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## Original Research

# Modeling and Analysis of Supplier Selection Method Using Analytical Hierarchy Process (AHP)

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Abstract	Article Information
<p>This research paper deals with the development of supplier selection methodology for an organization. In today's dynamic environment supplier selection decision presents organizations with a complex scenario and the age old tradition of selecting suppliers based on solitary criteria, mainly price and the practice of engaging in adversarial relation with suppliers is only history. Supplier evaluation and selection is recognized as a multi-criteria decision problem and the use of analytical and mathematical models is highly emphasized by professionals and researchers alike. However, in these parts of the world the application of tools and models for supplier selection problem is yet to surface and the banking and finance industry here in Ethiopia is no exception. Thus, the purpose of this research was to address supplier selection problem through modeling and application of analytical hierarchy process (AHP). As the result a model was developed via AHP and run using a historical data from AIB's (Awash International Bank S.C.) generator purchase and the result indicated that quality/technical has higher rank (46%), price/cost (25%), and followed by after sale service (11%). Furthermore, delivery, financial position and reputation have all equal importance and attribute 6% each. The use of such technique will reduce the level of subjectivity in supplier evaluation and selection, and allows one to reach an optimal selection decision.</p>	<p><b>Article History:</b>  <b>Received</b> : 20-01-2014  <b>Revised</b> : 15-03-2014  <b>Accepted</b> : 20-03-2014</p> <p><b>Keywords:</b>            Analytical Hierarchy Process            Multi-Criteria Decision Making            Supplier Selection</p>
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## INTRODUCTION

Multiple-criteria decision making (MCDM) is considered as one of the rapidly growing areas of operations research dedicated to the provision of mathematical and analytical tools or mechanisms to tackle complex problems involving multiple criteria, goals, or objectives of conflicting nature. One of such Decision Support System (DSS) techniques is analytic hierarchy process (AHP) which enables users to solve a complex problem reducing it into simple pairwise permutation and comparisons of criteria. AHP was invented by Thomas Saaty (Helms, 2006).

Moreover, Saaty, is internationally recognized for invention of Analytic Hierarchy Process (AHP) and its generalization to network decisions, the Analytic Network Process (ANP) (Saaty, 2008).

Dong, Xu, Li and Dai (2007), also acknowledge Saaty's contribution to development analytic hierarchy process (AHP) and further state that AHP is being widely applied in the past two decades in almost all decision making situations that had involved multiple criteria.

Amid the area of application for AHP is the supplier selection problem which involves multiple-criteria viz qualitative and quantitative variables and hence, number

of studies had surfaced in recent years in relation to supplier selection problem using AHP (e.g. Ayhan, 2013; Chakraborty, Ghosh and Dan, 2011, Onder and Dag, 2013; Politis, Klumpp and Celebi, 2010; Prusak, Stefanów, Niewczas, and Sikora, 2013).

Aktepe and Ersoz (2011) noted that numerous extant studies using AHP to solve supplier selection problem had used different terminologies such as supplier selection, evaluation and development as their topic for investigations which apparently had dealt was similar issues and virtually considered identical in meaning.

According to Tahriri, Osman, Ali and Yusuff (2008), AHP is the most commonly used tool for supplier selection problem as compared to several other mathematical as well as analytical tools. This claim is also supported by a number of other studies (e.g. Ayhan, 2013; Chakraborty, Ghosh and Dan, 2011, Onder and Dag, 2013; Politis, Klumpp and Celebi, 2010; Prusak, Stefanów, Niewczas, and Sikora, 2013).

Thus, the purpose of this case study was to develop a model for supplier selection for Awash International Bank S.C. (AIB) which is a market leader in the private banking industry here in Ethiopia.

### Analytic Hierarchy Process (AHP)

According to Tahri, Osman, Ali and Yusuff (2008) who have made a review of supplier selection methods Analytical Hierarchical Process (AHP) rated as most widely used, easily understood and the best to combine both objective as well as subjective decisions. Moreover, they point out that the method employed for decision making can have a significant impact on the decision reached.

