set. $Y_{imn} = 0$ for all other cases. Instead of maximizing Equation (3.14) directly, it is easier to maximize the corresponding log-likelihood function. The log-likelihood function appears as follows.

$$LL(\beta) = \sum_{i=1}^{I} \sum_{m=1}^{M} \sum_{n=1}^{N} Y_{imn} . \ln\left[P_{in}(\beta) \right] \tag{3.15}$$

We solve for the β parameters by finding β values that yields the maximum value for log-likelihood function. We consider the responses Y and our given design X to be constant for a specific optimization problem. This problem is a multi-dimensional non-linear maximization problem which requires the help of numerical methods. Among a number of numerical methods, Nelder-Mead simplex algorithm is used the most by various researchers. The Nelder-Mead simplex algorithm is designed to solve the classical unconstrained optimization problem of minimizing a given nonlinear function. The method uses only function values at some points and does not try to form an approximate gradient at any of these points [49]. Hence, it belongs to the general class of direct search methods for optimization. The values of these β parameters are finally used to calculate utility score and relative importance rating of the supplier which will be discussed in the subsequent chapters.

Discrete choice analysis technique is used in this thesis to calculate the relative importance rating of the supplier attributes in an experimental setting. Previously, it had been used in various sectors of social science and economics. It creates a clear distinction from the techniques that utilizes verbal qualitative responses from the respondents. On the contrary, in DCA, responses are collected by replicating a real-world scenario. In DCA, a respondent is asked to select an alternative by judging into the criteria of different alternatives like he does while making a real-world purchase decision. It is assumed that, an individual selects an alternative that provides him the highest utility.

CHAPTER 4
METHODOLOGY

4.1 Introduction

The importance of selecting the right supplier in the context of apparel industry of Bangladesh is discussed previously. In this thesis, we are proposing a supplier selection approach based on Discrete Choice Analysis (DCA) due to its fair share of advantages over other methods that utilizes verbal responses of the supplier selection criteria. First, we will discuss the detailed methodology to rank the supplier alternatives using discrete choice analysis also known as choice based conjoint analysis. We will also collect the verbal responses regarding the qualitative importance of each of the criteria from the same respondents. Finally, we will make a comparison that will indicate whether the verbal qualitative responses of the respondents match with their actual choice pattern.

4.2 Framework of Supplier Selection Using DCA

Discrete choice analysis is an experimental procedure for supplier selection. The total framework of supplier selection is shown in Figure 4.1. The process starts with identification of supplier selection criteria or attributes. Then, we need to specify the level of each of those criteria. After that, the experimental design for DCA is formulated and the experimental profiles are sent to the respondents for collecting responses. Utility score is calculated by analyzing the response from the respondents using software. Relative importance of each of the supplier criteria or attributes is calculated from those utility score. Then, the existing supplier alternatives are ranked according to their overall utility scores. The alternative having the highest utility is considered to be the most attractive.

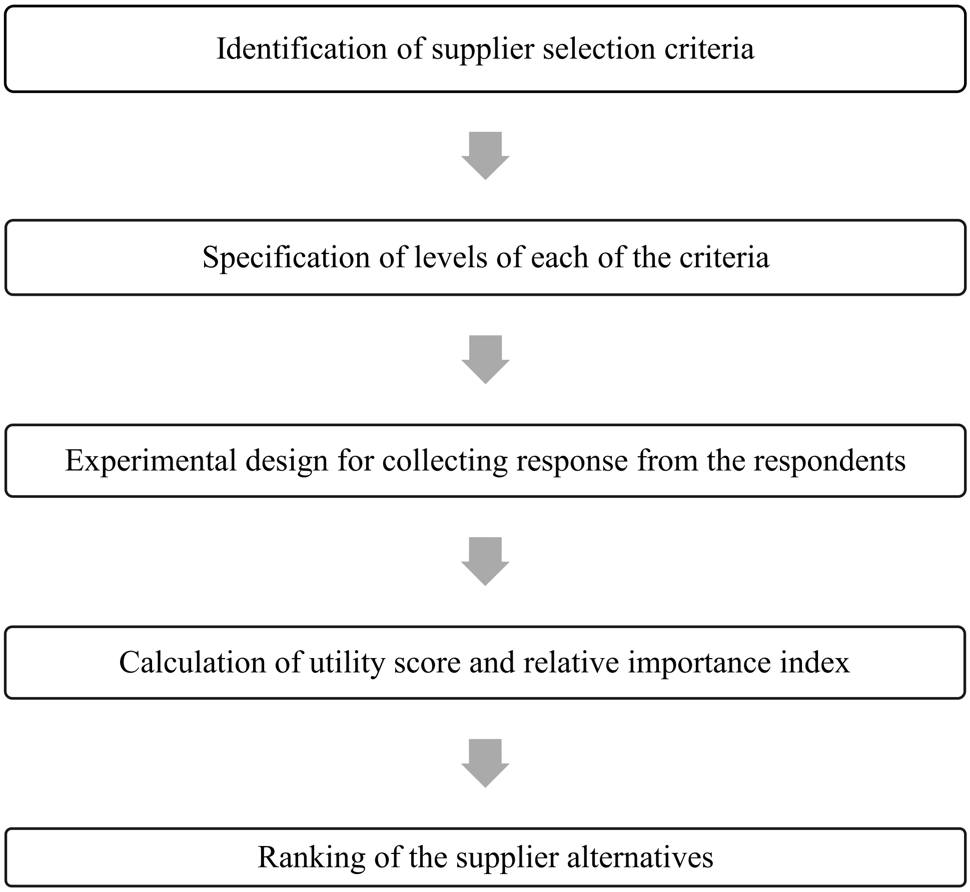

Figure 4.1: The flowchart of the proposed supplier selection method using DCA

4.2.1 Identification and Specification of Levels for Each of the Criteria

The manufacturers select a particular supplier or a group of suppliers based on certain features or attributes of their product. We are naming those attributes as criteria for the purpose of this thesis. First, it is required to identify the major criteria or aspects that play vital role in the selection procedure. These attributes and their relative importance may vary from industry to industry. Therefore, identification of the attributes must be done by taking insights from relevant experts in the field of study. An interview or market survey can be arranged to identify the determining criteria in the supplier selection process. Identification of the criteria is very much vital. As we are calculating relative weights of the attributes, the result of the study will be greatly misleading if we fail to identify any key attribute or criterion. Then, for the purpose of experimental design, which will be discussed in the latter section, we need to identify some levels for each of the criteria. We need to identify some probable performance levels for each of the attributes. For example, if cost is considered as one of the criteria, then high cost and low cost can be considered as two levels. As the numbers and levels of the criteria increase, we get a better understanding of the market scenario. However, higher number of levels and criteria will result complexity in data collection and calculation, which will be discussed later. Therefore, we need to make a trade-off here. Thus, to reduce complexity, we need to limit the study with only the major criteria and minimum number of levels of each criterion by taking suggestions from relevant experts in the field.

