Engineering Management
Field Project

Supplier Evaluation and Selection by Using The Analytic Hierarchy Process Approach

By

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Executive Summary

Supplier selection is not only a process to choose the lowest price, it is a process to select the best supplier that can submit the best deal on all required criteria among other suppliers. Selecting a supplier is a complex problem involving qualitative and quantitative multi-criteria. Selecting a vendor is now as important of a process as developing new products. There is no one best way to evaluate and select suppliers; organizations use a variety of different approaches. The AHP process is one of the approaches that are used to select the right supplier. Therefore, an AHP supplier selection model is formulated and then applied to a given set of data for ABC Company. The model provides a clear way to evaluate every criterion, depending on its importance in order to select the right supplier. To reduce the time and effort in selecting a supplier, a multi-criteria decision model is used for evaluation and selection of suppliers with the proposed AHP model by scoring the performance of suppliers. Choosing the right supplier could give the right quantity and the right cost on the right timeline.

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1- Introduction

In today's highly competitive environment, an effective supplier selection process is very important to the success of any manufacturing organization (Liu & Hai, 2005). Selecting the right supplier is always a difficult task for the purchasing manager. Suppliers have varied strengths and weaknesses, which require careful assessment by the purchasers before ranking, can be given to them. Therefore, every decision needs to be integrated by trading-off performances of different suppliers at each supply chain stage (Liu & Hai, 2005). In addition, choosing the right supplier will be positive for the company. For instance, firms should select the most appropriate suppliers according to the production capacity of all potential suppliers, and build long-term and profitable relationships with them (Wang & Yang, 2009). "Selecting the right suppliers is key to the procurement process and represents a major opportunity for companies to reduce costs. On the other hand, selecting the wrong suppliers can cause operational and financial problems" (Weber, Current, & Benton, 1991).

The procurement department in ABC Company, which is in the water industry, uses one criterion to select the supplier. The criterion is the price, and the price only, without giving attention to other criteria. Usually the supplier, who submits the lowest cost quotation, is chosen by ABC Company. One criterion is insufficient to choose the right supplier whether it was the cost or another criterion. Therefore, using more comprehensive multi-criteria decision making techniques is more useful. The vendor selection process would be simple if only

one criterion was used in the decision making process. However in many situations, purchasers have to take account of a range of criteria in making their decisions. “If several criteria are used, then it is necessary to determine how far each criterion influences the decision making process, whether all are to be equally weighted or whether the influence varies accordingly to the type of criteria” (Yahya & Kingsman, 1999). For example, it is not fair to give the same weight to the cost and the warranty. It is obvious that the cost is more important than the warranty when supplier evaluation is made.

The supplier selection problem can be solved with Multiple-Criteria Decision Making (MCDM), out of which quantities criteria have been considered for supplier selection in the previous and existing decision models so far (Chen-Tung, Ching-Torng & Huanget, 2006). In MCDM, a problem is affected by several conflicting factors in supplying selection, for which a purchasing manager must analyze the trade-off among several criteria. MCDM techniques support the decision-makers (DMs) in evaluating a set of alternatives. Depending upon the purchasing situations, criteria have varying importance, and there is a need to weigh them (Dulmin & Mininno, 2003).

The Analytic Hierarchy Process (AHP) approach is one that uses multi-criteria making techniques. The AHP has found widespread application in decision making problems, involving multiple criteria in systems of many levels (Liu & Hai, 2005). This method has the ability to structure complex, multi-person,

multi-attribute, and multi-period problems hierarchically (Yusuff, PohYee & Hashmi, 2001). The AHP can be very useful in involving several decision-makers with different conflicting objectives to arrive at a consensus (Tam & Tummala, 2001). The AHP method is identified to assist in decision making to resolve the supplier selection problem in choosing the optimal supplier combination (Yu & Jing, 2004) (Tahriri, Osman, Yusuff and Esfandiary, 2008).

"Most purchasing experts will agree that there is no one best way to evaluate and select suppliers; organization use a variety of different approaches" (Monczka, Trent, and Handfield, 2005). "Regardless of the approach employed, the overall objective of the evaluation process should be to reduce purchase risk and maximize overall value to the purchaser" (Monczka, Trent, and Handfield, 2005).

2- Literature Review

2.1 Supplier selection criteria

One major aspect of the procurement function is supplier selection criteria. The analysis of evaluation, selecting the right supplier, and creating the criteria that are needed in the organization to measure the performance of suppliers have been important for many scientists since the 1960s. In the mid 1960s, many researchers were developing different methods and approaches to choose the needed criteria that could be good tools to evaluate suppliers.

Dickson (1966) was the first researcher who performed an extensive study on criteria. His study was to determine, identify, and analyze what criteria were used in the selection of a firm as a supplier. Dickson's study (1966) was dependent on a questionnaire, sent to 273 purchasing agents and managers selected from the membership list of the National Association of Purchasing Managers. The list included purchasing agents and managers from the United States and Canada, which was a total of 170 regarding the importance of 23 criteria for supplier selection. Dickson asked them to order the importance of each criterion on a five point scale: extreme, considerable, average, slight, and of no importance. He came up with "quality" is the most important criterion. The important criteria dependent on the study were "delivery" and "performance history" (Tahriri, Osman, Yusuff and Esfandiary, 2008).

“ Weber, Current and Benton (1991) presented a classification of all the articles published since 1966 according to the treated criteria. Based on 74 papers, the outputs observe that Price, Delivery, Quality, and Production capacity and location were the criteria most often treated in the literature (Tahriri; Osman; Yusuff and Esfandiary ,2008).”