They further elucidate that, there are several well known selection methods that have been developed and classified by numerous scholars over the years: the categorical model, the weighted point model, Total cost approaches or the cost ratio method (Principal Component Analysis (PCA) and the Artificial Neural Network (ANN)), the Multiple Attribute Utility Theory (MAUT) method, Fuzzy logic approach and Analytical Hierarchical Process (AHP).

An extensive review of the supplier selection literature shows that among the methods mentioned in the preceding paragraph AHP is found to be one of the most commonly applied methods in practice (Tahri, et. al, 2008).

Politis, Klumpp and Celebi, (2010) also support the position of Tahri, et. al, (2008) that AHP provides a well-substantiated and easily comprehensible solution to supplier selection problem which makes it the most reliable decision making tool especially for groups decision making.

In addition, Chakraborty, Ghosh and Dan (2011) further support the idea that AHP has been widely recognized as supplier selection tool for decades (Narasimhan, 1983; Nydick et al., 1992; Partovi et al., 1989) attributing such popularity and recognition to the tools unique capability to deal with both quantifiable as well as unquantifiable criteria.

Further, Prusak, Stefanów, Niewczas, and Sikora (2013) labeled AHP as a superior model as compared to the DEA (Data Envelopment Analysis), MAUT (Multi-attribute utility theory), TCO (Total cost of ownership) and statistical models; particularly, because of its simplicity, flexibility and availability of dedicated software to make quick calculation.

Ayhan (2013), who had also reviewed numerous extant literatures, makes distinction of methodologies used for supplier selection problem categorizing them as the best, most important and outranked. According to this classification AHP and MAUT are considered the best, while, Goal Programming and Topsis as most important and ELECTRE and PROMETHEE as the outranked methods.

Therefore, based on the preceding discussions it is evident that numerous accounts proclaim AHP as the best tool for decision making in supplier selection problem and this makes the basis for selecting this multiple criteria decision making tool for this particular case study.

### Decision Criteria and Alternatives

Different studies have considered various criteria and variable range of alternatives. However, taking the

procurement practice of AIB into account, almost all supplier selection problems involve at least three suppliers and preferably five or better. Therefore, an alternative of five has been adapted.

However, with regard to the criteria a review of literatures has been considered. The assessment of literatures revealed that variability in the criteria used is highly pronounced. For instance, Politis *et al.*, (2010) had used delivery and quality as selection criteria attaching 90% weight, while, Chakraborty *et al.*, (2011), considered cost, quality and delivery. Yet another variation can be Prusak, Stefanów, Niewczas, and Sikora (2013) who had adapted price, assortment, logistics, service and quality.

Further, Onder and Dag (2013) considered criteria such as origin of raw material, quality, delivery, cost, availability and reliability in a similar fashion Ayhan (2013) employed quality, origin, cost, delivery and after sales.

More comprehensively Prusak *et al.* (2013) indicated that most frequently discussed criteria are price account 80% of the 74 reviewed articles, delivery (59%) and quality (54%). Perhaps one highly regarded work in this respect is the study by Aktepe and Ersoz (2011) who have reviewed the works of several authors outlining thirty five criteria (table, 1).

The table shows the different criteria used by different researchers for supplier selection over the years. Hence, analysis of the table indicated that among the thirty five criteria used five of them were used by more than half the research works outlined above and half of them had used additional one criterion (after sales service) (Aktepe and Ersoz, 2011). Similarly, Benyoucef, Ding and Xie (2003) who make references to one of earliest works in supplier selection criteria developed by Dickson (also mentioned in the above table) rate quality and delivery as extremely important; price, financial position and reputation as considerably important and repair or after sales service as an averagely important criteria.

Thus the six commonly used factors for supplier evaluations extracted from literatures are price, quality, delivery, financial position, reputation and position in the industry and after sales service.

### MATERIALS AND METHODS

The type of research used for this study was case study which is a strategy of inquiry in whereby the researcher investigates in depth a program, activity or an event and collects a detailed information using a variety of data collection procedure over a sustainable period of time (Stake, 1995) as cited in (Creswell, 2009).