4.2.2 Experimental Design for Collecting Response from the Respondents

Once the identification of the determining attributes and their probable performance levels are identified, we can proceed with the experimental design. In DCA, it is required to create a set of hypothetical supplier alternatives. These hypothetical supplier alternatives are created by varying the performance levels of the previously identified criteria. The supply chain experts of the relevant industry, who are the respondents of this experiment, are then presented with those set of supplier alternatives. In a typical DCA experiment, each time the respondents are asked to make a judgmental decision for selecting the better alternative from a group of two or more alternatives. Thus, the decision of the respondent can be estimated to be dependent upon the level of the criteria which were used to build the supplier alternatives. Here, the levels of the criteria are considered as the independent variables and the choices of the respondents as dependent variables. However, several studies have suggested that the quality of the response degrades when they are asked to evaluate more than 30 supplier alternatives [46-47]. In order to limit the number of supplier alternatives, we can limit the levels and criteria as discussed in the previous section. If we design the experiment with five attribute each having two performance levels, there will be 32 different supplier alternatives with a full factorial approach. However, we can use fractional factorial design to build supplier alternatives as we are interested only in estimating the relative importance of each of the criteria. Fractional factorial has been used to design experiments by a number of researchers as it has the capability to identify all the main and two-way interactions [47-48]. The number of experimental supplier alternatives will reduce to 16 by selecting fractional factorial design. The levels of each criterion are identified as “Level: A” and “Level: B”. The supplier alternatives presented to each respondent contain equal number of “Level: A” and “Level: B”. These levels can represent either quantitative or qualitative values. Each of the two performance levels is assigned a numerical value of −1 or +1 depending on the performance of the level on that particular criterion. In general, −1 is assigned to the worse performance level and +1 is assigned to the better performance level. The profiles of 16 supplier alternatives that are presented to each of the respondents are shown in Table 4.1. Each of these 16 alternatives will be paired with an alternative having the other level of the criteria. The respondent will be asked to choose between an experimental profile and its opposite profile. Therefore, we conducted our study with five criteria and two levels where a respondent has to evaluate a total of 32 supplier alternative during this data collection process. Survey software were used during the design of experimental profile and collection of response for discrete choice analysis.

Table 4.1: Fraction factorial design of supplier alternatives

Supplier Alternative	**Criterion 1**	**Criterion 2**	**Criterion 3**	**Criterion 4**	**Criterion 5**
1	A	A	A	A	A
2	A	A	A	B	B
3	A	A	B	A	B
4	A	A	B	B	A
5	A	B	A	A	B
6	A	B	A	B	A
7	A	B	B	A	A
8	A	B	B	B	B
9	B	A	A	A	B
10	B	A	A	B	A
11	B	A	B	A	A
12	B	A	B	B	B
13	B	B	A	A	A
14	B	B	A	B	B
15	B	B	B	A	B
16	B	B	B	B	A

Table 4.1 shows the 16 supplier alternatives for experimental design. Each of the five attributes has two performance levels A and B. The experimental profiles, following fractional factorial design, are formulated by using different combinations of the performance levels. These profiles will be paired with their corresponding opposite pair and will be sent to the respondents for collecting response. For example, the third alternative has the performance levels A, A, B, A and B in each of the five criteria. It will be paired with its opposite design having the performance levels B, B, A, B and A. The respondent will decide by judging the different performance levels of two alternatives.

4.2.3 Calculation of Utility Score and Relative Importance (RI) Index

Manual collection of these large number of responses is highly complex and susceptible to errors. Therefore, survey software packages are used that send these experimental supplier alternatives to the respondents and collect their choice responses from them. After collecting their choice responses, the utility values or the β parameters can be calculated using Multinomial Logistic (MNL) regression. The background of MNL model is discussed in Chapter 3. Let us consider, we have *M* respondents, where an individual respondent is denoted by *m*. A respondent is given a total of *N* choice sets, where an individual choice set is denoted by *n*. Each choice set contains *J* number of alternatives to choose from, where a particular alternative is denoted by *j*. Each alternative has a total of *K* attributes or criteria, where an individual criterion is denoted by *k*. Also, each attribute has a total of *L* performance levels, where an individual performance level is denoted by *l*.

Now, the additive utility function of a particular alternative can be calculated as the sum of individual utility scores of the criteria level. The additive utility function can be expressed by Equation (3.13). In Equation (3.13), x_{ikn} represents the performance level of criteria *k* of alternative *i* in the *n*th choice set and the utility of a particular criteria *k* is represented by β_k .The numerical value of x_{ikn} depends on the performance level of the criteria.

In a choice set containing *J* number of alternatives, the probability that a respondent selects a particular alternative *i* in the choice set *n* can be represented by Equation

(3.12). There are a number of ways to calculate the β parameters, but maximum likelihood estimation technique is used the most. The likelihood function for a total of M respondents can be expressed by Equation (3.14).

In Equation (3.14), $Y_{imn} = 1$ if the respondent m selects alternative i in the nth choice set. $Y_{imn} = 0$ for all other cases. Here, we are optimizing Equation (3.14) to find the values of β parameters. Here, the responses Y_{imn} and the design variables x_{ikn} are kept constant for a particular optimization problem. We need to set an initial value β parameters for solving the problem. However, instead of maximizing Equation (3.14) directly, it is easier to maximize the corresponding log-likelihood function. The log-likelihood function is given in Equation (3.15).

The problem is a multi-dimensional non-linear optimization problem and requires the help of software to estimate the values of β parameters. We can calculate the utility scores by multiplying the performance levels with the values of the β parameters. Finally, the Relative Importance (RI) index of each criterion can be calculated by simply calculating percentages of the utility scores.

4.2.4 Ranking of the Supplier Alternatives

The final step in supplier selection process is ranking the supplier alternatives. Once the ranking is done, we can choose the desired supplier alternative. First, the market is studied to find suitable existing supplier alternatives. Then, these alternatives are assessed by taking recommendations from the experts. The experts assess their performance levels in each of the criteria. The experts assign a performance level corresponding to each criterion to the existing supplier alternatives by looking into the historical data of the company or by comparison with the other alternatives. For example, an expert will make an assessment whether a particular alternative is expensive or cheap by looking into historical cost figures or the cost figures of other alternatives. Finally, we can make the ranking of the supplier alternative in the order of total utility scores. The alternative with the highest total utility is the most preferred alternative. The total utility score is calculated as the sum of individual utility scores in each of those assessed performance levels.

4.3 Comparison of Perception of the Respondents with Their Actual Practice

In this study, we are also willing to make a comparison between the verbal qualitative responses and the responses obtained using experimental supplier alternative profiles. We need to investigate whether the responses collected using discrete choice analysis match with the ones obtained using the method that utilizes verbal qualitative method for collecting responses by collecting responses from the same respondents. We are estimating a relative importance rating of the supplier selection attributes using discrete choice analysis as a part of our study. This result will be compared with the relative importance ratings estimated using verbal responses. For collecting the verbal responses about perceived importance of the supplier selection attributes, a Likert scale is used as shown in Table 4.2. Here, the same respondents of DCA study are asked to give an importance rating of 1 to 5 to each of the five criteria discussed above. Importance rating 1 indicates least important and 5 indicates most important. The respondents are asked to make an independent assessment about the importance of the supplier selection attributes and the responses are collected. These responses are then analyzed to calculate a weighted average of attribute importance. Finally, we calculate the relative importance of the attributes by dividing individual weighted average of importance by the sum of all weighted averages.

