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DECISION-MAKER'S PREFERENCES MODELLING THROUGH PROMETHEE METHOD FOR SUPPLIER SELECTION

BY

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ABSTRACT

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Title: Decision-Maker's Preferences Modelling through PROMETHEE Method for Supplier Selection

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Multi-Criteria Decision Aid (MCDA) approach is widely applied in different decision-making contexts including supply chain management and supplier selection. PROMETHEE is one of the most popular MCDA method that allows the Decision-Maker integrating explicitly his/her preference to choose the alternative of the best compromise. In this paper we are applying this method to select the best supplier where several incommensurable and conflicting criteria are simultaneously taken into consideration. The decision-making context is related to an Information Technology department within a management company in Doha, Qatar. We will illustrate how the Decision-Maker's preferences were integrated in the model for selecting the supplier of the best comprises and how the Decision-Maker was evolving towards the best recommendation.

Keywords: MCDM, PROMETHEE, Preferences Modeling, Supplier Selection, Supply Chain Management, Compromises.

DEDICATION

I dedicate this work to my father Mr. Izeddin Samha, my family, my supervisor Professor Belaid Aouni and everyone who helped and participated in this research.

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INTRODUCTION

Supplier selection process is one of the most important multi-criteria decision making problems, the importance of supplier selection process has increased significantly especially with the growing projects, needs and purchases of the organizations in various fields. The supplier selection problem is based on a multi-criteria and several alternatives, and this has increased the complexity of this process.

This paper introduces the supplier selection problem, giving a general view of the multi-criteria decision making, its early roots and development through decades and describe its models; value measurement models, Goal, aspiration and reference level models and lastly the outranking models which is the model used in this paper.

It is somewhat surprising that the frequently used techniques by the organizations in the evaluations for selecting suppliers have ignored the real and actual preferences of the decision maker for each criterion, as in the techniques which focused on the value that is based on a numerical score, and only considered the importance of the criteria. It is worth mentioning that no paper talking about the method adopted in this paper was found in Qatar in any field. Hence, this paper intends to tackle the multi-criteria decision problem of supplier selection for the first time in Qatar by using a multi-criteria aiding and supporting tool, that is called PROMETHEE II, this method is one of the most popular outranking methods, the paper aims to consider the preferences of the decision maker which is a critical part throughout the evaluation, and not depending on the value measurement models only represented using weights. Unlike other techniques,

PROMETHEE II is a standalone aiding tool that takes into consideration the preferences of the decision maker and provides a precise appraisal of the criteria and not having some arbitrary ones. This study will help and support any department or decision maker who is responsible of doing the technical and commercial proposals evaluations and all organizations that are seeking the efficiency and effectiveness throughout achieving its goals.

CHAPTER 1: LITERATURE REVIEW

Supplier Selection

General View

Supply Chain is a network of connected facilities and processes that starts from raw materials until the delivery of the finished products (Lambert et al., 2000), it may include warehouses, retailers or even transports and customers in addition to the suppliers and manufacturers, and it is essential part in the completion of customer requests either directly or indirectly (Chopra & Meindl, 2001).

Supply Chain Management (SCM) drew the attention of many scholars and researchers especially in the last ten years, it is considered one of the fast growing areas of management (Benyoucef et al., 2003). The term "Supply Chain Management (SCM)" was originally formulated by consultant Oliver and Weber in 1982, it connects different organizational units and integrate them throughout management activities that insure satisfying the customers' requests from production stage until the delivery of the final product with minimal costs for these organizational units (Chandra & Fisher, 1994) (Stadtler & Kilger,2005).

One of the important and critical issues that plays a key role in SCM is the supplier selection, it is considered one of the most significant product and services management processes for many corporates and enterprises within the supply chain (Nazeri et al., 2011), it is also considered as the most capital decision (Mobolurin, 1995) (Nydick & Hill, 1992). According to Thompson, 1990, it is one of the decisions which

determine the long-term viability of the corporate (Thompson, 1990). The good the company is efficient in choosing its suppliers (vendors) the better it can achieve the goals and objectives of its applied chain management; by having a faster delivery, lower production costs, higher quality and other objectives (Kumar et al., 2006) (Choi & Hartley, 1996), and assure constituting and continuing the supply chain (Chen et al., 2005).

Supplier selection includes both quantitative and qualitative factors to choose suppliers with the highest potential to achieve the organizations' objectives and it is one of the most important decision making problems (Safari et al., 2012).

Supplier Selection and MCDM

Supplier selection and evaluation process is among the most familiar Multi Criteria Decision Making (MCDM) problems (Timmerman, 1986), that is, final choice is often multi-objective , it includes many objectives (Criteria) to be considered, some of it are tangible and some are intangible (Thompson, 1990), these objectives are often conflicting objectives, hence, MCDM methods aim to support the decision makers to reach the best compromise solution (Zeleny, 1982), and provides and effective framework when suppliers are compared based on the evaluation of multiple conflict criteria (Hwang & Yoon, 1981).

Due to the importance of supplier evaluation and selection process, extensive research is being done to cope with MCDM problem, there was a great focus in recent years by researchers and who is interested in this topic to study the mathematical

methodologies that may help to answer the problem's complexity and make it easier for decision makers to make the best decisions, a total of sixty-eight articles from 2000 to 2011 were reviewed by Agrawal et al. (2011) to find the most important, clear and prominent MCDM methodologies for supplier evaluation and selection, such as Data Envelopment Analysis (DEA), Mathematical Programming Models, Analytic Network Process (ANP) and outranking methods such as ELECTRE and PROMETHEE (Agarwal et al., 2011).

Supplier Selection Criteria

A total of twenty-three criteria for supplier selection were identified and proposed by Dickson in 1996, his study showed that it is difficult to find a perfect supplier; as there are several criteria involved such as, price, quality, delivery and others. However, it is not all always included in the final decision making as each organization has its own strategy in the supply chain (Dickson, 1966).

Among plentiful methods of Multi-Criteria Decision Making (MCDM), outranking methods category is used in this paper to solve the supplier selection problem, this category wins the reputation of being a rapid progress due to its flexibility and applicability to the most real decision situations. PROMETHEE (Preference Ranking Organization METHods for Enrichment Evaluations) is the most popular and widely applied outranking method for pair wise comparison of the alternatives for each criterion.