According to Weber, Current and Benton (1991), the review of the articles about supplier selection between 1966 and 1991 were investigated. In a related study, Zhang, Lei, Cao and Ng (2003) collected 49 articles between 1991 and 2003, which was a comprehensive classification of supplier selections published. The study of Zhang, Lei, Cao and Ng (2003) was done based on the Weber, Current and Benton (1991) study, and the 23 criteria of Dickson’s (1966) study. The study concluded that net price, quality, and delivery were the most important supplier selection criteria. As concluded from three different studies, price is the number one selection factor, replacing Dickson’s (1966) number one ranked quality criterion (Tahriri, Osman, Yusuff and Esfandiary, 2008).

In addition to Dickson (1966), Weber, Current, and Benton (1991) and Zhang, Lei, Cao, and Ng (2003), other researchers have also recently begun discussing new important criteria to select suppliers. The definition of Dickson’s (1966) 23 criteria has been expanded, and some new criteria were developed with the growth of new business needs. The review performed by the Bross & Zhao study concluded that the most valuable supplier selection criteria were cost, quality, service, relationship, and organization (Bross & Zhao, 2004).

After Weber's work, most researchers focused on supplier-selection criteria in either specific industries or specific countries. Since Internet-based businesses have grown rapidly since 1995, vendor criteria have changed a great deal, thus corresponding to the business environmental changes (Sonmez,2006). While a number of supplier selection criteria studies have been conducted over the years, Dickson (1966), Weber, Current, and Benton (1991) and Zhang, Lei, Cao, and Ng (2003) are still recognized as the most common, and cited as the most comprehensive studies done on selection criteria. (Appendix1) summarizes some of these criteria, which have appeared in literature since 1966 (Ha and Krishnan, 2008).

One of the most important processes performed in organizations today is the evaluation, selection, and continuous measurement of suppliers. Selecting a vendor is now as important a process as developing new products. Supplier selection process is a multi-criteria problem, which includes both qualitative and quantitative factors. Purchasing commands a significant position in most organizations since purchased parts, components, and supplies typically represent 40 to 60 percent of the sales of its end products. Thus relatively small cost reductions gained in the acquisition of materials can have a greater impact on profits. Suppliers have a large and direct impact on the cost, quality, technology, and time-to-market of new products (Chen, Lin & Huang, 2006).

2.2 Supplier selection with AHP method

Analytic Hierarchy Process (AHP), since its invention, has been a tool at the hands of decision makers and researchers, and it is one of the most widely used multiple criteria decision-making tools (Omkarprasad & Kumar, 2006). Many outstanding works have been published based on AHP. They include applications of AHP in different fields, such as planning, selecting best alternatives, resource allocations, resolving conflict, optimization, etc., as well as numerical extensions of AHP (Vargas, 1990).

There are many strongest features of the AHP, for example it generates numerical priorities from the subjective knowledge expressed in the estimates of paired comparison matrices. The method is surely useful in evaluating suppliers' weights in marketing, or in ranking order for instance. It is, however, difficult to determine suitable weight and order of each alternative. It has been shown that different weights among objects give rise to different results in ranking (Liu & Hai, 2005).

Choosing the supplier who submits the lowest cost is not a good choice necessarily. It might cost more than what is submitted, when the merchandise is not high quality, for instance. Developing a model by using the AHP approach could decrease the delayed order. Giving other criteria the needed attention to select the supplier by focus on its financial stability, history, and other criteria

could be the right way to choose the correct supplier. Getting the right cost and the right time and the right specification is what needed in ABC Company.

Giving weight to every criterion can defer each criterion from another depends on its importance. The AHP approach uses this principle to evaluate alternatives. It is obvious that some criteria are more important than others. Therefore, given suitable weight could fix this problem. Although some managers consider some criteria more important than others, in real life they might do the opposite. “ It appears that managers perceive quality to be the most important attribute but they assign more weight to delivery performance and/or cost when actually choosing a supplier. These results imply that even though the managers believe that several attributes (for example, quality) are important for supplier selection, in actual practice the low cost supplier is selected” (Verma & Pullman, 1998).

3- Supplier selection in ABC Company

After the needed merchandise is identified by procurement department, some suppliers are contacted to buy and deliver them. ABC Company has a list of suppliers that are specified in many fields. The appropriate suppliers are contacted to submit their quotations. When receiving the submitted quotations, specialist engineers in ABC Company check the quotations to choose the one that agree with the company's terms. Then, evaluated phase is made to choose the supplier. The supplier is chosen in ABC Company depending on the lowest price. The other criteria are not given attention in decision-making. When receiving the goods, the items procured are reviewed and accepted.

4- Model development

In order to select the right supplier, the model is needed to develop the AHP approach. The methodology has been adopted from approaches mentioned in the literature review. The following steps could be applied by ABC Company in order to choose the supplier that is more appropriate than others after collecting quantitative and qualitative data for the AHP supplier selection model:

Step 1: Define criteria for supplier selection

The first step in any supplier rating procedure is to find the appropriate criteria to be used for assessing the supplier. To comply with the criteria for supplier selection and their importance, required data were collected based on the consideration of literature. Based on considering the studies of Dickson (1966); Weber, Current, and Benton (1991); Krishnan (2008); and Tahriri, Osman, Yusuff and Esfandiary, (2008), five important criteria were selected.