Table 4.2: Likert scale to collect verbal response about perceived importance of the supplier alternatives.

Attributes	**Least Important**				**Most Important**
Criterion 1	1	2	3	4	5
Criterion 2	1	2	3	4	5
Criterion 3	1	2	3	4	5
Criterion 4	1	2	3	4	5
Criterion 5	1	2	3	4	5

The generalized methodology for supplier selection is explained in this chapter. This methodology is applied for supplier selection in apparel industry of Bangladesh as a case study. The case study is presented in Chapter 5.

CHAPTER 5
CASE STUDY

5.1 Introduction

Our work is focused on the supplier selection for the apparel industry of Bangladesh. Among a number of raw materials required to run an apparel industry, we are focusing our interest on the supplier of the major raw material such as fabric. Fabric is required in large quantity and accounts for the majority portion of raw material cost. The overall quality of the product is also largely dependent upon fabric quality. For the purpose of consistency in data collection, we only collected data from industries producing denim products. In our study, we collected data from 33 supply chain experts serving across 12 different industries. As per request from the respondents, we are maintaining anonymity of their identity.

5.2 Identification and Specification of Levels for Each of the Criteria

For the identification of the criteria prominent for supplier selection and determining their levels, we consulted with a number of supply chain experts. A number of factors for supplier evaluation were identified from relevant literature. All of these factors are listed in Appendix A. However, we needed to reduce the number of factors to five in order to limit the number of supplier alternatives to be evaluated by the respondents. Experts were asked to identify five key supplier attributes for the apparel industry of Bangladesh from the given list. Definition of some factors were changed to cover all the key aspects of supplier selection by taking recommendations from experts. While collecting responses from the respondents, the definitions of the five identified criteria were clearly mentioned.

(i) **Cost:** This includes the unit cost of the raw material as well as the transportation cost.

(ii) **Lead Time:** Time between ordering the product and receiving it in the factory.

(iii) **Company Status:** It indicates the financial strength and experience of the raw material supplier company.

(iv) **Quality:** Conforming to the specification given by the manufacturer.

(v) **Responsiveness:** Time taken to respond while communicated.

We also identified the relevant qualitative and quantitative performance levels of each of the criteria whatever seems suitable by taking recommendations from the supply chain experts. These performance levels are shown in Table 5.1. A design variable X_{lk} is also defined to represent lth performance level of kth criterion. A numerical value of −1 or +1 is also associated to the corresponding design variable according to its performance level. For example, in case of cost, "Around \$2/yard" being the cheaper option is more favorable and is assigned a numerical value of +1. The least favorable option, "Around \$5/yard" is assigned a numerical score of −1. The numerical values of all other criteria are assigned in a similar way.

Table 5.1: Performance levels of the supplier criteria

Supplier Criteria	**Level A**	**Design Variable (X_{lk})**	**Level B**	**Design Variable (X_{lk})**
Cost	Around $2/yard	+1	Around $5/yard	-1
Lead Time	About 30 days	+1	About 60 days	-1
Company Status	New/ Not so reputed	-1	Highly reputed	+1
Quality	Superior	+1	Satisfy minimum requirements	-1
Responsiveness	Highly responsive	+1	Sometimes late	-1

5.3 Experimental Design for Collecting Response from the Respondents

For collecting responses from 33 different supply chain experts we took help of a survey software named QuestionPro (QuestionPro Inc.). The 16 experimental supplier profiles were carefully formulated and paired with alternatives having opposite level of performance. Then, each respondent was asked to make a careful choice between the two alternatives. The 1st set of choice question is presented in Table 5.2. All sets of choice questions are given in the Appendix B. We used the software to design the experiment with the desired criteria and performance level. An online link was sent to the respondents and their choice pattern were stored automatically in the software. There is a provision in the software that allowed to filter the response so that only one response was collected per respondent.

Table 5.2: Choice set 1 used for collecting response

Choose the better raw material supplier profile from the options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $2/yard	Around $5/yard
Lead Time	About 30 days	About 60 days
Company Status	New/ Not so reputed	Highly reputed
Quality	Superior	Satisfy minimum requirements
Responsiveness	Highly responsive	Sometimes late
Verdict	○	○

Table 5.2 shows the 1st choice set as a sample which was presented to the respondents. The verdict of the respondents was collected using the software for further analysis.

5.4 Calculation of Utility Score and Relative Importance (RI) Index

Utility score of each attribute is calculated from the response obtained from the supply chain experts using QuestionPro software. Calculation of utility score involves solving multi-dimensional non-linear maximization problem using Nelder-Mead simplex algorithm as discussed in Chapter 3. Each respondent was provided with the same 16 choice sets. These sets contain two option of supplier alternatives. Each option contains 5 criteria and two levels which are listed in Appendix B. We can get an understanding of the MNL model by analyzing the response of an individual respondent. The responses of the 1st respondent are listed in Table 5.3.

Table 5.3: Response collected from the 1st respondent

Choice Set	Option 1	Option 2
1	1	0
2	1	0
3	1	0
4	1	0
5	0	1
6	1	0
7	1	0
8	0	1
9	0	1
10	0	1
11	1	0
12	0	1
13	0	1
14	0	1
15	0	1
16	0	1

Here, Option 1 in the 1st choice set is assigned a numerical value of 1 as the respondent preferred Option 1 over Option 2. The same procedure is followed for all other sets. From Table 5.3, it is observed that Option 1 was selected 7 times while Option 2 was selected 9 times by the 1st respondent.

As discussed earlier, a log-likelihood function needs to be optimized to estimate the values of β parameters. The function can be expressed as Equation (3.15) derived in Chapter 3.

In Equation (3.15), Y_{imn} represent the choice of the respondent and P_{in} represent the probability of choosing alternative i in choice set n. For 16 choice sets having 2 alternatives each and considering the response of only the 1st respondent Equation (3.15) takes the following form.

$$LL(\beta)_1 = \sum_{i=1}^{I} \sum_{n=1}^{N} Y_{i1n} . \ln\left[P_{in}(\beta) \right]$$

$$= \sum_{i=1}^{2} \sum_{n=1}^{16} Y_{i1n} . \ln\left[P_{in}(\beta) \right] \tag{5.1}$$

P_{in}, the probability of choosing alternative i in choice set n has the form given in Equation (3.12). In the first choice set which is given in Table 5.2, the respondent preferred Option 1 over Option 2. Therefore, P_{in} takes the following form.

$$P_{11} = \frac{e^{v_{11}}}{e^{v_{11}} + e^{v_{21}}} \tag{5.2}$$

We know, the additive utility function can be expressed as Equation (3.13) derived in Chapter 3.