Multi-Criteria Decision Making (MCDM)

General View

Multiple criteria decision-making (MCDM) is a valuable tool in complex decision making that helps in taking decision in issues that include both quantitative and qualitative factors (Mardani et al., 2015), it has grown as part of operations research and it is concerned with designing a computational and mathematical tools for decision makers to help them having a subjective evaluation for their preference criteria (Zavadskas, 2014), and it is most applicable in solving problems in the areas which include several alternatives, where it assists in focusing more on the logical, important and easy to use alternatives (Price & Austin, 2016).

MCDM works by dividing the decision into smaller understandable parts, then takes each part and analyze it individually and eventually gather the parts together to produce a useful and meaningful solution (Natural Resources Leadership Institute, 2013)

Early Roots and Development

Decision making (DM) was known from the earlier times and inspired reflections of many thinkers. In the beginnings and for many years, Decision Making (DM) was done by defining only a single point of view, then give it a preference and an action if to minimize or maximize, however, this way can be described as reductive and unnatural in a world with many criteria to consider.

The first known recorded work in MCDM goes back to Benjamin Franklin (1706-1790), who wrote a letter to his friend Joseph Priestly describing his own way of making

decisions for important issues; he mentioned that he used to use a simple sheet of paper called " Moral Algebra", in one side of this paper he was writing the arguments that are in favor of a certain decision and on the other side he was writing the arguments against it, and then he was crossing out those arguments which had a relatively equal importance, he gave the arguments which were not crossed out more attention and support. Benjamin Franklin also mentioned about giving a weight to each argument, in other words, the arguments are the point of views or what is called "Criteria", what Benjamin Franklin was doing is what we call now the MCDM ("Multiple Criteria Decision Analysis", 2017).

Development in MCDM field continued over years, the economist Vilfredo Pareto (1848–1923) has introduced the efficiency concept, which was a key reference for economies, the modern MCDM and other fields. Many theories contributed in MCDM followed, such as Social Choice Theory, Game Theory, Set Theory, Number Theory Utility Theory, Theory of Value and others (Figueira et al., 2016).

Methods and Techniques

The interest in the application of MCDM tools has increased in the last decades due to the importance in solving complex decision problems and the higher availability of data (Huang et al., 2011). Despite that MCDM has several methods, techniques and approaches, it includes three basic elements; A set of alternatives (Actions, courses of actions, solutions), two criteria at least and one or more decision makers (Figueira et al.,

2016). Existing MCDM methods can be classified into the following three categories (Belton & Stewart, 2002):

1- Value Measurement Models:

In this model a numerical score (overall value) is constructed for each alternative (Action) and each criterion is given a weight which represents its importance. Some methods such as Analytic Hierarchy Process (AHP), Weighted Sum Method and Programme Budgeting and Marginal Analysis (PBMA) can be classified in this model category.

2-Goal, Aspiration and Reference Level Models:

In this model, methods work by measuring how good alternatives achieve and reach the determined goals and aspirations such as, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS).

3-Outranking Models:

Methods in this models use pairwise comparison for each criterion to compare between alternatives by giving the strength of one over the other, example of these methods are: ELimination and Choice Expressing Reality (ELECTRE) and Preference Ranking Organization METHods for Enrichment Evaluations (PROMETHEE).

Outranking Methods – PROMETHEE

History and Development

Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE) is one of the most popular MCDM methods and a family of outranking

methods, the first two versions; PROMETHEE I (Partial ranking) & PROMETHEE II (Complete ranking) were developed by J.P Brans and presented for the first time in a conference organized by M. Landry and R. Nadeau at the Université Laval, Québec, Canada in 1982 (Brans, 1982).

Few years later, new versions of PROMETHEE methods occurred, such as PROMETHEE III for interval based rankings, followed by PROMETHEE IV used when a set of feasible alternatives is continuous and it works for both partial or complete rankings, then PROMETHEE V method which is used to solve problems with segmentation constraints (Brans & Mareschal, 1992), The PROMETHEE VI method was developed later for the human brain representation (Macharis et al., 1998), followed by the development of PROMETHEE Group Decision Support System (GDSS) for group decision making (Silva et al., 2010).

One of the advantages of the earlier mentioned PROMETHEE methods (I, II, III, IV, V and GDSS) is that when the action or alternative is evaluated, it leads to a more reliable understanding of perception differences among decision makers as each criterion is assessed by the preference function (Mareschal & Brans, 1988).

After PROMETHEE GDSS, a new method called Geometrical Analysis for Interactive Aid (GAIA) were developed for the graphical representation purposes (Brans & Mareschal, 1994) (Figueira et al., 2016), and to help in complicated decision making situations (Brans & Mareschal, 2005).

Fields and Applications

Many contributions and applications using PROMETHEE method were clear from the journals and papers published in many field such as; Business and Financial Management in stock trading (Albadvi et al., 2007), and selecting optimal portfolio (Marasovic & Babic, 2011) (Vetschera & Almeida, 2012), Energy Management (Chafghazi, 2010) (Madlener et al., 2007), Environment Management (Hermans et al., 2007) (Llic et al., 2011) (Nikolic et al., 2009) (Vego et al., 2008) (Yan et al., 2007), Statistical Distribution Selection (Ishizaka & Nemery, 2011), Water Management Strategies Assessment (Simon et al., 2006), Chemistry (Zhag et al., 2006), Selection of Suppliers (Araz & Ozkarohan, 2007) (Dulmin & Mininno, 2003) and many other fields.

CHAPTER 2: RESEARCH METHODLOGY

Supplier selection problem is one of the complex multi-criteria decision making problems, as it involves many elements, such as criteria, weights, and many other sensitive corners that need to be touched while evaluating and selecting the right and most suitable supplier for the organization, in order to solve this problem while taking into considerations the preferences of the decision maker which are ignored in other methods, the outranking method "PROMETHEE" is utilized in this paper. Hence, this chapter explains and illustrates how this methodology is used to avoid similar problems in supplier selection process by describing the method, why it was selected, the data that are required to apply the method, how it was collected, the exact mathematical process and ending the chapter with giving a general numerical example to understand the method and the way of applying it.

PROMETHEE Method

PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluation) is considered a standalone aiding and support method that enriches the evaluation by taking care of the decision maker's preferences, this method was developed by Brans et al. (Brans & Vincke,1985) (Brans et al., 1986). PROMETHEE is a simple ranking method in conceptions and application compared to other ranking methods, where other methods may be generally considered suitable for multi-criteria decision making problems that do not include several criteria and many alternatives.