The criteria were selected are the most criteria used in many different industries. Many studies, mentioned in the literature review, rate each factor by using the four-category scale of "Not important (1 to 3)", "Some-what important (4 to 5)", "Important (6 to 7)" and "Very important (8 to 9)" (Tam and Tummala, 2001). The selected criteria were found cover ABC Company's needs. In addition, the presence of too many criteria makes the pair-wise comparisons in evaluating suppliers a difficult and time consuming process. To overcome these problems, the cut-off value to reduce the number of criteria to a few is desirable

Tam and Tummala (2001). Finally, the five important criteria were selected are cost, quality, delivery, management and organization, and financial. They were selected at level (2) in supplier selection model (The goals factor in Level (1) for supplier selection model is to select the best overall supplier).

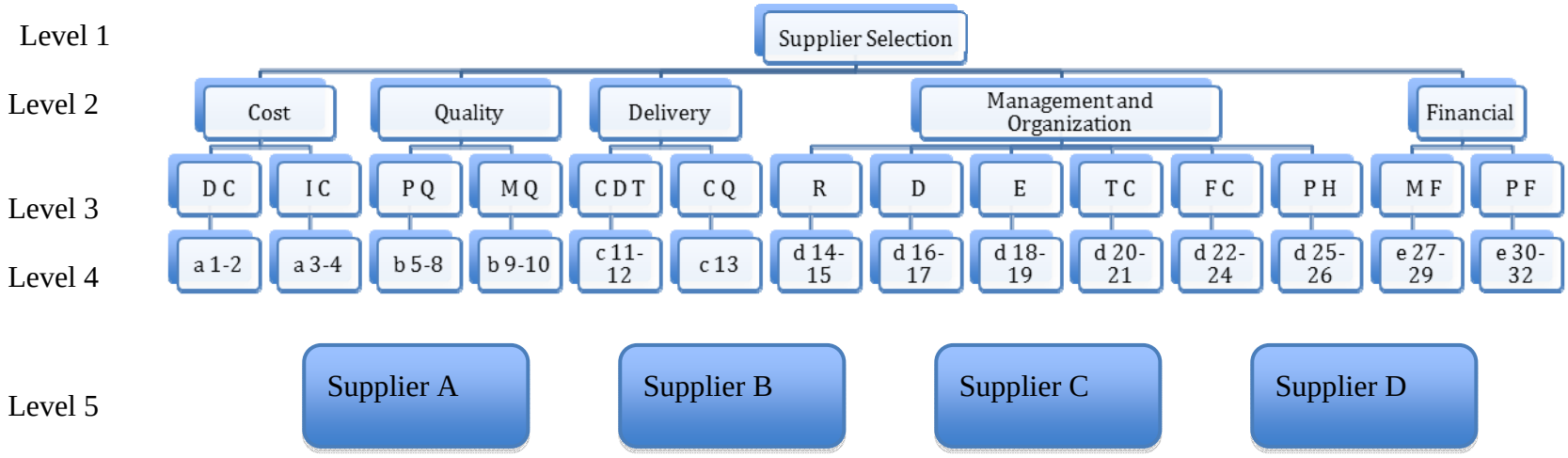
Step 2: Define sub-criteria and sub sub-criteria for supplier selection

In this step, the definition of the sub-criteria and sub sub-criteria has been done for supplier selection based on the five important criteria selected as the results of the previous step with the consideration of literature. Also, the sub and sub-criteria selected have been done by using the same rule that was used to select the criteria mentioned in the first step.

After gathering the needed sub and sub-criteria, they were identified and averaged. Fourteen sub-criteria and thirty-two sub sub-criteria were selected for levels (3) and (4) in supplier selection model as shown in (Figure 1).

Step 3: Structure the hierarchical model

This phase involves building the AHP hierarchy model and calculating the weights of each levels of supplier selection model. The developed AHP model, based on the identified criteria, sub-criteria and sub sub-criteria, contains five levels: the goal, the criteria, sub-criteria, sub-sub criteria, and alternatives.



D C	Direct cost	M F	Manufacturing financial	c 11	Percentage late delivery	d 23	Machinery
I C	Indirect cost	P F	Product financial	c 12	Delivery lead time	d 24	Layout
P Q	Product quality	a 1	Net price	c 13	Location	d 25	Product Variety
M Q	Manufacturing quality	a 2	Delivery cost	d 14	Urgent delivery	d 26	Product line
C D T	Compliance with due time	a 3	Ordering cost	d 15	Quantity problem	e 27	Finance stability
C Q	Compliance with quantity	a 4	Capital investment	d 16	Honesty	e 28	Capital and banking history
R	Responsiveness	b 5	Customer rejecter	d 17	Procedural compliment	e 29	Profit/sale trends
D	Discipline	b 6	Warranty	d 18	ISO 14000 certified	e 30	Discount
E	Environment	b 7	ISO 9000	d 19	Waste management	e 31	Turn-over
TC	Technical capability	b 8	Package	d 20	Product range	e 32	Interest on payment
F C	Facility and capacity	b 9	Customer focus	d 21	Technical problem solving		
P H	Performance history	b 10	Top management committee committee	d 22	Infrastructure		

Figure 1: An illustrative decision hierarchy for supplier selection (Yusuff, PohYee & Hashmi, 2001).

(Figure 1) shows an illustrative five-level hierarchy for the supplier selection problem. The first level of the hierarchy is identified to select the supplier for ABC Company. The second level (criteria) contains cost, quality, delivery, management and organization, and financial. The third and fourth level of the hierarchy consist fourteen sub-criteria and thirty-two sub sub-criteria. The lowest level of the hierarchy contains of the alternatives, namely the different supplier to be evaluated in order to select the best supplier. The AHP model shown in (figure 1) is generally applicable to any supplier selection process of ABC Company.