In Equation (3.13), the utility of a particular criteria k is represented by β_k and the level of the criteria k of alternative i in the nth choice set is represented by x_{ikn}. The additive utility function of Option 1 in the 1st choice set takes the following form.

$$v_{11} = \sum_{k=1}^{5} \beta_k x_{1k1}$$

$$= \beta_1 x_{111} + \beta_2 x_{121} + \beta_3 x_{131} + \beta_4 x_{141} + \beta_5 x_{151}$$

$$= \beta_1 X_{11} + \beta_2 X_{12} + \beta_3 X_{13} + \beta_4 X_{14} + \beta_5 X_{15} \tag{5.3}$$

We replaced the variable x_{ikn} with design variable, X_{lk} to reduce the number of variables. They both represent a particular level of a criterion. Similarly, we can calculate the additive utility function of Option 2 in the 1st choice set.

$$v_{21} = \beta_1 X_{21} + \beta_2 X_{22} + \beta_3 X_{23} + \beta_4 X_{24} + \beta_5 X_{25} \tag{5.4}$$

Now, we put the values of the utility functions from Equation (5.3) and (5.4) in Equation (5.2). We get,

$$P_{11} = \frac{e^{\beta_1 X_{11} + \beta_2 X_{12} + \beta_3 X_{13} + \beta_4 X_{14} + \beta_5 X_{15}}}{e^{\beta_1 X_{11} + \beta_2 X_{12} + \beta_3 X_{13} + \beta_4 X_{14} + \beta_5 X_{15}} + e^{\beta_1 X_{21} + \beta_2 X_{22} + \beta_3 X_{23} + \beta_4 X_{24} + \beta_5 X_{25}}} \tag{5.5}$$

Now, from Table 5.3, considering all 16 responses from the 1st respondent only, the log-likelihood function from Equation (3.15) takes the following form.

$$LL(\beta)_1 = \sum_{i=1}^{2} \sum_{n=1}^{16} Y_{i1n}.\ln\left[P_{in}(\beta) \right]$$

$$\begin{aligned} &= \ln P_{11} + \ln P_{12} + \ln P_{13} + \ln P_{14} + \ln P_{25} + \ln P_{16} + \ln P_{17} + \ln P_{28} + \ln P_{29} \\ &+ \ln P_{210} + \ln P_{111} + \ln P_{212} + \ln P_{213} + \ln P_{213} + \ln P_{214} + \ln P_{215} + \ln P_{216} \end{aligned} \tag{5.6}$$

The R.H.S. of Equation (5.6) contains 16 terms corresponding to 16 preferred alternatives from the 1st respondent. Since $Y_{imn} = 0$ for an alternative which was not selected by the respondent, the other 16 terms were eliminated from the equation.

Finally, considering responses from all 33 respondents, the log-likelihood function would take the following form.

$$LL(\beta) = \sum_{i=1}^{2} \sum_{m=1}^{33} \sum_{n=1}^{16} Y_{imn} . \ln\left[P_{in}(\beta) \right]$$

$$= LL(\beta)_1 + LL(\beta)_2 + LL(\beta)_3 + LL(\beta)_4 + ... + LL(\beta)_{33} \qquad (5.7)$$

The responses were collected from all 33 respondents. Some samples of these responses are given in Appendix C. Equation (5.7) is non-linear and multi-dimensional. We need to optimize the equation with respect to β parameters, to estimate the required β parameters that maximize the equation. The process requires the help of standard solver. We used Nelder-Mead simplex algorithm in QuestionPro to estimate the values of β parameters. The values β parameters that maximize Equation (5.7) are listed in Table 5.4. We obtained five β values corresponding to five supplier selection attributes. We calculated the utility scores by multiplying these values with the corresponding performance levels. Here, a negative utility score signifies that the performance level puts a negative impact during selection of an alternative. Finally, the Relative Importance (RI) index of each criterion can be calculated by dividing the value of β parameter of a particular criteria by the sum of all β parameters. The values of the utility scores and relative importance ratings are also listed in Table 5.4. By analyzing the data, we found that cost has the highest importance while selecting a supplier attribute with an importance rating of around 29%. The relative importance of cost was followed by responsiveness (24%), lead time (18%), company status (15%) and finally quality (14%). The distribution of importance among these 5 criteria is displayed in Figure 5.1. We can observe from the figure that cost (29%) has almost the same importance as the company status (15%) and quality (14%) combined.

Table 5.4: Utility score and relative importance of the supplier criteria

Criterion	β_k	**Level**	X_{lk}	**Utility Score**	**Relative Importance**	**Ranking**
Cost	1.67	Around $2/yard	+1	1.67	28.86%	1
		Around $5/yard	-1	-1.67		
Lead Time	1.02	About 30 days	+1	1.02	17.61%	3
		About 60 days	-1	-1.02		
Company Status	0.86	New/ Not so reputed	-1	-0.86	14.88%	4
		Highly reputed	+1	0.86		
Quality	0.83	Superior	+1	0.83	14.31%	5
		Satisfy minimum requirements	-1	-0.83		
Responsiveness	1.41	Highly responsive	+1	1.41	24.35%	2
		Sometimes late	-1	-1.41		

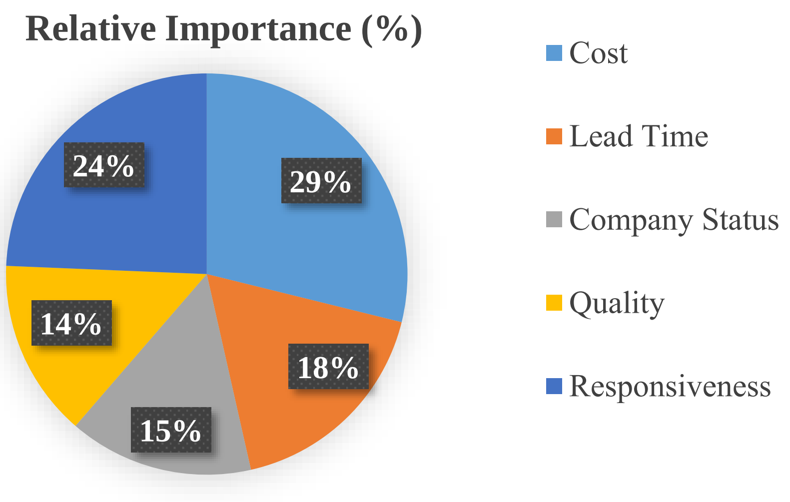

Figure 5.1: Relative importance rating of the supplier selection criteria using DCA

5.5 Ranking of the Supplier Alternatives

After the relative importance of the supplier attributes are estimated, we are only left with assessing the supplier alternatives. For this, we need to study the market for potential supplier alternatives and assess their performance levels in each of the criteria. This assessment is done by taking recommendations from experts. We identified three potential supplier alternatives by taking recommendations from experts. These alternatives are coded as “SA 1”, “SA 2” and “SA 3”. These alternatives are then shown to the experts for assessment. The experts were asked to assess the existing condition of the alternatives from the aspect of cost, lead time, company status, quality and responsiveness. The experts assigned one of the two previously mentioned performance levels for each criterion whichever they seem fit by analyzing the historical data of the supplier or by comparing with the data of other supplier alternatives. The assessment of the three supplier alternatives is given in Table 5.5.