One of the advantages of PROMETHEE is that it is not requiring normalization of the values of the evaluation matrix, and it allows to allocate a different preference model criterion to each criterion by choosing one of six preference functions or called generalized criteria fixed by the decision maker based on a logical consideration. Other advantages of PROMETHEE method were listed by (Ulengin et al., 2001) as follows:

1- PROMETHEE methods is an easy and user friendly outranking method
2- It is successfully applied to the planning problems in real life.
3- PROMETHEE I & II are considered simple and allow to rank the alternatives in both partially and complete rankings

PROMETHEE II is the exact method used in this paper, it is the developed version of PROMETHEE I, and the reason of choosing the second version is that it gives a full ranking unlike the first version which gives only partial ranking.

Mathematical Methodology of PROMETHEE

PROMETHEE methods starts from the evaluation part which involve numerical data, the alternatives (actions) are evaluated with respect to different criteria, it assumes that the decision makers have the capability to evaluate the weights properly. (Macharis et al., 2004), also stated that in addition to available criteria and available set of finite alternatives (actions), there are two additional important types of information required for the PROMETHEE implementation, which are as follows (Macharis et al., 2004):

1- A weight (w) for the criteria showing the relative importance of each.

2- Information on the preference function of the decision makers which is used when the contribution of the alternatives is compared based on each criterion.

Criteria and Weights

Weights and criteria are two of most important and basic components of any evaluation of a multi-criteria decision making problem. The required data of criteria and the weights were collected directly from the decision maker, PROMETHEE method assumes that the decision maker is capable and have a logical methods and techniques based on their own field experience to identify and set any related criteria. Criteria is considered as one of the most important information given by the decision maker along with the weights. The weight expresses the importance of the criteria relative to the main goal of the evaluation and in this case the supplier selection.

Preference Function

PROMETHEE method works by comparing each pair of alternatives mutually with respect to each selected criterion. In order to rank alternatives using PROMETHEE method, it is essential to define a preference function P*j* (*a*,*b*) after defining the criteria fj to give a degree of preference for alternative *a* over alternative *b*.

In most cases, the preference function will often be the function of the deviation or difference between two alternatives Pj (*a*,*b*) = P(d) where d= fj (*a*) - fj (*b*), the preference function takes values on the scale from 0 to 1 represented by the following relations:

- P(*a*,*b*)=0 , if d≤0 , no preference of *a* over *b* or indifference between a and b;
- P(*a*,*b*)≈0 , if d>0 , weak preference of *a* over *b*;
- P(*a*,*b*)≈1 , if d>>0 , strong preference of *a* over *b*;
- P(*a*,*b*)=1 , if d>>>0 , strict preference of *a* over *b*.

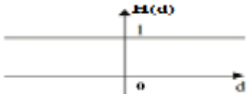
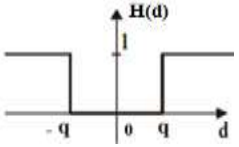
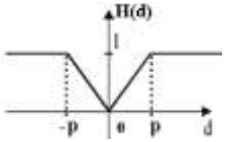
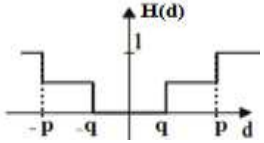
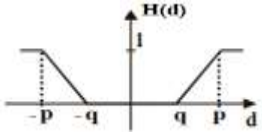
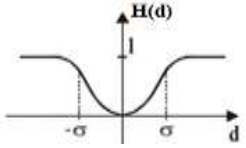
And in order to take into account the extent of the deviations between the alternatives, the notion of "Generalized Criteria" is introduced in this paper.

Generalized Criteria and Relevant Parameters

We consider a generalized criterion for each criterion f_j. This section will describe six types of generalized criteria that are sufficient and applicable in most cases, these six criteria are different in their degree of complexity and involvement of parameters, where these parameters are defined by decision maker. Four of these generalized criteria are using one or two of the following parameters which are decided by the decision maker:

- A preference threshold (**p)**: the lowest value of *d* above which there is strict preference.
- An indifference threshold (**q)**: the greatest value of *d* below which there is indifference.
- **(σ)** Threshold: is an approximate value between p & q and can be decided easily through the experience of Normal distribution in statistics. Figure (2.1) shows the six types of the generalized criteria along with their analytical definition and the shape (Brans & J.P., 1982):

Table 2.1 Types of Generalized Criteria

			Parameters
I. Usual criterion		$H(d) = \begin{cases} 0 & if\ d = 0, \\ 1 & if\ d \neq 0. \end{cases}$	-
II. Quasi-criterion		$H(d) = \begin{cases} 0 & if -q \leq d \leq q, \\ 1 & if\ d < -q\ or\ d > q. \end{cases}$	q
III. Criterion with linear preference		$H(d) = \begin{cases} d/p & if -p \leq d \leq p, \\ 1 & if\ d < -p\ or\ d > p. \end{cases}$	p
IV. Level criterion		$H(d) = \begin{cases} 0 & if\ \lvert d\rvert \leq q, \\ 1/2 & if\ q < \lvert d\rvert \leq p, \\ 1 & if\ p < \lvert d\rvert. \end{cases}$	q,p
V. Criterion with linear preference and indifference area		$H(d) = \begin{cases} 0 & if\ \lvert d\rvert \leq q, \\ (\lvert d\rvert - q)/(p-q) & if\ q < \lvert d\rvert \leq p, \\ 1 & if\ p < \lvert d\rvert. \end{cases}$	q,p
VI. Gaussian criterion		$H(d) = 1 - e^{\left(-\frac{d^2}{2\sigma^2}\right)}$	σ

Multi-Criteria Preference Index

Assuming that decision maker has set the criteria, weights for each criterion and determined the preference function value using the suitable type of generalized criteria, a multi-criteria preference index $\prod$ is then defined as the weighted moving average of the preference function $P_j\,(a,b)$ representing the intensity of preference of the decision maker of alternative *a* over alternative *b* simultaneously considering all the criteria, the relation is represented by the following:

$$\prod(a,b) = \frac{\sum_{i=1}^{k} w_i\, p_i\,(a,b)}{\sum_{i=1}^{k} w_i} \tag{2.1}$$

Where w_i is the weight for each criterion f_1 (i=1,…,k) and $\prod(a,b)$ takes value on scale between 0 -1 where:

- $\prod(a,b) \approx 0$ → Indicates a weak preference of alternative *a* over alternative *b* for all criteria.
- $\prod(a,b) \approx 1$ → Indicates a strong preference of alternative *a* over alternative *b* for all criteria.

This index is then calculated for each pair of the stated alternatives for all criteria.