Hence, case study is considered for this research at least for three reasons; first, the purpose of the study is to investigate a single activity or process in business organization i.e. supplier selection process, second, the study was aimed at understanding the issue in depth, third, the study is restricted or limited to Awash International Bank's head office and finally, because case studies often use quantitative measures as pointed out by "yin and others (Glatthorn, 1998) and hence, this strategy fits very well with AHP since AHP considers both qualitative and quantitative criteria.

**Table 1:** List of criteria used in supplier selection problem

Criteria	Dickson	Lehmann	Abratt	Weber	Min	Stravropolous	Ghodsy-pour	Chan	Chen	Lin
Price	X	X	X	X	X	X	X	X		
Quality	X			X	X		X	X	X	
Delivery	X	X		X	X		X	X		
Warranties and Claims	X	X								
After Sales Service	X	X	X	X				X		
Technical Support		X	X					X		
Training Aids	X	X		X						
Attitude	X		X	X						
Performance History	X			X				X		
Financial Position	X	X		X				X	X	
Geographical Location	X			X				X		
Management and Organization	X			X						
Labor Relations	X			X						
Communication System	X			X				X		X
Response to Customer Request		X						X		
E-commerce Capability					X	X				
JIT Capability										
Technical Capability	X			X					X	
Production Facilities and Capacity	X			X			X	X		
Packaging Ability	X			X						
Operational Controls	X			X						
Ease-of-Use		X	X							
Maintainability		X	X							
Amount of Past Business	X	X		X						
Reputation and position in industry	X	X	X	X				X		X
Reciprocal Arrangements	X			X						
Impression	X	X	X	X						
Environmentally Friendly Products					X					
Product Appearance						X				
Catalog Technology						X				
Relationship Closeness									X	X
Conflict Resolution									X	X
Political Stability								X		
Economy								X		
Terrorism								X		

Source: Aktepe and Ersoz (2011)

Hence, focused group discussion to rate the pair wise comparison of six criteria's were made by AIB procurement and materials management unit.

Supplier selection and evaluation process represents a typical multi-criteria decision making that entails multiple criteria involving both qualitative and quantitative factors. AHP is chosen because it permits decision makers to model a complex problem into a hierarchical structure showing the linkage amid, goal, criteria, and alternatives (Enyinda, Dunu and Bell-Hanyes, 2010). Moreover, AHP has been widely used in supplier selection (e.g., Aktepe and Ersoz, 2011; Tahriri, et. al; Chakraborty, Ghosh and Dan, 2011 and Politis, Klump and Celebi, 2010).

Hence, the overall methodology adopted for supplier selection process in AIB was composed of three levels as depicted in Figure 1. At the structural apex there is the overall goal of the problem, whereas the middle level is poised of the multiple selection criteria and finally, at the bottom level of the structure there are contending alternative suppliers.

**Procedure for Application of AHP Model**

To apply an AHP the following standard algorithms were employed which consists six steps with sub procedures.

**Step 1:** The problem is selecting the best supplier among five alternative suppliers which are A, B, C, D and E equipment suppliers of Awash International Bank S.C. The best alternative supplier must be selected according to six criteria which are six most addressed criteria in the literature (Aktepe and Ersoz, 2011) price/cost, quality/technical, delivery time, financial position, reputation and position in the industry and after sales service.