Table 5.5: Assessment of supplier alternatives by experts

Criterion	SA 1	SA 2	SA 3
Cost	Around 2$/yard	Around 2$/yard	Around 5$/yard
Lead Time	About 60 days	About 30 days	About 30 days
Company Status	New/ Not so reputed	Highly Reputed	Highly Reputed
Quality	Superior	Satisfy minimum requirements	Superior
Responsiveness	Highly responsive	Highly responsive	Highly responsive

The ranking of the supplier alternatives is done by assessing their overall utility score. The total utility score is the sum of the utility scores corresponding to each level of the criteria. The supplier alternative with the highest total utility score is considered as the best supplier alternatives. The ranking of the supplier alternatives is displayed in Table 5.6.

Table 5.6: Ranking of the existing supplier alternatives

Supplier Alternative	**Criterion**	**Level**	**Utility Score**	**Total Utility Score**	**Ranking**
SA 1	Cost	Around 2$/yard	1.67	2.03	3
	Lead Time	About 60 days	-1.02		
	Company Status	New/ Not so reputed	-0.86		
	Quality	Superior	0.83		
	Responsiveness	Highly responsive	1.41		
SA 2	Cost	Around 2$/yard	1.67	4.13	1
	Lead Time	About 30 days	1.02		
	Company Status	Highly Reputed	0.86		
	Quality	Satisfy minimum requirements	-0.83		
	Responsiveness	Highly responsive	1.41		
SA 3	Cost	Around 5$/yard	-1.67	2.45	2
	Lead Time	About 30 days	1.02		
	Company Status	Highly Reputed	0.86		
	Quality	Superior	0.83		
	Responsiveness	Highly responsive	1.41		

It is observed from Table 5.6 that “SA 2” has the highest overall utility score of 4.13. The total utility score is calculated by taking sum of the utility scores in individual level of the criteria. “SA 2” is followed by “SA 3” with utility score 2.45 and “SA 1” with utility score 2.03. From the assumption that an individual will prefer an alternative with maximum utility, “SA 2” is the best alternative having the highest utility score. Therefore, whenever we need a product we will always look for “SA 2” first.

5.6 Comparison of Perception of the Respondents with Their Actual Practice

In this thesis, we were also interested in obtaining the verbal quantitative responses regarding the relative importance of the criteria from the same respondents of DCA experiment. We asked the respondents to rate the supplier selection attributes (cost, quality, lead time, company status and responsiveness) in a Likert scale of 1 to 5. Here, 1 indicates least significant and 5 to be the most significant. We wanted to check whether their verbal response matched with the importance rating obtained using DCA experiment. The verbal responses collected from the respondents are shown in the following figures. The summary of the responses and the relative importance of the attributes are listed in Table 5.7.

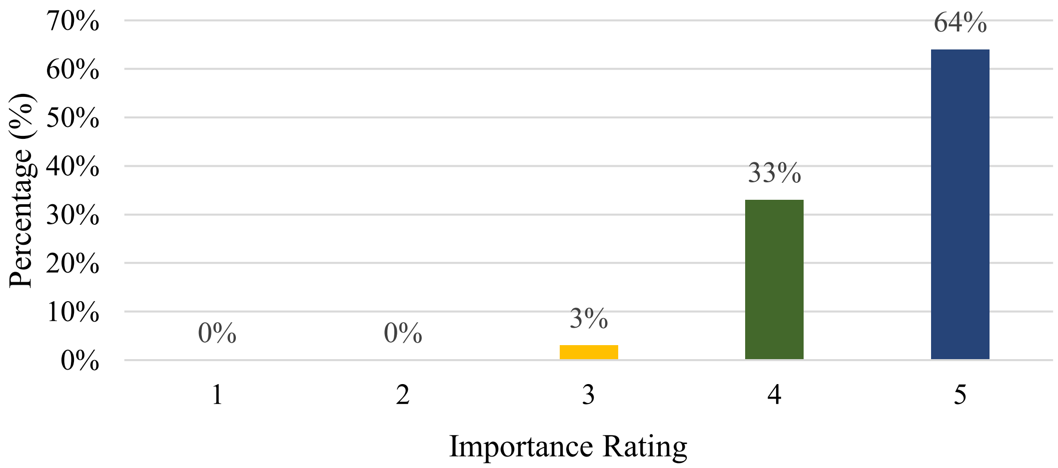

Figure 5.2: Verbal responses regarding importance of cost in a scale of 1 to 5

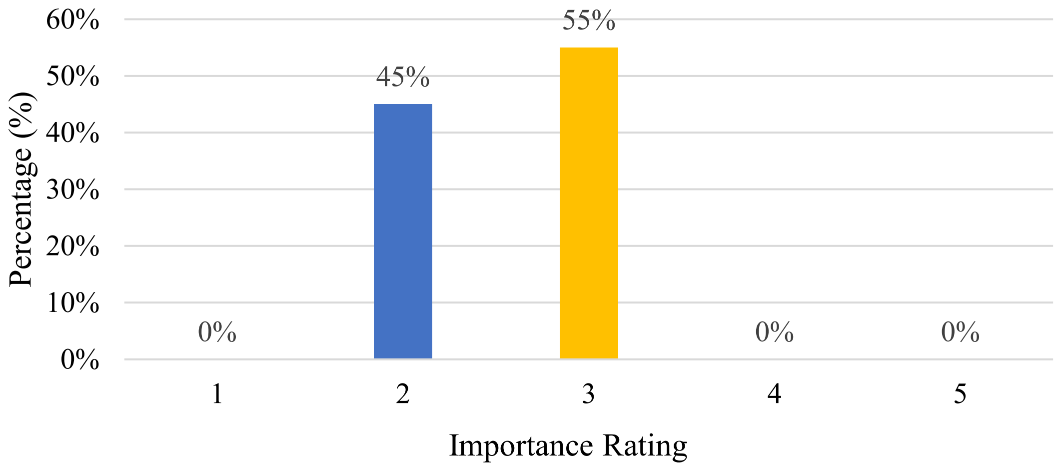

Figure 5.3: Verbal responses regarding importance of lead time in a scale of 1 to 5