Positive, Negative and Net Flows

In order to express how much alternative outranks all other n-1 alternatives respectively, an aggregation of the preference indices into positive flow $\phi^{+}(a)$ and negative flow $\phi^{-}(a)$ is required. Positive flow which is also called leaving flow is the measure of *outranking character* of *a* and defined by:

$$\phi^{+}(a) = \sum_{b \in K} \prod(\mathrm{a}, \mathrm{b}) \tag{2.2}$$

Negative flow which is also called entering flow is the measure of *outranked character* of *a* and defined by:

$$\phi^{-}(a) = \sum_{b \in K} \prod(\mathrm{b}, \mathrm{a}) \tag{2.3}$$

And the net flow which is represented with the following relation:

$$\phi(a) = \phi^{+}(a) - \phi^{-}(a) \tag{2.4}$$

In PROMETHEE method, the higher the positive flow and the lower the negative flow, the better the alternative is, the positive and negative flows induce, respectively the following preorders:

$$\begin{cases} aP^{+}b, & iff\ \phi^{+}(a) > \phi^{+}(b); \\ aI^{+}b, & iff\ \phi^{+}(a) = \phi^{+}(b); \end{cases} \tag{2.5}$$

$$\begin{cases} aP^{-}b, & iff\ \phi^{-}(a) < \phi^{-}(b); \\ aI^{-}b, & iff\ \phi^{-}(a) = \phi^{-}(b); \end{cases} \tag{2.6}$$

Methodology of PROMETHEE II

The decision makers usually prefer to have a complete outranking not a partial as in the case of PROMETHEE I where some actions are remaining incomparable and only the confirmed outranking are given. PROMETHEE II on the other hand is the second and developed version of PROMETHEE I, this method represents a complete preorder and is induced by the net outranking flow $\phi(a)$ by deducting the negative flow from the positive flow as follows:

$$\phi(a) = \phi^{+}(a) - \phi^{-}(a) \tag{2.4}$$

PROMETHEE II is a balance between the negative and positive flow, the higher the net flow, the better the alternative, considering that no incomparable do exist in this methods as all alternatives are comparable, so that:

$$\begin{cases} aP^{II}b \ (a\ outranks\ b), & iff\ \phi(a) > \phi(b); \\ aI^{II}b \ (a\ is\ indifferent\ to\ b), & iff\ \phi(a) = \phi(b); \end{cases} \tag{2.7}$$

General Numerical Example

Let us consider a company that has a multi-criteria decision making problem in selecting the best supplier among six alternatives x_i (suppliers), a total of six criteria *fi* were decided by the decision maker along with the weights *wi* for each criterion, these criteria are (Brans, 1986):

f_1: manpower.

f_2: power (MW),

f_3: construction cost (10^9 $),

f_4: maintenance cost (10^6 $),

f_5: number of villages to evacuate,

f_6: security level.

The direction of each criterion (Min/Max) were added, for example, the cost in criteria 3 and 4 need to be minimized, unlike the power in criterion 2 which needs to be maximized. The supplier proposals' results are filled in the table below. Table (2.2) includes all the required information to start applying PROMETHEE:

Table 2.2

Evaluation Matrix – General Example

Criteria	Min Max	a_1	a_2	a_3	a_4	a_5	a_6	Type of Criteria	Parameters
$f_1(.)$	min	80	65	83	40	52	94	II	q = 10
$f_2(.)$	max	90	58	60	80	72	96	III	p = 30
$f_3(.)$	min	60	20	40	100	60	70	V	q = 5; p = 45
$f_4(.)$	min	5.4	9.7	7.2	7.5	2	3.6	IV	q = 1; p = 5
$f_5(.)$	min	8	1	4	7	3	5	I	-
$f_6(.)$	max	5	1	7	10	8	6	VI	$\sigma = 5$

The type of the generalized criteria differs from one criterion to another, and the type is decided by the decision maker, some parameter (s) have to be define as well by the decision maker based on the chosen generalized criteria.

Once all the required information is filled in, the difference between alternatives for each criterion is calculated and compared with the stated parameters, and then applying the suitable type of generalized criteria for each criterion. The result then is multiplied by the weight of each criterion the total is filled in table (2.3):

Table 2.3

Preference Index Matrix – General Example

$\prod$	x_1	x_2	x_3	x_4	x_5	x_6	ϕ^+ (a)
x_1		0.296	0.250	0.268	0.100	0.185	1.099
x_2	0.462		0.389	0.333	0.296	0.500	1.980
x_3	0.236	0.180		0.333	0.056	0.429	1.234
x_4	0.399	0.505	0.305		0.223	0.212	1.644
x_5	0.444	0.515	0.487	0.380		0.448	2.274
x_6	0.286	0.399	0.250	0.432	0.133		1.500
ϕ^- (a)	1.827	1.895	1.681	1.746	0.808	1.774	

The negative flow for each alternative over other alternatives is then calculated, the next step is to calculate the net flow which is the difference between the positive and negative flow for each alternative as sin table 2.4, the results are then ordered from the

highest to the lowest, ranking suppliers from the best performing to the lowest, figure 2.1 shows the ranking of the suppliers.

Table 2.4

Net Flow– General Example

	x_1	x_2	x_3	x_4	x_5	x_6
ϕ (a)	-0.728	0.085	-0.447	-0.102	1.466	-0.274

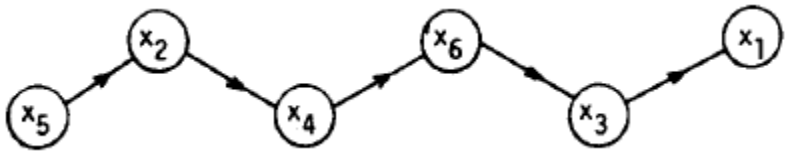


Figure 2.1 Suppliers Ranking – General Example

CHAPTER 3: REAL APPLICATION – ANALYSIS AND FINDINGS

Background

The real application in this paper is conducted in a project management company located in Doha, Qatar. This company offers a full range of professional Project Management Services including Program Development, Health and Safety, Cost Management, Risk Management and others. The company always try to adapt with the latest technologies and to to develop its existing systems by transforming the legacy ones into developed systems that are capable to cope with the technology evolution. This firm includes many departments; such as Operations, Business Development, Advisory Services, Management Services, Human Resources (HR), Information Technology (IT), Procurement, Administrations, and others. This paper is discussing the supplier selection problem, hence, the sponsored Department, Procurement Department and Tendering Department are the core departments considered, our focus and use of PROMETHEE method will benefit these departments in particular and the organization in general in achieving its objectives.