**Step 2:** Developing the hierarchical structure of the problem, as show on figure 1.

**Step 3:** The Saaty's scale of comparisons in a multi-criteria decision making area in this study is given in Table 2.

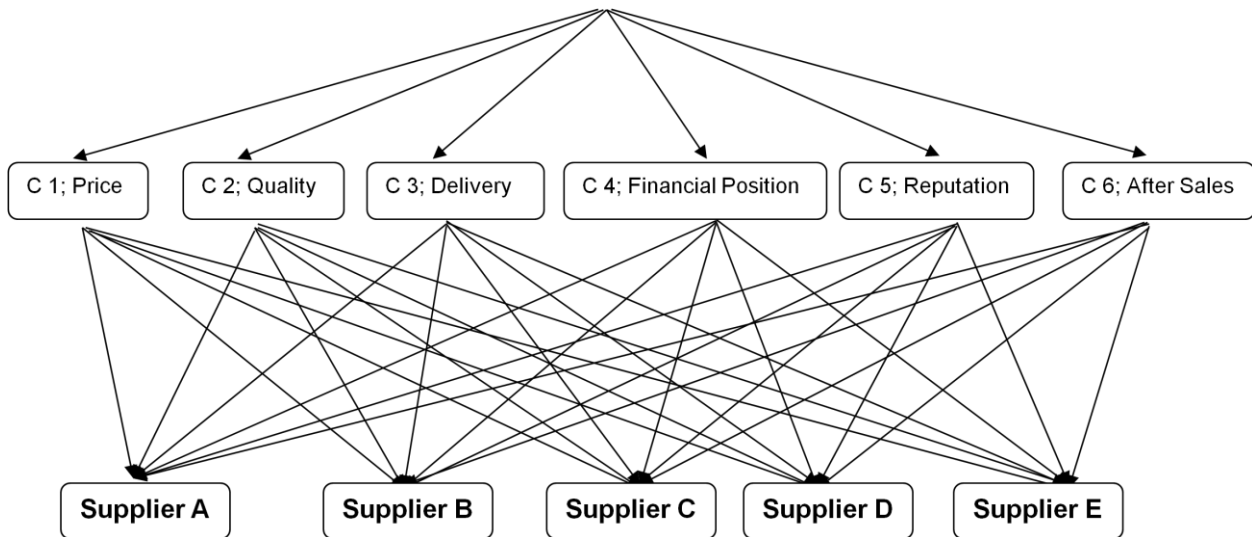


Figure 1: Hierarchical structure of the problem.

Table 2: The Saaty’s scale of comparisons in a multi-criteria decision making.

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favors one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favors one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	A reasonable assumption
1.1–1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

Source: (Saaty *et al.*, 2008)

Adoption of Saaty’s scale is well supported by the study conducted by Kumar and Ganesh (1996) cited in Dong, Xu, Li and Dai (2007) which had compared different numerical scales and prioritizations and the result revealed that that prioritizations using the eigenvalue method (EVM) is better than the logarithmic least squares methods (LLSM) using the simulation method of Triantaphyllou and Mann (1990).

**Step 4:** Construct a set of pair-wise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it (Saaty *et al.*, 2008).

**Step 5:** (Perform consistency check) Prof. Saaty proved that for consistent reciprocal matrix, the largest Eigen value is equal to the size of comparison matrix, or  $\max \lambda = n$ . Then he gave a measure of consistency, called

Consistency Index as deviation or degree of consistency using the following formula (www.Revoledu.com).

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

Then, he proposed what is called Consistency Ratio, which is a comparison between Consistency Index and Random Consistency Index, or in formula, (www.Revoledu.com).

$$CR = \frac{CI}{RI}$$

If the value of Consistency Ratio is smaller or equal to 10%, the inconsistency is acceptable. If the Consistency Ratio is greater than 10%, we need to revise the subjective judgment however, in practice, you don’t need RI for more than  $n=7$  because the number of pair comparisons  $n*(n-1)/2$  become so large. Final, we utilize

the hierarchy by grouping some criteria into a higher level hierarchy of the criteria (table 3 and 4).

For the particular problem structure the numbers of comparisons are 15 which are calculated as follows.

$$N = \frac{6(6-1)}{2} = 30/2 = 15$$

**Table 3:** Number of comparison

Number of Criteria	1	2	3	4	5	6	7	N
Number of comparison	0	1	3	6	10	15	21	$\frac{n(n-1)}{2}$

**Table 4:** Random Index (R.I).

Matrix Size	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

The Random Index (R.I) shown in table 4 contains the random index values calculated from randomly generated weights as a function of the pair-wise matrix size or number of criteria (Ravindran, 2009).

**Step 6:** Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained (Saaty *et al.*, 2008).

**RESULTS**

The hierarchical structure of the supplier selection model is shown in figure 1. As per the procurement practice of AIB, five alternative suppliers A, B, C, D and E whose names are not mentioned for confidentiality are considered and six criteria were adopted for evaluation that are quality, price, delivery, financial position, reputation and after sales service.

The pair-wise comparison matrix shown in table 5 is scored by the AIB's procurement and materials management unit using the given questioner and focused group discussion.