Based on the consideration of literature, the priority weight of each criterion in each level was determined. The pair-wise comparison judgments were used to find the important criteria in level two. This approach is found to be very useful in collecting data. The function of the pair-wise comparisons is by finding the relative importance of the criteria and sub-criteria, which is rated by the nine-point scale proposed by Saaty (1980), as shown in Table 1, indicating the level of relative importance from equal, moderate, strong, very strong, to extreme level by 1, 3, 5, 7, and 9, respectively. The intermediate values between two adjacent arguments were represented by 2, 4, 6, and 8.

Verbal judgment or preference	Numerical rating
Extremely preferred	9
Very strongly preferred	7
Strongly preferred	5
Moderately preferred	3
Equally preferred	1
Intermediate values between two adjacent judgments (when compromise is needed)	2, 4, 6, and 8

Table 1. “Measurement scales”. Source: Saaty (1980)

As mentioned, the priority weight was determined. Here is a sample of pair-wise comparison matrix that shows how to calculate criteria, in level two, which were judged by other studies mentioned in the literature. The entry for the five row and the five column gives the importance of that row's criterion relative to the column's criterion as shown in Table 2.

Criteria for Supplier selection	Cost	Quality	Delivery	Management and Organization	Financial
Cost	1	2	4	5	5
Quality	½	1	2	4	4
Delivery	¼	1/2	1	2	2
Management and Organization	1/5	¼	½	1	2
Financial	1/5	1/4	½	1/2	1

Table 2. “Example for pair-wise comparison matrix”.

It is obvious that the cost criterion is the heaviest among other criteria. The first row illustrates how the cost weight strongly compares to the others. For example, the cost criterion is preferred to the quality by the value of 2, preferred to the delivery by the value of 4 and preferred to the management and organization and financial by the value of 5 for each of them. A good performance on quality, the criterion for the second row and column, is moderately more important than having good delivery, the management and organization and financial, (shown by the value of 2,4 and 4 Sequentially). A value of 1 is assigned to the diagonal elements since delivery (row) is equally preferred to delivery (column).

After obtaining the pair-wise judgments as in Table 3, the next step is the computation of weighting of elements in the matrix. After calculating each column to find the total, divided the elements of that column by the total of the column. Finally, add the elements in each resulting row and divide this sum by the number of elements in the row to get the average. (Appendix 2) illustrates the calculations of the matrix. The results of priority weights are cost (0.444), quality (0.268), delivery (0.134), the management and organization (0.088) and financial (0.066).

Criteria for supplier selection	Average	Row Total	Cost	Quality	Delivery	Management and Organization	Financial
Cost	0.444	2.222	0.465	0.5	0.5	0.4	0.357
Quality	0.268	1.339	0.233	0.25	0.25	0.32	0.286
Delivery	0.134	0.669	0.116	0.125	0.125	0.16	0.143
Management &Organization	0.088	0.44	0.093	0.062	0.062	0.08	0.143
Financial	0.066	0.328	0.093	0.062	0.062	0.04	0.071
Total	1		1	1	1	1	1

Table 3. “Normalized matrix of paired comparisons and calculation of priority weights”.

The consistency ratio (C.R.) for the comparison above is calculated to determine the acceptance of the priority weighting. The consistency test is one of the essential features of the AHP method, which aims to eliminate the possible inconsistency revealed in the criteria weights through the computation of consistency level of each matrix. The consistency ratio (CR) was used to determine and justify the inconsistency in the pair-wise comparison made by the respondents. Based on Saaty's (1980) empirical suggestion that a C.R. = 0.10 is acceptable, it is concluded that the foregoing pair-wise comparisons to obtain attribute weights are reasonably consistent. If the CR value is lower than the

acceptable value, the weight results are valid and consistent. In contrast, if the CR value is larger than the acceptable value, the matrix results are inconsistent and are exempted for the further analysis.

Estimating the consistency ratio is as follows: The following can be done manually or automatically by the AHP software, Expert Choice:

$$0.444\begin{bmatrix}1\\1/2\\1/4\\1/5\\1/5\end{bmatrix}+0.268\begin{bmatrix}2\\1\\1/2\\1/4\\1/4\end{bmatrix}+0.134\begin{bmatrix}4\\2\\1\\1/2\\1/2\end{bmatrix}+0.088\begin{bmatrix}5\\4\\2\\2\\1/2\end{bmatrix}+0.066\begin{bmatrix}5\\4\\2\\2\\1\end{bmatrix}=\begin{bmatrix}2.286\\1.374\\0.687\\0.4428\\0.3328\end{bmatrix}$$

Dividing all the elements of the weighted sum matrices by their respective priority

$$\frac{2.286}{0.444}=5.1486 \quad ,\frac{1.374}{0.268}=5.1269 \quad , \frac{0.687}{0.134}=5.1269$$

$$\frac{0.4428}{0088}=5.0318\ , \frac{0.3328}{0.066}=5.0424$$

Then compute the average of these values to obtain:

$$\lambda_{max}=\frac{(5.1486+5.1269+5.1269+5.0318+5.0424)}{5}$$

$$=5.0953$$

$$\text{CI}=\frac{\lambda\max-n}{n-1}=\frac{5.0953-5}{5-1}=0.0238$$

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random Consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 4.”Average random consistency”.

Selecting appropriate value of random consistency ratio, RI, for a matrix size of five using Table 4, we find RI = 1.12. We then calculate the consistency ratio, CR, as follows:

$$\text{CR}= \frac{CI}{RI} = \frac{0.0238}{1.12} = 0.02128$$

As the value of CR is less than 0.1, the judgments are acceptable (Al-Harbi, 2001).