The application of the PROMETHEE method in this paper is done on a decision making problem took a place in the second quarter of 2017, it is related to the process of upgrading its ERP (Enterprise Resource Planning system) to cope with the latest technologies, gain more functionality and ensure the efficiency of its systems all the time. One of the most crucial and critical processes is the Supplier Selection process; in addition to the technical reasons behind it, this process has an influence on the

organization's economic growth and can result in a great cost savings. The decision maker in our case operates in the Information Technology Department (IT) which is one of the most important departments in the firm, and this usually this department has a high allocated budget compared to other departments.

The Decision maker has selected the list of suppliers (alternatives), criteria and the weightage values for each criterion, then a technical and commercial evaluations have been done separately to select the best supplier. These information about criteria, weights and evaluations of the suppliers in the technical and commercial parts were collected from the existing info within the department in the firm, and additional information were obtained as required by PROMETHEE method that is applied in this paper, such as the preference functions and the threshold parameters for each criterion according to the preference function chosen for each. The following section explains in details how the PROMETHEE method was applied.

Real Application – ERP System Upgrade

This section will describe in details the methodology used and how was it applied on the problem selected and explained in the previous section, following are the steps used and described in the methodology chapter, starting with collecting the criteria and weights from the decision maker, going through all the followed steps and ending with having ranked alternatives based on the preferences of the decision maker.

Step (1): Criteria, Weights and Alternatives

Defining criteria, weights and choosing the list of suppliers to invite are steps that are expected to be assigned to and done properly by the decision maker based on the experience and logical methods. Hence, the information provided in this paper about the criteria, weights and alternatives is collected directly from the decision maker. Table (3.1) represents the evaluation criteria collected from the decision maker along with the description of each. This supplier selection problem contains five main criteria; Cost, Company Profile, Key Personnel, Technical Fulfillment and Professionalism. Each main criterion has sub-criteria, giving in total a number of 18 sub-criteria named and described as in table (3.1).

It is worth mentioning that the usual practice in the firm is to attend a meeting to open the technical proposals of the participated suppliers as a first step, and then meet again with the tendering committee to present the technical evaluation that is done by the decision maker in the sponsoring department which is the Information Technology department (IT) in the case presented here in this paper. After having the technical evaluation approved by the tender committee, the commercial proposals for the suppliers which achieved a high score and passed the technical evaluation is then opened by the committee and again evaluated separately by the sponsoring department. Hence, the weights were collected for the technical and commercial separately considering each is out of 100; the technical separately is out of 100 and same case of the commercial. In order to have the technical and commercial proposals united in one evaluation, a question

was addressed to the decision maker about the weightage that can be allocated to the commercial part compared to the technical part to have one evaluation out of 100, the response was 20:80; 20% for the commercial and 80% for the technical. The technical weights were converted to be out of 80 and a weight of 20 was allocated for the commercial part which represented by the cost criterion in table (3.1).

Table 3.1

Criteria Description – ERP System Upgrade

No.	Main Criteria	Sub-criteria No.	Sub Criteria	Description
1	Cost	101	Cost	The cost of implementing services for whole project, full data migration, applicant portal and post Go-Live.
2	Company Profile	201	Years of Experience in Qatar	More experience years in Qatar is preferred (1 point for every 2 years)
		202	Reputation	corporate performance and organization structure (1-3)
		203	Number of Projects	Number of achieved or completed similar projects (1 point/each)
		204	Microsoft Partnership	Suppliers' Microsoft partnership class; Silver, Gold or President Club
		205	Microsoft Certificates	Microsoft certificates gained by the supplier
		206	Payroll Microsoft Certificates	Payroll Microsoft certificates gained by the supplier
3	Key Personnel	301	CVs	Number of CVs provided by the supplier (1 point for each 2 CVs)
		302	Relative Experience	Based on the similar expertise level on scale from 1-4
		303	Team Locality	Location of the project team, in Qatar=5, Mix1=4, Mix2=3, External=2, Dubai/Bahrain/KSA=1

		304	Project Management Certificates	PMP/Prince2 certificates obtained.
4	Technical Fulfillment	401	SOW Coverage	The scope of work including reports and data migration, based on limitations, assumptions, in scope, out of scope and flexibility (Scale from 1-10)
		402	Finance Department Evaluation	Based on the Demo presented by the supplier to Finance Department (scale from 1-15)
		403	HR Department Finance Department (scale from 1-35)	Evaluation Based on the Demo presented by the supplier to
5	Professionalism	501	Communication Channels	Using the right and official communication channels
		502	Supplier Engagement	Supplier enquiries and requests for meeting
		503	Responding	The time to respond to the request for proposal and clarifications
		504	Proposal Quality	Quality of proposal (Paper, Printing and finishing)

Step (2): Direction and Evaluation

After collecting the information about the criteria and weights, the evaluation values of the suppliers for all criteria are then collected from the proposals received from the suppliers who participated, and filled in the evaluation matrix by the decision maker, the evaluation matrix values differ from one criteria to another and they are not normalized, this does not cause any difficulty with our applied method PROMETHEE II, as one of the advantages of this method is that it does not require a normalized data to be done and applied, because the difference between the suppliers or in another words the difference in values of the suppliers is the key element. Then after applying the suitable generalized criteria on all the difference values, all values will be automatically normalized from 0-1. The number of alternatives/suppliers is five suppliers named from X_1-X_2.

The next step is understanding which direction is the criteria taking, this depends and reflects the need of the decision maker of the criteria, if the criterion need to be maximized, then a comment under the direction column will label it with “Max” as indicated in table (3.2), and if the criterion need to be minimized then another comment will be labeled with “Min” under the direction column for this criteria.

Criteria can take both types; Qualitative and Quantitative, the case of quantitative is presented by “Max” or “Min”, some qualitative criteria are answered by (Yes or No) and labeled with “Y/N” as in table (3.2). In this paper we assumed that this type of criteria can use the first type of the generalized criteria called “Usual Criterion”.

From all the criteria listed by the decision maker, only one criterion had the "Min" direction which is the Cost Criteria and this is reasonable; it is not usual and rational that organizations want their cost to be maximized as most of the profitable organizations' goal is to maximize their shareholders' wealth and this can be done by reducing cost as one of the choices to achieve this aim. The direction of the rest of the criteria took the direction of "Y/N" and "Max" based on the discussion with the decision maker. Table (3.2) presents the weightage, direction and the supplier original and real evaluation values, noting that the values of criteria 101 were multiplied by a factor to keep the confidentiality of the information.

