Facility Location Selection For Seasonal Product: A Case Study For New Business And A Comparative Study Of AHP And ANP

Shahed Mahmud, Dewan Sabbir Ahammed Rayhan, Tanvir Ahamed

Abstract: Decision making and choosing the right decision is one of the main activities of businessmen. Taking a decision without proper knowledge and methods the performance of the business will reduce and businessmen will fail to earn optimum profit. Facility location selection is the fast and foremost decision of businessmen when starting a new supplying business. Without a proper, accurate and standard method for selecting the most profitable facility location for supplier business, the performance of this business will affect. Rajshahi is a city of mangoes in Bangladesh and a seasonal business of mangoes held here every year. Supplying of mangoes can become a profitable business by selecting the best location for supplying mangoes to the different areas of the country. But due to the wrong selection of the location, most suppliers fail to earn the maximum profit. The objective of this case study is to provide a decision support system to select the facility location for mango supplying business. Moreover, for conducting this investigation a survey data is collected of 37 samples to identify the criteria and sub-criteria of the mango supplying business. In order to resolve the case, AHP and ANP the two MCDM techniques are used for resolving this decision making problem. This investigation also demonstrates a brief look at the foundation of AHP and ANP and their major differences.

Keywords: AHP, ANP, Methodology, Problem structure and Solution, Facility location selection for seasonal mango business.

1. Introduction

FACILITY location selection is one of the main essential decisions made by the supplier before starting a business. Without selecting the facility location a supplier can't success in his supplying business. In this paper it has been shown how AHP and ANP work and apply those two methods for selecting a facility location for a new business. The objective of this study is to select facility location in which a supplier can earn maximum profit by supplying mangoes in different regions of a country. Rajshahi is a city of mangoes in Bangladesh. Every year a huge amount of mangoes grow here. But those mangoes can't be supplied in the other cities properly due to the lack of proper experience and capability of decision making. The suppliers or businessmen in Rajshahi city can't know which area is best for supplying mangoes so that they can earn the maximum profit from this seasonal mango business. This problem is identified as a multi-criteria decision making problem. Firstly, this problem is divided into multiple-criteria and those criteria have divided into many sub-criteria also. This problem can be resolved by using the Multi-criteria Decision Making Methods shortly known as the MCDM tool. A scientific and standard decision making process can be recognized by [3];

- Identifying and understanding the problem,
- Gathering the quantitative data,
- Analyzing using appropriate scientific models,
- Structuring the alternatives which will be a base to objective decisions and presenting to the decision maker.

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Actually, different kinds of methods for resolving the multi-criteria are made and these back up the decision maker to select the best decision but there are limited number of studies about the challenge of selecting the best decision making method for a specific situation, specifically in decision making methods that have multiple criteria or sub-criteria . The Analytic Hierarchy Process (AHP) and the Analytic Network Process (ANP) are the two most important methods of Multi Criteria Decision Making (MCDM) and other methods are known as the Fuzzy Set Theory (FST), the Weight Sum Model (WSM) and the Weight Product Model (WPM) etc. If this problem is minimized by using AHP and ANP then businessmen or suppliers of Rajshahi city area can earn a maximum profit by supplying mangoes and people of different regions of our country can get those mangoes easily from a nearby fruit stall. As a result demand of mangoes in those regions will meet. To solve this problem we use both AHP and ANP. When independencies are considered among the criteria then the AHP was used and when interdependencies or relationships from top to bottom and bottom to top among the criteria are considered then the ANP was used. This is a new implementation of AHP and ANP in the business field respect to Bangladesh. So it can be said that this case study will bring a revolution in the research field.

2. LITERATURE REVIEW

Selection of facility location for a new business purpose is a new evaluation of AHP and ANP in Business research field. But past studies on AHP and ANP methods have focused upon particular applications of these methods. Despite this there are many other studies compare the two MCDM methods [5]-[16] and pointed out the following major advantages and differences between AHP & ANP;

a) Previous research evinces that ANP goes away from linear relationships among elements and permits interrelationships among elements [16]. Rather than a hierarchy, a network is developed by ANP that occupies single directional relationships with dependence and feedback [8]. Hence, ANP is more influential than AHP in the decision making environment with uncertainty and dynamics [5].

b) Rank reversal is problem in AHP that is conciliated in ANP, thus ANP is more accurate and useful than the AHP in convoluted situations [5]-[10].
c) The order change was another problem in the AHP that first noted by Dagdeviren and colleagues. Order change means change of alternative priorities while a new alternative is added or subtracted. This problem was curtailed by applying the ANP method [5]-[13].