The prioritized of sub-criteria in the third level and sub sub-criteria in the fourth level also depend on the local weights. The global weights are calculated by multiplying the local weights with criteria, sub-criteria and sub sub-criteria. As an example the calculations of the global weights of cost criteria are shown as follows. The result of priority criteria's with local weights of each level is shown in Table 5a.

Cost	Direct cost	Net price	Global Weights
0.444	0.857	0.849	0.3231

Table 5a. “Composite priority weights for sub sub-criteria”.

Table 5b exhibits the local weights for each criterion in each level. The results show that in the second level of criteria, cost with local weight of (0.444) had been prioritized as the first criteria followed by quality (0.268), delivery (0.134), management and organization (0.088), and financial (0.066).

Criteria	Local Weights	Sub Criteria	Local Weights	Sub sub-criteria	Local Weights	Global Weights
Cost	0.444	Direct cost	0.857	Net price	0.849	0.3231
				Delivery cost	0.15	0.0571
		Indirect cost	0.142	Ordering cost	0.8	0.0504
				Capital investment	0.2	0.0126
Quality	0.268	Product quality	0.857	Customer rejecter	0.37	0.0850
				Warranty	0.33	0.0758
				ISO 9000	0.23	0.0528
				Package	0.05	0.0115
		Manufacturing quality	0.142	Customer focus	0.842	0.0320
				Top management committee	0.157	0.0060
Delivery	0.134	Compliance with due time	0.849	Percentage late delivery	0.75	0.0853
				Delivery lead time	0.25	0.0284
		Compliance with quantity	0.15	Location	1	0.0201
Management and Organization	0.088	Responsiveness	0.422	Urgent delivery	0.4	0.0149
				Quantity problem	0.2	0.0074
		Discipline	0.268	Honesty	0.842	0.0199
				Procedural compliment	0.157	0.0037
		Environment	0.112	ISO 14000 certified	0.769	0.0076
				Waste management	0.23	0.0023
		Technical capability	0.087	Product range	0.726	0.0056
				Technical problem solving	0.273	0.0021
		Facility and capacity	0.069	Infrastructure	0.587	0.0036
				Machinery	0.232	0.0014
				Layout	0.18	0.0011
		Performance history	0.039	Product Variety	0.785	0.0027
				Product line	0.214	0.0007
Financial	0.066	Manufacturing financial	0.785	Finance stability	0.613	0.0318
				Capital and banking history	0.236	0.0122
				Profit/sale trends	0.149	0.0077
		Product financial	0.214	Discount	0.694	0.0098
				Turn-over	0.185	0.0026
				Interest on payment	0.119	0.0017
Total						1.000

Table 5b. “Composite priority weights for sub sub-criteria”.

Step 4: Prioritize the order of criteria or sub-criteria

Having completed mathematical calculations, comparisons of criteria and allocating weights for each criterion in each level is performed. As criterion weight becomes big, it would be more important to select the supplier than another criterion that is less. After calculating the global weights of each sub sub-criteria of level 4, the result is rearranged in descending order of priority, as shown in Table 6.

Rank	Factors (Sub sub-criteria)	Global weights
1	Net price	0.3231
2	Percentage late delivery	0.0853
3	Customer rejecter	0.085
4	Warranty	0.0758
5	Delivery cost	0.0571
6	ISO 9000	0.0528
7	Ordering cost	0.0504
8	Customer focus	0.032
9	Finance stability	0.0318
10	Delivery lead time	0.0284
11	Location	0.0201
12	Honesty	0.0199
13	Urgent delivery	0.0149
14	Capital investment	0.0126
15	Capital and banking history	0.0122
16	Package	0.0115
17	Discount	0.0098
18	Profit/sale trends	0.0077
19	ISO 14000 certified	0.0076
20	Quantity problem	0.0074
21	Top management committee	0.006
22	Product range	0.0056
23	Procedural compliment	0.0037
24	Infrastructure	0.0036
25	Product Variety	0.0027
26	Turn-over	0.0026
27	Waste management	0.0023
28	Technical problem solving	0.0021
29	Interest on payment	0.0017
30	Machinery	0.0014
31	Layout	0.0011
32	Product line	0.0007

Table 6. “Ranking of sub sub-critical”.

The ranking list of factors can be seen that cost and quality factors occupy the top-most ranking in the list, the top rank being the net price (0.3231), followed by Percentage late delivery (0.0853), and Customer rejecter (0.085). The Financial Factors that are in the top ten ranking include only Finance stability (0.0318).

Step 5: Measure supplier performance

Evaluating the alternative suppliers according to the used model to select the best supplier is the next step. Every supplier has to be evaluated factor by factor by the purchasing team in order to get the total score of all factors. Because there is not real data of alternatives available, given data were used to calculate the global weights of each alternative. After finding the local weights of each alternative, the global weights of each alternative in each level can be calculated. The global weights evaluation of each alternative can be obtained through multiplying the global weights of sub sub-criteria by the local weights of each alternative. The results and priority weight for each alternative are shown in Table 7. (Appendix 3) illustrates the calculations of the alternatives.

Step 6: Identify supplier priority and selection

Based on the global priority, weights of each alternative can be evaluated and summarized. The summaries of overall attributes are shown in Table 7. It can be noted that among the four given suppliers, supplier "A" has the highest weight.