Table 3.2

Supplier Evaluation Matrix – ERP System Upgrade

Criteria No.	Weight	Direction	X_1	X_2	X_3	X_4	X_5
101	20	Min	1,633,164	1,480,500	1,233,687	1,160,700	2,100,000
201	4	Max	4	4	3	4	3
202	2.4	Max	3	3	3	3	3
203	4	Max	3	2	2	3	3
204	3.2	Max	3	3	4	3	3
205	0.8	Y/N	1	0	1	1	0
206	1.6	Y/N	2	0	1	0	0
301	2.8	Max	0.5	3	3	3	3
302	3.6	Max	3	2	3	3	3
303	4.4	Max	2	2	1	4	4
304	1.2	Y/N	1	1	1	1	1
401	8	Max	10	10	10	10	10
402	12	Max	10.5	12.75	12	12.75	13.2
403	28	Max	24.5	21	29.75	29.75	21
501	0.8	Y/N	1	1	1	1	1
502	1.6	Max	2	2	1	2	2
503	0.8	Y/N	1	1	1	1	0
504	0.8	Max	1	1	1	1	0.5

Step (3): Defining a Preference Function

PROMETHEE method works by comparing each pair of alternatives mutually with respect to each selected criterion, in order to have this comparison done, a degree of preference of each alternative over the other has to be performed. To find the preference degree, the difference *d* between the real evaluation values of each participated supplier over other suppliers or alternatives is computed, for example: the difference between supplier X_1 and all other four suppliers; X_2, X_3, X_4 and X_5 should be calculated, except of X_1 with itself. The same process is repeated with the rest four suppliers giving a 20 differences calculated for each criterion. The results of calculating the differences are shown in table (3.3):

Table 3.3

Degree of Preference Between Suppliers - ERP System Upgrade

Criteria No.	1→2	1→3	1→4	1→5	2→1	2→3	2→4	2→5	3→1	3→2
101	0	0	0	466,866	152,664	0	0	619,500	399,477	246,813
201	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00
202	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
203	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
204	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00
205	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00
206	2.00	2.00	2.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00
301	0.00	0.00	0.00	0.00	2.50	0.00	0.00	0.00	2.50	0.00
302	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
303	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
304	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
401	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
402	0.00	0.00	0.00	0.00	2.25	0.75	0.00	0.00	1.50	0.00
403	3.50	0.00	0.00	3.50	0.00	0.00	0.00	0.00	5.25	8.75
501	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
502	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
503	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00
504	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.50	0.00	0.00

Continuation

Criteria No.	3→4	3→5	4→1	4→2	4→3	4→5	5→1	5→2	5→3	5→4
101	0	866,313	472,464	319,800	72,987	939,300	0	0	0	0
201	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00
202	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
203	0.00	0.00	0.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00
204	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
205	0.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
206	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
301	0.00	0.00	2.50	0.00	0.00	0.00	2.00	0.00	0.00	0.00
302	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00
303	0.00	0.00	2.00	2.00	3.00	0.00	2.00	2.00	3.00	0.00
304	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
401	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
402	0.00	0.00	2.25	0.00	0.75	0.00	2.70	0.45	1.20	0.45
403	0.00	8.75	5.25	8.75	0.00	8.75	0.00	0.00	0.00	0.00
501	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
502	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00
503	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
504	0.00	0.50	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00

Step (4): Generalized Criteria

In step (3), the degree of preference was computed by calculating the difference between the suppliers, in this step, the intensity of that degree is being calculated. The decision maker was involved in this step to be able to determine the correct and the most suitable generalized criteria for each criterion, as discussed in Methodology chapter, there exist 6 types of generalized criteria, and each one works based on the characteristics of the criterion itself and requires different parameter. The parameters and the suitable generalized criteria were chosen for each one of the eighteen criteria in accordance with the decision maker. Main parameters used are the preference threshold **(p)** which is the lowest value of *d* above which there is strict preference, and the indifference threshold **(q)** which is the greatest value of *d* below which there is indifference. The parameters were fixed upon a discussion with the decision maker. Table (3.4) shows the additional required info collected from the decision maker.

Table 3.4

Additional Data - ERP System Upgrade

Criteria No.	Weight	Direction	Generalized Criteria	p	q
101	20	Min	V	250,000	100,000
201	4	Max	IV	3	1
202	2.4	Max	III	2	-
203	4	Max	III	1	-
204	3.2	Max	IV	2	1
205	0.8	Y/N	I	-	-
206	1.6	Y/N	I	-	-
301	2.8	Max	V	2	0.5
302	3.6	Max	III	2	-
303	4.4	Max	IV	2	1
304	1.2	Y/N	I	-	-
401	8	Max	III	5	-
402	12	Max	V	2	1
403	28	Max	V	3	2
501	0.8	Y/N	I	-	-
502	1.6	Max	II	-	1
503	0.8	Y/N	I	-	-
504	0.8	Max	II	-	0.5

Applying the generalized criteria automatically normalizes the data and gives it a range value from 0-1 for all criteria. Table (3.5) lists the values after applying the suitable generalized criteria for each of the eighteen criteria:

Table 3.5

Evaluation Matrix (Generalized Criteria Applied) - ERP System Upgrade

Criteria No.	1→2	1→3	1→4	1→5	2→1	2→3	2→4	2→5	3→1	3→2	3→4	3→5	4→1	4→2	4→3	4→5	5→1	5→2	5→3	5→4
101	0.00	0.00	0.00	1.00	0.35	0.00	0.00	1.00	1.00	0.99	0.00	1.00	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
201	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
202	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
203	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	1.00	1.00	0.00
204	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
205	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
206	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
301	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
302	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.50	0.00	0.00
303	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	1.00	0.00	0.50	0.50	1.00	0.00
304	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
401	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
402	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.20	0.00
403	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00
501	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
502	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
503	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
504	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Step (5): Multi-criteria Preference Index

The normalized values obtained in step (4) are then multiplied with the weight of each criterion and this is called the Multi-Criteria Preference Index. As mentioned earlier in this paper, the weights are done by the decision maker, but since the technical and commercial evaluations were done separately by the firm, a combined version of both technical and commercial evaluations was done in one evaluation to be out of 100%, and as advised by the decision maker the proper weight of commercial is 20% compared to 80% for the technical part; as the decision maker believes that technical performance plays a very critical role in the success of upgrading ERP system; as applying information technology systems on the business processes of the organization assures the success in delivering its goals.

The matrix shown in table (3.6) resulted from multiplying the weight for each criterion with the values constructed when the suitable generalized criteria was applied.