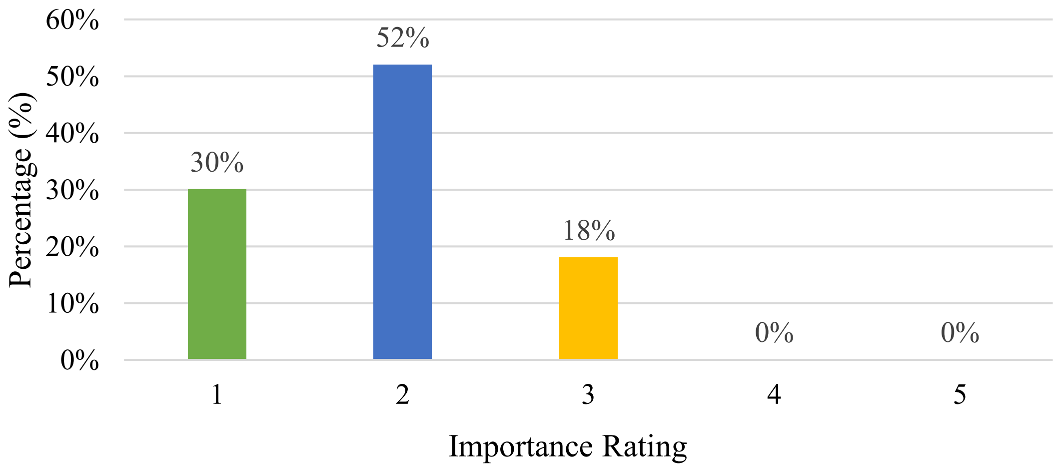

Figure 5.4: Verbal responses regarding importance of company status in a scale of 1 to 5

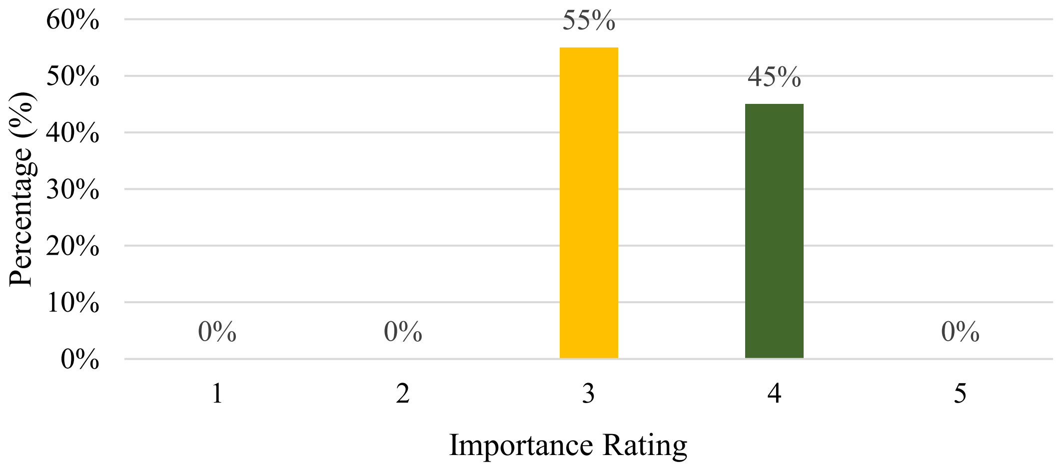

Figure 5.5: Verbal responses regarding importance of quality in a scale of 1 to 5

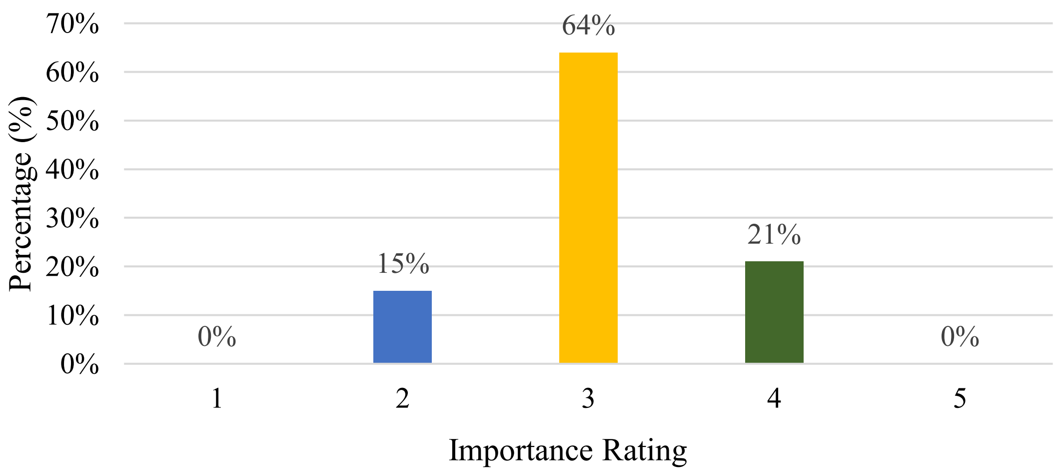

Figure 5.6: Verbal responses regarding importance of responsiveness in a scale of 1 to 5

Table 5.7: Summary of the response obtained from verbal qualitative response

Criterion	Weighted Average	Relative Importance (%)	Ranking
Cost	4.61	29.63	1
Lead Time	2.55	16.39	4
Company Status	1.88	12.08	5
Quality	3.46	22.24	2
Responsiveness	3.06	19.66	3

We calculated weighted average from the verbal responses regarding the importance of the supplier selection attributes obtained in Likert scale. At first, we multiplied the response in each category with the corresponding importance level. Then, we took the sum of those responses. Finally, we divided the sum with the total number of responses to obtain the weighted average. For example, 21 people perceived that cost has an importance of 5, 11 people perceived an importance of 4 and only 1 respondent perceived the importance to be 3. By multiplying the number of responses with corresponding importance rating we get a sum of 152. By dividing it with the number of respondents we get the required weighted average for cost (4.61). Weighted average of each criterion was divided by the sum of all the weighted averages to obtain the relative importance of each criterion. We observe by analyzing the verbal responses of the respondents that cost is the most important supplier attribute (30%) followed by quality (22%), responsiveness (20%), lead time (16%) and finally company status (12%). The comparison between relative importance of supplier attributes obtained using DCA and verbal qualitative response is displayed in Figure 5.7.