Critical success factors for supplier selection	Global weights	Supplier (A)		Supplier (B)		Supplier (C)		Supplier (D)	
		Local weights	Global weights	Local weights	Global weights	Local weights	Global weights	Local weights	Global weights
Net price	0.3231	0.32	0.1034	0.21	0.0679	0.29	0.0937	0.18	0.0582
Delivery cost	0.0571	0.28	0.0160	0.22	0.0126	0.18	0.0103	0.32	0.0183
Ordering cost	0.0504	0.41	0.0207	0.17	0.0086	0.23	0.0116	0.19	0.0096
Capital investment	0.0126	0.11	0.0014	0.36	0.0045	0.25	0.0032	0.28	0.0035
Customer rejecter	0.0850	0.19	0.0162	0.25	0.0213	0.39	0.0332	0.17	0.0145
Warranty	0.0758	0.34	0.0258	0.13	0.0099	0.19	0.0144	0.34	0.0258
ISO 9000	0.0528	0.17	0.0090	0.24	0.0127	0.14	0.0074	0.45	0.0238
Package	0.0115	0.25	0.0029	0.23	0.0026	0.31	0.0036	0.21	0.0024
Customer focus	0.0320	0.43	0.0138	0.23	0.0074	0.17	0.0054	0.17	0.0054
Top management committee	0.0060	0.32	0.0019	0.39	0.0023	0.19	0.0011	0.1	0.0006
Percentage late delivery	0.0853	0.24	0.0205	0.21	0.0179	0.31	0.0264	0.24	0.0205
Delivery lead time	0.0284	0.36	0.0102	0.35	0.0099	0.14	0.0040	0.15	0.0043
Location	0.0201	0.11	0.0022	0.17	0.0034	0.32	0.0064	0.4	0.0080
Urgent delivery	0.0149	0.19	0.0028	0.18	0.0027	0.29	0.0043	0.34	0.0051
Quantity problem	0.0074	0.21	0.0016	0.25	0.0019	0.29	0.0021	0.25	0.0019
Honesty	0.0199	0.17	0.0034	0.27	0.0054	0.35	0.0070	0.21	0.0042
Procedural compliment	0.0037	0.26	0.0010	0.29	0.0011	0.27	0.0010	0.18	0.0007
ISO 14000 certified	0.0076	0.41	0.0031	0.32	0.0024	0.13	0.0010	0.14	0.0011
Waste management	0.0023	0.24	0.0006	0.14	0.0003	0.34	0.0008	0.22	0.0005
Product range	0.0056	0.26	0.0015	0.24	0.0013	0.36	0.0020	0.14	0.0008
Technical problem solving	0.0021	0.16	0.0003	0.19	0.0004	0.27	0.0006	0.38	0.0008
Infrastructure	0.0036	0.19	0.0007	0.24	0.0009	0.24	0.0009	0.33	0.0012
Machinery	0.0014	0.36	0.0005	0.16	0.0002	0.24	0.0003	0.24	0.0003
Layout	0.0011	0.14	0.0002	0.12	0.0001	0.29	0.0003	0.45	0.0005
Product Variety	0.0027	0.31	0.0008	0.28	0.0008	0.29	0.0008	0.12	0.0003
Product line	0.0007	0.32	0.0002	0.24	0.0002	0.31	0.0002	0.13	0.0001
Finance stability	0.0318	0.26	0.0083	0.25	0.0080	0.31	0.0099	0.18	0.0057
Capital and banking history	0.0122	0.19	0.0023	0.29	0.0035	0.17	0.0021	0.35	0.0043
Profit/sale trends	0.0077	0.26	0.0020	0.21	0.0016	0.34	0.0026	0.19	0.0015
Discount	0.0098	0.19	0.0019	0.34	0.0033	0.21	0.0021	0.26	0.0025
Turn-over	0.0026	0.31	0.0008	0.11	0.0003	0.29	0.0008	0.29	0.0008
Interest on payment	0.0017	0.24	0.0004	0.17	0.0003	0.23	0.0004	0.36	0.0006
Total Scores		0.2760		0.2155		0.2597		0.2275	

Table 7. “Summarizes of priority weights of each alternative”

Therefore, it may be selected as the best supplier to satisfy the goals and objectives of the ABC Company. Table 6 shows the final score of each supplier s' results and ranking. As can be seen, supplier As’ score of (0.2760) is greater than the other three suppliers' scores such as supplier B (0.2155), supplier C (0.2597), and supplier D (0.2275). Even though the submitted quotations were close, the model could select the best supplier among them. Global weights of net price that has the highest weight among criteria (0.3231) gives supplier A priority to be the best supplier when he achieved (0.1034) in this criteria as global weights. Even though supplier D has lower value in the net price criterion than supplier B, it got the higher total score. Therefore, it is a major criterion to select the right supplier but it is not the only once.

In short, the developed model helps to choose the right supplier. It consists of many steps which are in order defining criteria for supplier selection, defining sub-criteria and sub sub-criteria, structuring the hierarchical model, prioritizing the order of criteria, measuring supplier performance, and identifying supplier priority and selection.

5- Conclusion

The issues of supplier selection have attracted the interest of researchers since the 1960s, and research in this area has evolved. Continuing the previous works in supplier selection area, the work has successfully achieved its objectives.

The main contribution of the work was the identification of the important criteria for the supplier selection process. Then a multi-criteria decision model for evaluating and selecting a supplier was developed. The model for supplier evaluation and selection was developed using the AHP method. The AHP model is assessing decision-makers to identify and evaluate the supplier selection.