**Table 5:** Pairwise Comparison matrix for the six criteria.

	Price/Cost	Quality/Technical	Delivery	Financial position	Reputation	After sales service
Price/Cost	1	1/3	5	5	5	3
Quality/Technical	3	1	7	7	7	4
Delivery	1/5	1/7	1	1	1	1/2
Financial Position	1/5	1/7	1	1	1	1/2
Reputation	1/5	1/7	1	1	1	1/2
After sales service	1/3	1/4	2	2	2	1
Total	74/15	169/54	17	17	17	19/2

The synthesized matrix for the six supplier selection criteria is shown in Table 6. For example, the priority vector associated with price is obtained as follows:  $(0.2027 + 0.1657 + 0.2941 + 0.2941 + 0.3158)/6 = 0.2611$ .

The reminder of the priorities for quality/ technical, delivery, financial position, reputation and after sales are 0.4602, 0.0568, 0.0568, 0.0568 and 0.1083 respectively.

**Table 6:** Synthesized (or Normalized) Matrix for the Six Criteria.

	Price/Cost	Quality/Technical	Delivery	Financial position	Reputation	After sales service	Priority
Price/Cost	0.2027	0.1657	0.2941	0.2941	0.2941	0.3158	0.2611
Quality/ Technical	0.6081	0.4970	0.4118	0.4118	0.4118	0.4211	0.4602
Delivery	0.0405	0.0710	0.0588	0.0588	0.0588	0.0526	0.0568
Financial position	0.0405	0.0710	0.0588	0.0588	0.0588	0.0526	0.0568
Reputation	0.0405	0.0710	0.0588	0.0588	0.0588	0.0526	0.0568
After sales service	0.0676	0.1243	0.1176	0.1176	0.1176	0.1053	0.1083
Sum							1.0000

Tables 7-12 show the pairwise comparison matrices of five suppliers with respect to each criterion and priorities. This process is similar to the procedure used to create the criteria comparison matrix. For example, the purchasing and materials management section head compare each pair of suppliers with respect to price/cost,

quality/technical, delivery, reputation, after sales service and financial position. And the priorities of the suppliers, for each criterion, derived employing the four steps procedure identified in the procedure for application section.

**Table 7:** Pairwise comparison with respect to price/cost

Price/Cost	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Priority
Supplier A	1	2	2	1/3	1	0.1717
Supplier B	1/2	1	1	1/5	1/2	0.0891
Supplier C	1/2	1	1	1/5	1/2	0.0891
Supplier D	3	5	5	1	3	0.4786
Supplier E	1	2	2	1/3	1	0.1717
<b>Sum</b>						<b>1.0000</b>

**Table 8:** Pairwise comparison with respect to quality/technical.

Quality/technical	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Priority
Supplier A	1	1	3	3	5	0.3474
Supplier B	1	1	3	3	5	0.3474
Supplier C	1/3	1/3	1	1	2	0.1202
Supplier D	1/3	1/3	1	1	2	0.1202
Supplier E	1/5	1/5	1/2	1/2	1	0.0648
<b>Sum</b>						<b>1.0000</b>

**Table 9:** Pairwise comparison with respect to delivery.

Delivery	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Priority
Supplier A	1	1/3	1	1/3	1/3	0.1251
Supplier B	3	1	3	1	1	0.3754
Supplier C	1	1/3	1	1/3	1/3	0.1251
Supplier D	1/3	1	1/3	1	1	0.1872
Supplier E	1/3	1	1/3	1	1	0.1872
<b>Sum</b>						<b>1.0000</b>

**Table 10:** Pair wise comparison with respect to financial position.

Financial Position	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Priority
Supplier A	1	3	1	5	5	0.3642
Supplier B	1/3	1	1/3	2	2	0.1309
Supplier C	1	3	1	5	5	0.3642
Supplier D	1/5	1/2	1/5	1	1	0.0703
Supplier E	1/5	1/2	1/5	1	1	0.0703
<b>Sum</b>						<b>1.0000</b>