Table 3.6

Evaluation Matrix (Preference Index) - ERP System Upgrade

Cr. No	W	1→2	1→3	1→4	1→5	2→1	2→3	2→4	2→5	3→1	3→2	3→4	3→5	4→1	4→2	4→3	4→5	5→1	5→2	5→3	5→4
101	20	0.00	0.00	0.00	20.00	7.02	0.00	0.00	20.00	20.00	19.78	0.00	20.00	20.00	20.00	0.00	20.00	0.00	0.00	0.00	0.00
201	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
202	2.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
203	4	4.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	4.00	0.00	0.00	4.00	4.00	0.00
204	3.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
205	0.8	0.80	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.80	0.00	0.80	0.00	0.80	0.00	0.00	0.00	0.00
206	1.6	1.60	1.60	1.60	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
301	2.8	0.00	0.00	0.00	0.00	2.80	0.00	0.00	0.00	2.80	0.00	0.00	0.00	2.80	0.00	0.00	0.00	2.80	0.00	0.00	0.00
302	3.6	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.80	0.00	0.00	0.00	1.80	0.00	0.00	0.00	1.80	0.00	0.00
303	4.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.20	2.20	4.40	0.00	2.20	2.20	4.40	0.00
304	1.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
401	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
402	12	0.00	0.00	0.00	0.00	12.00	0.00	0.00	0.00	6.00	0.00	0.00	0.00	12.00	0.00	0.00	0.00	12.00	0.00	2.40	0.00
403	28	28.00	0.00	0.00	28.00	0.00	0.00	0.00	0.00	28.00	28.00	0.00	28.00	28.00	28.00	0.00	28.00	0.00	0.00	0.00	0.00
501	0.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
502	1.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
503	0.8	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00
504	0.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Step (6): Positive, Negative and Net Flows

In the previous step, the values generated by applying the suitable generalized criteria were multiplied by the weight of each criterion. In this step, the summation of these values is computed for each mix of the five suppliers; X1→ X2, X1→ X3, etc.…, and then combined in one matrix. The usual practice in the firm is to have separated technical and commercial evaluations, hence, this paper considered this issue and built up 3 separated matrices; one to rank suppliers based on their commercial and technical evaluations as illustrated in table (3.7), one to rank suppliers based only on their technical evaluation as in table (3.8), and one to rank them based only on their commercial evaluation table (3.9).

The positive flow $\phi^{+}(a)$ is then calculated for each supplier over all other suppliers to check by how much does this supplier *outrank* others. Same thing happens with the calculation of the negative flow $\phi^{-}(a)$ to check by how much does the same supplier is *outranked* by other suppliers.

Table 3.7

Positive and Negative Flows- Technical & Commercial

	X1	X2	X3	X4	X5	Φ + (X)
X1		0.362	0.056	0.016	0.512	0.946
X2	0.218		0.000	0.000	0.208	0.426
X3	0.568	0.504		0.000	0.496	1.568
X4	0.650	0.568	0.084		0.496	1.798
X5	0.170	0.080	0.108	0.000		0.358
Φ - (X)	1.6062	1.514	0.248	0.016	1.712	

Table 3.8

Positive and Negative Flows – Technical

	X1	X2	X3	X4	X5	Φ + (X)
X1		0.453	0.070	0.020	0.390	0.920
X2	0.185		0.000	0.000	0.010	0.183
X3	0.460	0.383		0.000	0.370	1.188
X4	0.563	0.460	0.105		0.370	1.485
X5	0.213	0.100	0.135	0.000		0.448
Φ - (X)	1.420	1.395	0.310	0.020	1.140	

Table 3.9

Positive and Negative Flows - Commercial

	X1	X2	X3	X4	X5	Φ + (X)
X1		0.000	0.000	0.000	1.000	1.000
X2	0.351		0.000	0.000	1.000	1.351
X3	1.000	0.989		0.000	1.000	3.038
X4	1.000	1.000	0.000		1.000	3.050
X5	0.000	0.000	0.000	0.000		0.000
Φ - (X)	2.351	1.989	0.000	0.000	4.000	

Since the methodology applied in this report supports complete ranking, the net flow $\phi(a)$ need to be calculated, this is done by calculating the difference between the positive flow $\phi^{+}(a)$ and the negative flow $\phi^{-}(a)$ as shown in table (3.10, 3.11 and 3.12) respectively.

Table 3.10

Net Flow – Technical and Commercial

	X1	X2	X3	X4	X5
Φ (X)	-0.660	-1.088	1.320	1.782	-1.354

Ranking	X4	X3	X1	X2	X5

Table 3.11

Net Flow- Technical

	X1	X2	X3	X4	X5
Φ (X)	-0.500	-1.213	0.878	1.465	-0.693

Ranking	X4	X3	X1	X5	X2

Table 3.12

Net Flow- Commercial

	X1	X2	X3	X4	X5
Φ (X)	-1.351	-0.638	3.038	3.050	-4.000

Ranking	X4	X3	X2	X1	X5

Research Findings

This Chapter represents and interprets the main results and findings discovered throughout applying PROMETHEE II method on the chosen organization, it also describes opinions and observations of the decision maker that resulted from the discussion of the analysis part. PROMETHEE II is an outranking method applied for pair wise comparison of alternatives for each criterion, hence, the suppliers were ranked based on their outranking values resulted from applying this method. The inputs of the decision

maker were employed, and the calculations and analysis of PROMETHEE II method were carried out using excel spread sheets. After Applying, analyzing and comparing the results of PROMETHEE II method with the analysis of the firm, some observations that would make a difference in decision making were found, which in turn will affect the way the organization works and how to achieve its objectives.