Finally, the developed model is tested on four supplier selection problems. The results show the models are able to assist decision-makers to examine the strengths and weaknesses of supplier selection by comparing them with appropriate criteria, sub-criteria and sub sub-criteria.

The developed model has not been implemented yet. It is just tested on four supplier selection problems as mentioned, but the outcome implies that the price criterion has the majority weight among other criteria. That’s suitable for using in ABC Company who uses the only price criterion to select and evaluate suppliers. Even though it was given the highest weight to the price the other criteria were given unbiased weights. In other words, every criterion had been given what was deserved weight in order to achieve the best method to select the right supplier. In addition, ABC Company could be satisfied when using the developed model that gives the price criterion unbiased ability to evaluate

suppliers. Choosing the right supplier could give the right quantity and the right cost on the right timeline.

Suggestions for Additional Work

This work is focused on selecting a supplier by using the AHP approach. In the future this inquisition method can be generalized to all the ABC Company's branches to facilitate the supplier selection.

Furthermore, another approach using multi-criteria decision to evaluate and select an appropriate contractor should be investigated for future work.

Appendix 1. Various selection criteria that have emerged in literature (Ha and Krishnan, 2008)

Selection criteria	A	B	C	D	E	F	G	H	I	J
Price	✓	✓	✓	✓	✓	✓	✓		✓	✓
Quality	✓	✓		✓		✓	✓		✓	
Delivery	✓	✓	✓	✓		✓	✓		✓	
Warranties and claims	✓		✓							
After sales service	✓		✓		✓		✓			
Technical support			✓		✓	✓				
Training aids	✓		✓				✓			
Attitude	✓				✓		✓			
Performance history	✓						✓			
Financial position	✓		✓				✓			
Geographical location	✓	✓		✓			✓			
Management and organization	✓			✓			✓			
Labor relations	✓						✓			
Communication system	✓						✓			
Response to customer request			✓			✓				
E-commerce capability								✓	✓	✓
JIT capability						✓		✓		
Technical capability	✓	✓					✓	✓		
Production facilities and capacity	✓						✓			
Packaging ability	✓						✓			
Operational controls	✓						✓			
Ease-of-use			✓		✓					
Maintainability			✓		✓					
Amount of past business	✓	✓	✓				✓			
Reputation and position in industry	✓	✓	✓		✓		✓			
Reciprocal arrangements	✓	✓		✓			✓			
Impression	✓		✓		✓		✓			
Environmentally friendly products									✓	
Product appearance										✓

A, Dickson (1966); B, Wind et al. (1968); C, Lehmann and O'Shaughnessy (1974); D, Perreault and Russ (1976); E, Abratt (1986); F, Billesbach et al. (1991); G, Weber et al. (1991); H, Segev et al. (1998); I, Min and Galle (1999); J, Stavropolous (2000).

Appendix 2. Calculation of the matrix

Criteria	Cost	Weight	Weight (used)
Cost	1	0.465116279	0.465
Quality	0.5	0.23255814	0.233
Delivery	0.25	0.11627907	0.116
Management and Organization	0.2	0.093023256	0.093
Financial	0.2	0.093023256	0.093
Total	2.15	1	1

Criteria	Quality	Weight	Weight (used)
Cost	2	0.5	0.5
Quality	1	0.25	0.25
Delivery	0.5	0.125	0.125
Management and Organization	0.25	0.0625	0.062
Financial	0.25	0.0625	0.062
Total	4	1	0.999

Criteria	Delivery	Weight	Weight (used)
Cost	4	0.5	0.5
Quality	2	0.25	0.25
Delivery	1	0.125	0.125
Management and Organization	0.5	0.0625	0.062
Financial	0.5	0.0625	0.062
Total	8	1	0.999

Criteria	Management and Organization	Weight	Weight (used)
Cost	5	0.4	0.4
Quality	4	0.32	0.32
Delivery	2	0.16	0.16
Management and Organization	1	0.08	0.08
Financial	0.5	0.04	0.04
Total	12.5	1	1

Criteria	Financial	Weight	Weight (used)
Cost	5	0.357142857	0.357
Quality	4	0.285714286	0.286
Delivery	2	0.142857143	0.143
Management and Organization	2	0.142857143	0.143
Financial	1	0.071428571	0.071
Total	14	1	1

Appendix 3. Calculation of the alternatives

Supplier A

Sub sub-criteria	Global Weights	criteria evaluation	achieved weight
Net price	0.3231	0.32	0.1034
Delivery cost	0.0571	0.28	0.0160
Ordering cost	0.0504	0.41	0.0207
Capital investment	0.0126	0.11	0.0014
Customer rejecter	0.085	0.19	0.0162
Warranty	0.0758	0.34	0.0258
ISO 9000	0.0528	0.17	0.0090
Package	0.0115	0.25	0.0029
Customer focus	0.032	0.43	0.0138
Top management	0.006	0.32	0.0019
Percentage late delivery	0.0853	0.24	0.0205
Delivery lead time	0.0284	0.36	0.0102
Location	0.0201	0.11	0.0022
Urgent delivery	0.0149	0.19	0.0028
Quantity problem	0.0074	0.21	0.0016
Honesty	0.0199	0.17	0.0034
Procedural compliment	0.0037	0.26	0.0010
ISO 14000 certified	0.0076	0.41	0.0031
Waste management	0.0023	0.24	0.0006
Product range	0.0056	0.26	0.0015
Technical problem solving	0.0021	0.16	0.0003
Infrastructure	0.0036	0.19	0.0007
Machinery	0.0014	0.36	0.0005
Layout	0.0011	0.14	0.0002
Product Variety	0.0027	0.31	0.0008
Product line	0.0007	0.32	0.0002
Finance stability	0.0318	0.26	0.0083
Capital and banking history	0.0122	0.19	0.0023
Profit/sale trends	0.0077	0.26	0.0020
Discount	0.0098	0.19	0.0019
Turn-over	0.0026	0.31	0.0008
Interest on payment	0.0017	0.24	0.0004
Total			0.2760