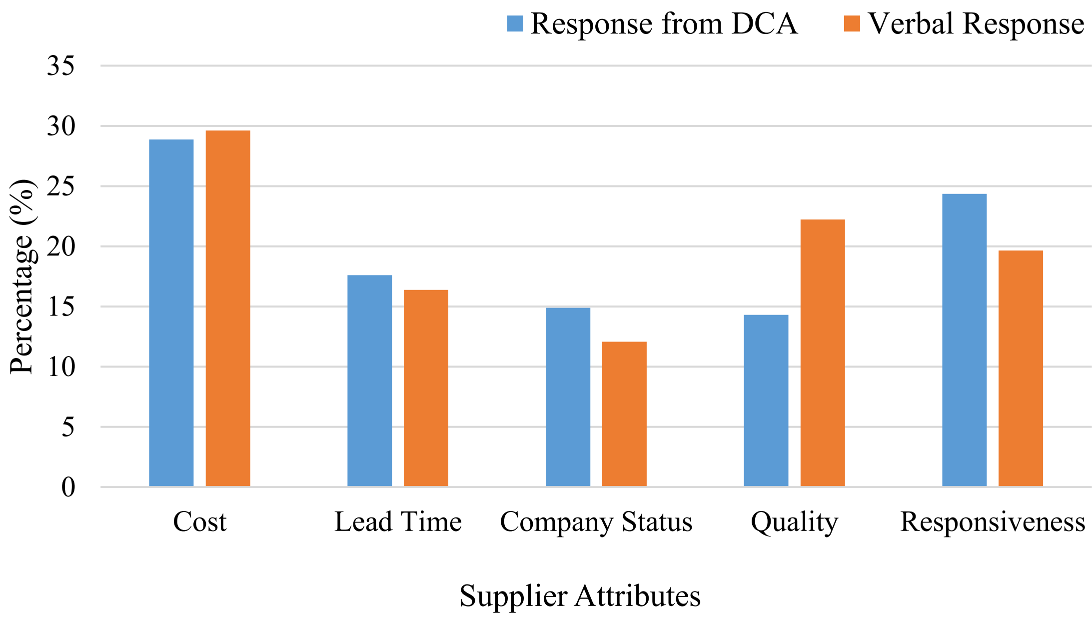

Figure 5.7: A comparison of relative importance of supplier attributes obtained using DCA and verbal qualitative response

The relative importance rating of the supplier attributes varies depending on the method of collecting data even if the data are collected from the same respondent. By analyzing Figure 5.7, we observe that the relative importance of cost, lead time and company status is almost same using two different methods. However, we can see a clear difference in the importance of quality and responsiveness between the two methods. Cost (29%) is identified as the most significant criterion and quality (14%) is identified as the least significant criterion from the responses collected using DCA. Although cost (30%) is identified as the most significant criterion, company status (12%) has the least significance according to the verbal responses collected from the respondents. According to the verbal response, quality (22%) has the second highest importance amongst the five criteria. Quality has about 8% more relative importance when the data is collected using verbal qualitative response than the response from DCA. One possible reason behind this might be the differences between operational strategy and actual practice in the organization.

CHAPTER 6
CONCLUSIONS AND FUTURE WORK

6.1 Conclusions

Understanding of the decision-making process and practices of a manufacturing organization is vital for any supplier. Without this understanding, it becomes very difficult for the suppliers to focus on particular aspects of the selection process. The objective of this study is to build a complete framework for supplier selection based on discrete choice analysis. The study was focused primarily to identify the key factors for supplier selection for the major raw material for apparel industry in Bangladesh. The study identified the key attributes to be cost, responsiveness, lead time, company status and quality, mentioned in the order of their decreasing importance. Finally, a method to assess and rank the existing supplier alternatives was proposed in this thesis. The study was also aimed at identifying the difference between actual practice and perception about the importance of the supplier selection attributes. The results obtained using DCA replicates the actual practice of the manufacturing organization. The perceived importance of a supplier attribute was collected using verbal qualitative responses from the same respondents. The respondents perceived quality to be the 2nd most important parameter with a relative importance rating of 22%. However, the same batch of respondents identified quality with an importance rating of 14% as the least important supplier selection attribute while giving response in an experimental setting. The respondents put more importance towards cost and responsiveness while selecting the alternatives, though they perceive quality to be one of the important parameters. The reason of this discrepancy might be the inconsistency in the operational practices with the strategic decisions of the organization. Therefore, effort should be given to identify possible gaps between the operational strategy and its actual implementation.

6.2 Future Work

We identified the key supplier selection attributes in our study. Our study was limited to five criteria each having two levels. However, designing the experiment with more levels and criteria would provide a better understanding of the market scenario. We used two level for Quality attribute, “Satisfy minimum requirements” and “Superior”. This might be one possible explanation for the lower importance of quality parameters in practice. The managers generally assess the alternatives that meet the minimum quality standards. Therefore, using more levels in future might clear the confusion. We also identified a gap between the operational strategies and its implementation. However, the results of our study are based on limited sample size, both considering the number of respondents and the industries. Therefore, further studies are required to validate it. We focused our study towards suppliers of major raw materials for apparel industry of Bangladesh. These results may vary across industries and geographical locations. Therefore, future studies involving different industries located across different geographical regions might provide a better understanding of the complex process of supplier selection.

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APPENDICES

Appendix A: List of All Factors for Supplier Evaluation

A number of factors were considered as evaluating criteria for supplier selection. These factors were sent to the experts for pre-evaluation. We asked the experts to select the vital five supplier criteria from the list containing all the factors, in order to limit the number of supplier alternatives to be evaluated by the respondents. The list of factors is given below:

(i) Raw Material Cost
(ii) Transportation Cost
(iii) Flexibility
(iv) Risk Factor
(v) Lead Time
(vi) Quality
(vii) Responsiveness
(viii) Geographical Location
(ix) Financial Strength of the Company
(x) Experience of the Company
(xi) Research and Development Facility
(xii) Technology

Appendix B: Survey Questionnaire Used to Collect Responses for DCA

A survey questionnaire was sent to the respondents for collecting response. The questionnaire used to collect responses for DCA contained a welcome instruction note and 16 set of choice questions.

Welcome Instruction Note:

Hello:

You are invited to participate in the survey aimed to address the problem of selecting raw materials supplier in the apparel industry of Bangladesh. For this survey we are focusing only on fabric as our primary raw material. In this survey, approximately fifty (50) experts from this field will be asked to complete a survey that asks questions about two questions. It will take approximately ten (10) minutes to complete the questionnaire.

First, you will be shown sixteen (16) set of supplier profiles, each containing two distinct set of varying supplier attributes/factors. Each time the respondent has to select one supplier profile whichever seem better to him.

Secondly, you will be asked to rate the importance of those supplier selection attributes/factors in a graphic scale of 1-5 stars, where 1 star signifies least importance and 5 stars being the most important.

Your participation in this study is completely voluntary. There are no foreseeable risks associated with this project. It is very important for us to learn your valuable opinions. Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential. If you have questions at any time about the survey or the procedures, you may contact me (Shourav Ahmed, Lecturer, Department of IPE, BUET) at 01882398825 or by email at (shourav2113@gmail.com).

Here is a brief description of the supplier selection attributes:

1. Cost: This includes the unit cost of the raw material as well as the transportation cost.
2. Lead Time: Time between ordering the product and receiving it in the factory.
3. Company Status: It indicates the financial strength and experience of the raw material supplier company.
4. Quality: Conforming to the specification.
5. Responsiveness: Time taken to response while communicated.