One research questioned both AHP and ANP that these methods will support the company to utilize the resources efficiently and aid decision makers to select the best alternative [2]. That research investigated the supplier selection problem and further investigated on ANP approach by Dagdeviren and Eren (2001) had suggested ANP for obtaining solution. Taslicali & Ercan (2006) questioned in their research that does the ANP method represent reality in a decision making process better than the AHP method. In our research, ANP and AHP results different and more precise values of the final priority for alternatives and hence it can be said that ANP method represent reality in a decision making process better than the AHP method. Therefore ANP is more reliable than AHP. In this case study, for developing the comparison matrix, the hypothesis is utilized when uncertainty present in the comparisons of criteria. By surveying, some data about the importance of the criteria were collected. By implementing these data the comparison matrix were developed to get the final priority. From the Literature these following gaps about AHP and ANP are collected:

a. If there are any kinds of uncertainty about the importance of the criteria (or sub-criteria) then how the AHP and ANP solve the decision making problem?
b. There are only a few studies on the comparison of AHP and ANP.
c. The comparison of AHP and ANP in organizational structures is limited in number but there have huge examples about only one model selection and sensitivity analysis [18].

3. DATA COLLECTION AND ANALYSIS

In this investigation a primary data is used for analyzing the present scenario of mango distribution from the Rajshahi city to the various regions of Bangladesh. This data is collected from several local distributor and local mango businessmen. The primary data obtained from field survey was collected through visit to mango distribution center in the Rajshahi city. About 37 local distribution center located in the city were all visited. Onsite observations and use of questionnaires and interviews were also used in data collection process to identify the criteria and sub-criteria of the seasonal mango supplying business. Moreover, it is known from the local distributor and businessmen that every year between June and mid-September, mango supplying business from Rajshahi city is took place. It was observed from preliminary studies that most of the local suppliers emphasis on price, consumer, transportation, political condition and demand of the supplying or distributing area. After completing data collection this data is analyzed to utilized in this study by computing the comparison matrix of the criteria and sub-criteria. After processing the survey data the following percentages of importance for each criterion are calculated;

- About 5.42% importance for Price criterion
- About 13.51% importance for Consumer criterion
- About 24.33% importance for Transportation criterion
- About 32.43% importance for Political Condition criterion
- About 24.31% importance for Demand criterion

4. THE ANALYTICAL HIERARCHY PROCESS (AHP)

The Analytic Hierarchy Process shortly known as the AHP is first introduced by one of the pioneer of Operation Research Thomas L. Saaty in 1977. Basically, AHP is a decision making method which can solve the problem that have multiple criteria and so it is known as the MCDM tool. Moreover, it is a decision support tool used for resolving complex decision problems and follows a multi-level hierarchical structure of objectives, criteria, sub criteria and alternatives [17]. Widespread and judicious framework is provided by AHP in order to create a decision problem, to represent and quantify its elements, to relate those elements to overall goals, and to evaluate alternative solutions. Today every developed country when faces with variety of decision situations like the fields as government, industry, business, healthcare and education widely use it. Embodying people's notions and judgments the Analytic Hierarchy Process (AHP) assists people to take more effective decisions. Mainly, the principle work of the AHP is to evaluate priorities for alternatives and the criteria used to judge the alternatives [3]. According to Saaty this method consists of three phases: decomposition, comparative judgment and synthesizing. The problem which has element is organized in the form of a hierarchy in the decomposition phase, then elements of one level of a hierarchy are compared pairwise as to the strength of their influence on an element of the next higher level in comparative judgment phase and finally synthesize the priorities in the next phase [6].

4.1. Process of AHP

The basic procedure of AHP consists of following these steps [19]. These are given below;

Step 1: Developing the weights for the criteria by
a) evaluating a single a pairwise matrix for the criteria;
b) normalizing the each column of the matrix and calculating appropriate priority or weights;
c) computing and checking the Consistency Ratio **(CR)** by using the following equation;

$$CR = \frac{CI}{RI} \qquad (1)$$

Here, **CI = Consistency index =** $\frac{Eigen\ value - n}{n-1}$

Where, the small n denotes the number of criteria. Random Consistency Index **(RI)** and which is taken from the table below;

Table 1: *Value of random consistency index (RI)*

Criteria	3	4	5	6	7	8	9	10
RI	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

If the value of CR is less than 0.1 (10%), then the pairwise comparison is considered as acceptable. If the consistency is greater than 0.1 then this comparison matrix will not accurate. The relative importance values in the comparison matrix are determined with Saaty's 1-9 scale (Table 2), where a score of 1 represents equal importance between the two elements and a score of 9 shows the extreme importance of one element (row component in the comparison matrix) compared to the other one (column component in the comparison matrix). Saaty's 1-9 scale is given below;

Table 2: *Saaty's 1-9 Scale for AHP Preference (Yurdakul 2003, Cheng & Li 2001)*

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective.
3	Moderate importance	Experience and judgment slightly favor one over another.
5	Strong importance	Experience and judgment strongly favor one over another.
7	Very strong importance	Activity is strongly favored and its dominance is demonstrated in practice.
9	Absolute importance	Importance of one over another affirmed on the highest possible order.
2,4,6,8	Intermediate values	Used to represent compromise between the priorities.