Supplier B

Sub sub-criteria	Global Weights	criteria evaluation	achieved weight
Net price	0.3231	0.21	0.0679
Delivery cost	0.0571	0.22	0.0126
Ordering cost	0.0504	0.17	0.0086
Capital investment	0.0126	0.36	0.0045
Customer rejecter	0.085	0.25	0.0213
Warranty	0.0758	0.13	0.0099
ISO 9000	0.0528	0.24	0.0127
Package	0.0115	0.23	0.0026
Customer focus	0.032	0.23	0.0074
Top management	0.006	0.39	0.0023
Percentage late delivery	0.0853	0.21	0.0179
Delivery lead time	0.0284	0.35	0.0099
Location	0.0201	0.17	0.0034
Urgent delivery	0.0149	0.18	0.0027
Quantity problem	0.0074	0.25	0.0019
Honesty	0.0199	0.27	0.0054
Procedural compliment	0.0037	0.29	0.0011
ISO 14000 certified	0.0076	0.32	0.0024
Waste management	0.0023	0.14	0.0003
Product range	0.0056	0.24	0.0013
Technical problem solving	0.0021	0.19	0.0004
Infrastructure	0.0036	0.24	0.0009
Machinery	0.0014	0.16	0.0002
Layout	0.0011	0.12	0.0001
Product Variety	0.0027	0.28	0.0008
Product line	0.0007	0.24	0.0002
Finance stability	0.0318	0.25	0.0080
Capital and banking history	0.0122	0.29	0.0035
Profit/sale trends	0.0077	0.21	0.0016
Discount	0.0098	0.34	0.0033
Turn-over	0.0026	0.11	0.0003
Interest on payment	0.0017	0.17	0.0003
Total			0.2155

Supplier C

Sub sub-criteria	Global Weights	criteria evaluation	achieved weight
Net price	0.3231	0.29	0.0937
Delivery cost	0.0571	0.18	0.0103
Ordering cost	0.0504	0.23	0.0116
Capital investment	0.0126	0.25	0.0032
Customer rejecter	0.085	0.39	0.0332
Warranty	0.0758	0.19	0.0144
ISO 9000	0.0528	0.14	0.0074
Package	0.0115	0.31	0.0036
Customer focus	0.032	0.17	0.0054
Top management	0.006	0.19	0.0011
Percentage late delivery	0.0853	0.31	0.0264
Delivery lead time	0.0284	0.14	0.0040
Location	0.0201	0.32	0.0064
Urgent delivery	0.0149	0.29	0.0043
Quantity problem	0.0074	0.29	0.0021
Honesty	0.0199	0.35	0.0070
Procedural compliment	0.0037	0.27	0.0010
ISO 14000 certified	0.0076	0.13	0.0010
Waste management	0.0023	0.34	0.0008
Product range	0.0056	0.36	0.0020
Technical problem solving	0.0021	0.27	0.0006
Infrastructure	0.0036	0.24	0.0009
Machinery	0.0014	0.24	0.0003
Layout	0.0011	0.29	0.0003
Product Variety	0.0027	0.29	0.0008
Product line	0.0007	0.31	0.0002
Finance stability	0.0318	0.31	0.0099
Capital and banking history	0.0122	0.17	0.0021
Profit/sale trends	0.0077	0.34	0.0026
Discount	0.0098	0.21	0.0021
Turn-over	0.0026	0.29	0.0008
Interest on payment	0.0017	0.23	0.0004
Total			0.2597

Supplier D

Sub sub-criteria	Global Weights	criteria evaluation	achieved weight
Net price	0.3231	0.18	0.0582
Delivery cost	0.0571	0.32	0.0183
Ordering cost	0.0504	0.19	0.0096
Capital investment	0.0126	0.28	0.0035
Customer rejecter	0.085	0.17	0.0145
Warranty	0.0758	0.34	0.0258
ISO 9000	0.0528	0.45	0.0238
Package	0.0115	0.21	0.0024
Customer focus	0.032	0.17	0.0054
Top management	0.006	0.1	0.0006
Percentage late delivery	0.0853	0.24	0.0205
Delivery lead time	0.0284	0.15	0.0043
Location	0.0201	0.4	0.0080
Urgent delivery	0.0149	0.34	0.0051
Quantity problem	0.0074	0.25	0.0019
Honesty	0.0199	0.21	0.0042
Procedural compliment	0.0037	0.18	0.0007
ISO 14000 certified	0.0076	0.14	0.0011
Waste management	0.0023	0.22	0.0005
Product range	0.0056	0.14	0.0008
Technical problem solving	0.0021	0.38	0.0008
Infrastructure	0.0036	0.33	0.0012
Machinery	0.0014	0.24	0.0003
Layout	0.0011	0.45	0.0005
Product Variety	0.0027	0.12	0.0003
Product line	0.0007	0.13	0.0001
Finance stability	0.0318	0.18	0.0057
Capital and banking history	0.0122	0.35	0.0043
Profit/sale trends	0.0077	0.19	0.0015
Discount	0.0098	0.26	0.0025
Turn-over	0.0026	0.29	0.0008
Interest on payment	0.0017	0.36	0.0006
Total			0.2275

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