Choice Sets 1:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $2/yard	Around $5/yard
Lead Time	About 30 days	About 60 days
Company Status	New/ Not so reputed	Highly reputed
Quality	Superior	Satisfy minimum requirements
Responsiveness	Highly responsive	Sometimes late
Verdict	○	○

Choice Sets 2:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $2/yard	Around $5/yard
Lead Time	About 30 days	About 60 days
Company Status	New/ Not so reputed	Highly reputed
Quality	Satisfy minimum requirements	Superior
Responsiveness	Sometimes late	Highly responsive
Verdict	◯	◯

Choice Sets 3:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $2/yard	Around $5/yard
Lead Time	About 30 days	About 60 days
Company Status	Highly reputed	New/ Not so reputed
Quality	Superior	Satisfy minimum requirements
Responsiveness	Sometimes late	Highly responsive
Verdict	◯	◯

Choice Sets 4:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $2/yard	Around $5/yard
Lead Time	About 30 days	About 60 days
Company Status	Highly reputed	New/ Not so reputed
Quality	Satisfy minimum requirements	Superior
Responsiveness	Highly responsive	Sometimes late
Verdict	◯	◯

Choice Sets 5:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $2/yard	Around $5/yard
Lead Time	About 60 days	About 30 days
Company Status	New/ Not so reputed	Highly reputed
Quality	Superior	Satisfy minimum requirements
Responsiveness	Sometimes late	Highly responsive
Verdict	◯	◯

Choice Sets 6:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $2/yard	Around $5/yard
Lead Time	About 60 days	About 30 days
Company Status	New/ Not so reputed	Highly reputed
Quality	Satisfy minimum requirements	Superior
Responsiveness	Highly responsive	Sometimes late
Verdict	◯	◯

Choice Sets 7:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $2/yard	Around $5/yard
Lead Time	About 60 days	About 30 days
Company Status	Highly reputed	New/ Not so reputed
Quality	Superior	Satisfy minimum requirements
Responsiveness	Highly responsive	Sometimes late
Verdict	◯	◯

Choice Sets 8:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $2/yard	Around $5/yard
Lead Time	About 60 days	About 30 days
Company Status	Highly reputed	New/ Not so reputed
Quality	Satisfy minimum requirements	Superior
Responsiveness	Sometimes late	Highly responsive
Verdict	○	○

Choice Sets 9:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $5/yard	Around $2/yard
Lead Time	About 30 days	About 60 days
Company Status	New/ Not so reputed	Highly reputed
Quality	Superior	Satisfy minimum requirements
Responsiveness	Sometimes late	Highly responsive
Verdict	○	○

Choice Sets 10:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $5/yard	Around $2/yard
Lead Time	About 30 days	About 60 days
Company Status	New/ Not so reputed	Highly reputed
Quality	Satisfy minimum requirements	Superior
Responsiveness	Highly responsive	Sometimes late
Verdict	◯	◯

Choice Sets 11:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $5/yard	Around $2/yard
Lead Time	About 30 days	About 60 days
Company Status	Highly reputed	New/ Not so reputed
Quality	Superior	Satisfy minimum requirements
Responsiveness	Highly responsive	Sometimes late
Verdict	◯	◯

Choice Sets 12:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $5/yard	Around $2/yard
Lead Time	About 30 days	About 60 days
Company Status	Highly reputed	New/ Not so reputed
Quality	Satisfy minimum requirements	Superior
Responsiveness	Sometimes late	Highly responsive
Verdict	◯	◯

Choice Sets 13:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $5/yard	Around $2/yard
Lead Time	About 60 days	About 30 days
Company Status	New/ Not so reputed	Highly reputed
Quality	Superior	Satisfy minimum requirements
Responsiveness	Highly responsive	Sometimes late
Verdict	◯	◯

Choice Sets 14:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $5/yard	Around $2/yard
Lead Time	About 60 days	About 30 days
Company Status	New/ Not so reputed	Highly reputed
Quality	Satisfy minimum requirements	Superior
Responsiveness	Sometimes late	Highly responsive
Verdict	◯	◯

Choice Sets 15:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $5/yard	Around $2/yard
Lead Time	About 60 days	About 30 days
Company Status	Highly reputed	New/ Not so reputed
Quality	Superior	Satisfy minimum requirements
Responsiveness	Sometimes late	Highly responsive
Verdict	◯	◯

Choice Sets 16:

Choose the better raw material supplier profile from the two options given below:		
Criteria	**Option 1**	**Option 2**
Cost	Around $5/yard	Around $2/yard
Lead Time	About 60 days	About 30 days
Company Status	Highly reputed	New/ Not so reputed
Quality	Satisfy minimum requirements	Superior
Responsiveness	Highly responsive	Sometimes late
Verdict	◯	◯

Appendix C: Sample of Collected Choice Responses for DCA

Choice responses were collected from 33 supply chain experts from 12 different company. Each respondent was asked to choose one of the two alternatives from 16 sets of choice questions. Some of their responses are listed below.

Responses of 1st Respondent:

Response ID	Designation	Experience (Years)	Choice Set	Alternative	Selected
36212557	Manager, IE	7	1	Option 1	1
				Option 2	0
			2	Option 1	1
				Option 2	0
			3	Option 1	1
				Option 2	0
			4	Option 1	1
				Option 2	0
			5	Option 1	0
				Option 2	1
			6	Option 1	1
				Option 2	0
			7	Option 1	1
				Option 2	0
			8	Option 1	0
				Option 2	1
			9	Option 1	0
				Option 2	1
			10	Option 1	0
				Option 2	1
			11	Option 1	1
				Option 2	0
			12	Option 1	0
				Option 2	1
			13	Option 1	0
				Option 2	1
			14	Option 1	0
				Option 2	1
			15	Option 1	0
				Option 2	1
			16	Option 1	0
				Option 2	1

Responses of 2nd Respondent:

Response ID	Designation	Experience (Years)	Choice Set	Alternative	Selected
36212896	Deputy Manager, IE	3	1	Option 1	1
				Option 2	0
			2	Option 1	0
				Option 2	1
			3	Option 1	1
				Option 2	0
			4	Option 1	1
				Option 2	0
			5	Option 1	0
				Option 2	1
			6	Option 1	1
				Option 2	0
			7	Option 1	1
				Option 2	0
			8	Option 1	0
				Option 2	1
			9	Option 1	0
				Option 2	1
			10	Option 1	1
				Option 2	0
			11	Option 1	1
				Option 2	0
			12	Option 1	0
				Option 2	1
			13	Option 1	0
				Option 2	1
			14	Option 1	0
				Option 2	1
			15	Option 1	0
				Option 2	1
			16	Option 1	0
				Option 2	1

Responses of 3rd Respondent:

Response ID	Designation	Experience (Years)	Choice Set	Alternative	Selected
36225824	Deputy General Manager	9	1	Option 1	1
				Option 2	0
			2	Option 1	0
				Option 2	1
			3	Option 1	1
				Option 2	0
			4	Option 1	1
				Option 2	0
			5	Option 1	0
				Option 2	1
			6	Option 1	0
				Option 2	1
			7	Option 1	1
				Option 2	0
			8	Option 1	0
				Option 2	1
			9	Option 1	0
				Option 2	1
			10	Option 1	1
				Option 2	0
			11	Option 1	1
				Option 2	0
			12	Option 1	0
				Option 2	1
			13	Option 1	0
				Option 2	1
			14	Option 1	0
				Option 2	1
			15	Option 1	0
				Option 2	1
			16	Option 1	1
				Option 2	0