Step 2: Developing the ratings for each decision alternative for each criterion by,

a) constructing a pair-wise comparison matrix for each criteria and each matrix containing the pair-wise comparisons of the performance of decision alternatives on each criteria;
b) multiplying the values in each row together and calculating the nth root of above said product;
c) normalizing the nth root of product values that is mentioned above to obtain the corresponding ratings and calculating and checking the Consistency Ratio (CR).

Step 3: Finally the weighted average rating for each decision alternative is calculated. Then the highest score is chosen.

4.2. Problem Structure and Solution Methodology for AHP

Our goal is to select the facility location from where a supplier can earn maximum profit. To solve this problem we have selected some criteria and divided these criteria into subsequent sub-criteria. Considering that these criteria are independent and so a Hierarchical structure for this problem is constructed. The hierarchical structure is given Fig.1 represents that criteria and sub-criteria of this problem don't have any relationship or interdependency among them. Furthermore, AHP method is used to resolve this case.

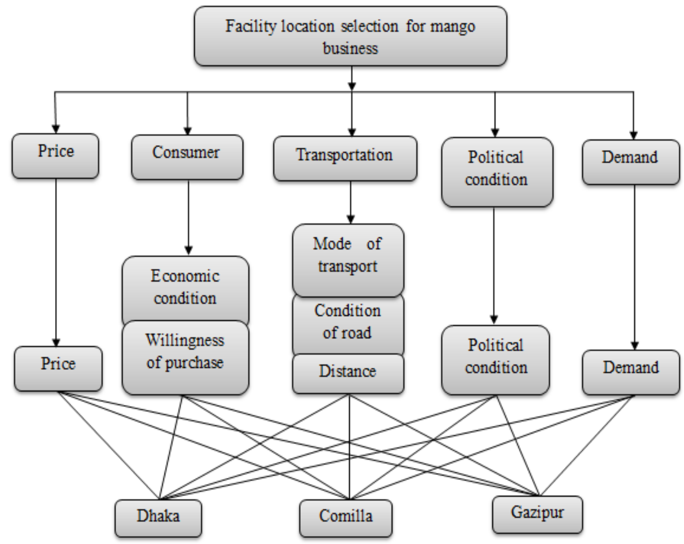

Fig.1. *Hierarchical structure for selection facility location*

The Hierarchical structure shows that this problem has five criteria, eight sub-criteria and three alternatives. At the first stage we need to determine priority vector for the criteria. The priority vector provides the priority indices for the criteria. The pairwise comparisons of the criteria in terms of their relative importance values along with column totals are shown in the Table 3 below considering these short terms for the criteria and sub-criteria,

P=Price, C=Consumer, T=Transportation, Pol=Political Condition, D=demand, E.C=Economic Condition, W.B=Willingness of Buy, M.T= Mode of Transportation, R.C=Road Condition, Dis =Distance.

Table 3: *Matrixes of Pairwise Comparisons of Criteria along with Column Totals*

Goal	P	C	T	Pol	D
P	1	1/3	1/5	1/7	1/5
C	3	1	½	¼	½
T	5	2	1	½	1
Pol	7	4	2	1	2
D	5	2	1	½	1

Table 4: *Normalized Weights of Matrix of Pairwise Comparisons of Criteria with Priority*

Criteria	P	C	T	Pol	D	Priority
P	1/21	1/28	2/47	4/67	2/47	0.0456
C	3/21	3/28	5/47	7/67	5/47	0.1134
T	5/21	6/28	10/47	14/64	10/47	0.2193
Pol	7/21	12/28	20/47	28/67	20/47	0.4061
D	5/21	6/28	10/47	14/67	10/47	0.2173
Total	1	1	1	1	1	1.0000

Check for Consistency:
Eigen value = 5.0397
CI = (5.0397-5)/ (5-1) = 0.00993
RI = 1.12 for criteria, n = 5
CR = CI / RI = 0.008866=0.886% < 10%

Computing all the comparison, priority of criterion and sub-criterion have found and by using these priority the overall criteria weight (OCW) is determined (table 5). Weight Score of alternatives are measured by multiplying the OCW with the alternatives priority weight (table 6);

Table 5: *Computation of Overall criteria weight (OCW) of each criterion*

Criteria	Criteria Weight	Sub-criteria	Sub-criteria Weight	OCW
P	0.0456			0.0456
C	0.1134	E.C	0.1000	0.0113
		W.B	0.9000	0.1021
T	0.2193	M.T	0.6583	0.1444
		R.C	0.2819	0.0618
		Dis	0.0598	0.0131
Pol	0.4061			0.4061
D	0.2173			0.2173

From the Appendix (Table A1) total score of Dhaka is greater than Comilla and Gazipur so we will select Dhaka for supplying mangoes from Rajshahi city first. Between Comilla and Gazipur, score of Comilla is greater than Gazipur. Secondly, we will select Comilla for supplying mangoes and thirdly Gazipur will be selected.