First Finding was that there was a partial difference in terms of Suppliers Ranking between PROMETHEE II and the method adopted by the firm; the selected firm has selected the weighted sum technique which is a value-based method, this method required to assign weight to each criterion and then multiply it with the evaluation values and sum up these weighted values for each criterion to have the final score. The weights express the importance of the criteria, however, unlike PROMETHEE II method, it does not take into considerations the preference of the decision maker. PROMETHEE II method was applied by finding the suitable generalized criteria, multiplying it by the weights provided by the decision maker, sum up the values to get the multi-criteria preference index and finally calculating the net flow which is a result of computing the difference between the positive and negative flows for each criterion. Calculating the net flow resulted in giving suppliers' outranking values, which allowed to rank the suppliers based on these values. As mentioned earlier in this paper, the selected firm usually asks the decision maker to prepare the technical and commercial evaluations separately, where technical evaluation is presented first followed by the commercial evaluation. In the case of the firm selected in this paper, and based on the Net Flows calculated earlier in tables (3.10, 3.11, and 3.12) and illustrated in chapter (3), the suppliers in the technical -

commercial evaluation, technical evaluation and commercial evaluation were ranked as shown in tables (3.13, 3.14 and 3.15) respectively. These tables compares between PROMETHEE II method and the Value Measurement Method adopted by the selected firm in terms of supplier ranking. Table (3.13) shows how supplier X_4 occupied the first place by gaining the highest outranking value in both methods, followed by X_3 and X_1. However, X_2 and X_5 were ranked differently in both methods; PROMETHEE II states that X_2 outranks X_5 while the method adopted by the firm states the otherwise. This could result in a different decision in case the company wants to evaluate supplier or even consider it in future purchases. Same scenario happens with the technical evaluation shown in table (3.14), where the last two suppliers are ranked differently in both methods.

Table 3.13

Suppliers Ranking - Technical and Commercial

PROMETHEE II Ranking	X_4	X_3	X_1	X_2	X_5
Weight-based Ranking	X_4	X_3	X_1	X_5	X_2

Table 3.14

Suppliers Ranking - Technical

PROMETHEE II Ranking	X_4	X_3	X_1	X_5	X_2
Weight-based Ranking	X_4	X_3	X_1	X_2	X_5

Table 3.15

Suppliers Ranking - Commercial

PROMETHEE II Ranking	X_4	X_3	X_2	X_1	X_5
Weight-based Ranking	X_4	X_3	X_2	X_1	X_5

In the case of the firm for which the study was conducted on, it only adopted the value measurement models using weights to do the evaluation, and this gave it a slightly different ranking than the one obtained using the PROMETHEE II method. It is worth mentioning that the firm has canceled some suppliers for private reasons related to the firm and its higher management, for example if the firm decided to remove the first three suppliers, it will end up with selecting the forth supplier, hence, what if the forth supplier was supposed to rank the fifth. Wrong supplier outranking may cause a wrong supplier selection.

The second finding is that some criteria were written and expressed in general, and is not detailed enough to describe the real concern of the sponsoring department and the decision maker; many enquiries and questions were addressed to and answered by the decision maker about the criteria in order to be able to identify the suitable generalized criteria, hence, many clarifications were required to check each criterion if it needs parameters related to its generalized criteria like **p** and **q**, and as illustrated earlier in the methodology chapter, **p** is the lowest value of *d* above which there is strict preference and **q** is the greatest value of *d* below which there is indifference. Identifying the parameters **p** and **q** forced the decision maker to feel and understand the actual meaning of each criteria, in addition to the ability of specifying the preference based on the experience gained through the time in the decision maker's field and not only through the weights which is a measure of importance of the criteria to the organization and the department in general. For example: Identifying the relative parameters for criteria 101, 402 and 403 mentioned in table (3.1) which are related to the cost, Finance department evaluation and Human Resources department evaluation respectively, resulted in knowing the gap between suppliers by numbers and figures and only by seeing and feeling the difference.

The proposed method was presented to the people involved in the decision making process, and they were impressed with the method and its results, they showed interest in applying it in the future technical and commercial evaluations, as it can select the supplier with best technical performance with an acceptable cost at the same time. On the other hand, one of their comments was that this method consumes time. Based on one of the discussions with the decision maker, it was obvious that the firm has purchases

that are frequently done on a yearly basis or periodically; quarterly, semiannually or monthly, hence, in this case, applying this method would be much easier and will not consume time except at the first time using it, where employees who are involved in the decision making process need to be trained and should understand how the mechanism of how this method works. Setting criteria, weights, parameters, generalized criteria and other requirements will be almost repetitive for the frequent purchases. And the only change will be the change on the values provided by the supplier in their proposals.

From this point, methods used in solving a multi-criteria decision making problem, such as the methods used in solving supplier selection problem, contributes directly and indirectly in the field of Business Administration; the method adopted in this paper has considered the preferences of the decision maker, which is a very critical issue specially in the appearance of a business problem like supplier selection problem in the organizations where frequent purchases occur. Choosing the right supplier will result in saving cost, help suppliers to perform better for the organizations, evaluate suppliers based on their ranking levels, knowing the weakness and strength points of the organizations' suppliers, a precise supplier evaluation that is periodically done and any other relative actions related to the supplier.

CHAPTER 4: CONCLUSION

Conclusion

Supplier selection is one of the most important decision making problems, hence, selecting the right supplier is essential and critical point in the purchasing process; it may lead to a significantly reduced purchasing costs and improve corporate competitiveness. Supplier selection involves comparing between more than one alternative and is based on a finite set of criteria to choose the suppliers with the highest potential by meeting the firm's needs at acceptable cost. Selecting the right supplier requires a good and logical method to adopt, many of the methods applied in the organizations are based on the numerical value without taking into consideration the preference of the decision maker which is a very important step when evaluating the suppliers. Hence, in order to tackle the problem of supplier selection, PROMETHEE II which is one of the most popular outranking methods was used by taking the preference of the decision maker into considerations. It was obvious from the results yielded from ERP system upgrading that ranking suppliers based on a solid base is essential especially if the firm may eliminate some suppliers for any reason and choose the next ones, and here the right ranking of suppliers based on their outranking value is critical and important.

Research Limits

Although the research has reached its goals, there were some limitations that are unavoidable. First, because of the confidentiality, the firm could share only few topics, one of which is the case of ERP system upgrade, this particular case was selected due to having enough number of criteria and alternatives and represents a good and a recent case in the firm. Secondly, the decision maker and the concerned department are always busy due to the workload, other contributions and proposed solutions with regards to the criteria could have been done.

Future Research Directions

Knowing the fact that no studies or papers were done in Qatar using the proposed method in this research (PROMETHEE) is enough to realize the number of opportunities available to apply this method in different fields other than the project management field. Also, going through the literature review and applying PROMETHEE II method generated many ideas with regards to the supplier selection problem, such as the possibility of merging two multi-criteria decision making methods; such as integrating and outranking method with a value measurement method or find a combined mechanism to define the criteria from the beginning and apply the PROMETHEE method immediately. This can result in a very efficient and effective supplier ranking. Finally, this method was originated in the 80s and evolved through years, however, there is no specific automated program designed to assist in applying PROMETHEE in a

computerized system. Deeper understanding of PROMETHEE method can result in building a strong automated system instead of using paper and excel sheets.

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