**Table 11:** Pair wise comparison with respect to reputation.

Reputation	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Priority
Supplier A	1	3	1	5	5	0.3642
Supplier B	1/3	1	1/3	2	2	0.1309
Supplier C	1	3	1	5	5	0.3642
Supplier D	1/5	1/2	1/5	1	1	0.0703
Supplier E	1/5	1/2	1/5	1	1	0.0703
<b>Sum</b>						<b>1.0000</b>

**Table 12:** Pair wise comparison with respect to after sales.

After Sales	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Priority
Supplier A	1	5	1	5	5	0.5197
Supplier B	1/5	1	1/5	1	1	0.1039
Supplier C	1	1/5	1	1/5	1/5	0.1685
Supplier D	1/5	1	1/5	1	1	0.1039
Supplier E	1/5	1	1/5	1	1	0.1039
<b>Sum</b>						<b>1.0000</b>

**Table 13:** Priority matrix of supplier selection alternatives.

	Supplier A	Supplier B	Supplier C	Supplier D	Supplier E	Preference Vector
Price/Cost	0.1717	0.0891	0.0891	0.4780	0.1717	0.2610
Quality/ Technical	0.3474	0.3474	0.1202	0.1202	0.0648	0.4602
Delivery	0.1251	0.3754	0.1251	0.1872	0.1872	0.0568
Financial position	0.3642	0.1309	0.3642	0.0703	0.0703	0.0568
Reputation	0.3642	0.1309	0.3642	0.0703	0.0703	0.0568
After sales service	0.5197	0.1039	0.1685	0.1039	0.1039	0.1113
<b>Overall Priority Vector</b>	<b>0.31</b>	<b>0.23</b>	<b>0.15</b>	<b>0.21</b>	<b>0.10</b>	<b>1.00</b>

With respect to the overall priority scores of alternative suppliers it is obtained by calculating overall priority or global priorities of supplier. To calculate supplier A's global priority A, Global priority A =  $0.1717(0.2611) + 0.13474(0.4602) + 0.1251(0.0568) + 0.3642(0.0568) + 0.3642(0.0568) + 0.5197(0.1083) = 0.31$  By doing similar algorithms for all suppliers results in global priority B = 0.23, global priority C = 0.15, global priority D = 0.21, and global priority E = 0.10.

Hence, supplier A with global priority equal to 0.31 is most preferred followed by supplier B (0.23), supplier D (0.21), supplier C (0.15) and supplier E (0.1), respectively. That is, supplier A > supplier B > supplier D > supplier C > supplier E. Essentially, supplier A is judged to be the overall best.

## DISCUSSION

The criteria rating practice at AIB revealed that quality/technical is rated higher than any of six criteria considered for evaluation and selection. This practice of assigning the highest weight for quality is well supported by several other studies (Chakraborty *et al.*, 2011; Politis, *et al.*, 2010; Hudymáčová *et al.*, 2010).

The result also indicated that supplier "A" is most preferred to all other suppliers which is the same as the decision made by the procurement and materials management unit of AIB. However, contrary to the decision of the procurement unit are suppliers "C" and "D" which are ranked in reversed orders as fourth and third preferred suppliers respectively. Nonetheless it has to be noted that current procedure for supplier selection at AIB is nearly perfectly matches with the result obtained using AHP.

Another point worth mentioning here can be the recreation by the procurement and materials management unit to the tool: the unit indicated that AHP is an easier tool to use as compared to the traditional method of scoring but more importantly, it reduces the subjectivity involved.

## CONCLUSION

The research had introduced and demonstrated the use of analytical hierarchy process (AHP) for supplier selection in the banking industry. It is believed that AHP is quiet a powerful model particularly in multi-criteria decision making. Given the complexity of the problem in supplier selection especially in large purchases AHP can be considered as an ideal tool. However, it was evident that AIB's procurement unit was unfamiliar AHP and arguably the Ethiopian banking industry.

Hence, the mission is to introduce the concept had been successful. Moreover, it ensure the validity of the measurement of criteria for supplier evaluation and selection criteria had been extracted from literatures and further a historical data from AIB's generator procurement was employed for application. The result indicated that the unit uses similar mechanisms that sharply correspond to AHP thus the introduction of AHP would help formalize their effort. To this end AIB's procurement unit is considering the use of AHP with collaboration of its technique department which takes the leading position in criteria development.

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