5. THE ANALYTIC NETWORKING PROCESS (ANP)

There are a lot of decision making related problem that can't be structured hierarchically when higher level elements having an interaction with lower level elements and their dependency should be taken into account. Such kind of complicated problem can't be structured hierarchically. The importance of the criteria not only determines the importance of the alternatives as in a hierarchy but also the importance of the alternatives determines the importance of the criteria [6]. Therefore, a hierarchical structure having a linear top-to-bottom or bottom to top form is not applicable for a complex system. A problem having functional dependence is structured which allows for feedback among clusters. This is a network system [11]. The AHP is used to solve these problems having independencies on alternatives or criteria and ANP is used to solve the problem having dependence or relationship among alternatives or criteria [8]. This is the main difference between AHP and ANP. Also a 'supermatrix' concept is used in ANP for finding the ultimate result.

5.1. Process of ANP

The ANP is a generalized from of AHP and it is mainly for more complicated problems. The mathematical calculations for AHP and ANP are same but in ANP criteria interdependency comparison matrixes are computed and formed a 'Supermatrix' that is not done in AHP. The ANP method can be applied by following these steps for facility location selection [4]-[8].

Step 1: Model construction and problem formulation.
Step 2: Establishment of the pair-wise comparison matrixes and criteria interdependency matrixes.
Step 3: Calculation of the priority vectors or priority weights.
Step 5: Consistency test by using the Eigen value and Random consistency index.
Step 6: Construction of supermatrix by using the priority that are calculated in the comparison matrixes.
Step 7: Computations of limit supermatrix by multiplying the supermatrix itself numerical times.
Step 8: Selection of best alternatives from the Limit matrix.

5.2 Problem Structure and Solution Methodology for ANP

Our goal is to select the facility location from where a supplier can earn maximum profit by supplying the mangoes from Rajshahi. For this purpose a networking model is constructed which shows the relationship and dependencies among criteria. This networking structure is given below in Fig. 2.

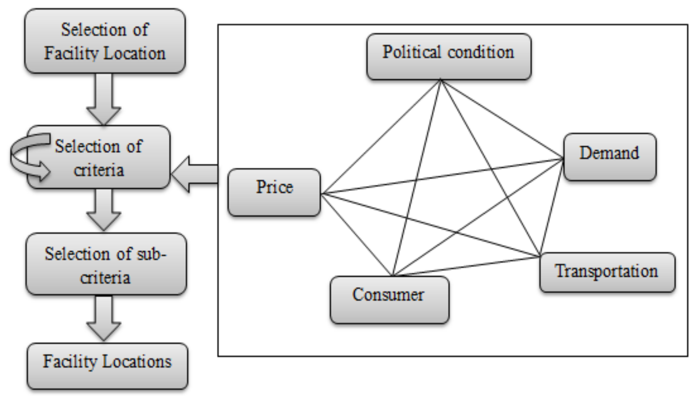

Fig.2. *the ANP network component*

5.2.1. Formation of Supermatrix

The "supermatrix" is required for representing the relationships of criteria and the degree of importance in ANP. In a quest of global priorities in a system with interdependent influences, the clusters and necessary elements of all the sub-matrixes forming of all in order on the left and upper sides of the matrix are listed down by the supermatrix, where each matrix segment denotes a relationship between two nodes (clusters or components) in a system [4]-[8]-[12]. By using the priority vectors in each comparison matrix, a supermatrix (Table A2 in Appendix) is constructed for this facility location problem which is used to evaluate the Limit matrix.

5.2.2. Formation of Limit matrix

The limit matrix is found by multiplying the 'Supermatrix' by itself numerical times. This matrix is also known as an un-weighted super matrix. The summation of each column vectors of a super matrix is not equal to 1and so is called as un-weighted supermatrix. This un-weighted supermatrix is converted to weighted supermatrix with specific procedures. This weighted supermatrix can be obtained by multiplying the un-weighted supermatrix by itself numerical times since the elements of every row become equal. This weighted supermatrix is called as 'Limit matrix or Limiting matrix'. This limit matrix is obtained by multiplying the supermatrix 37 times by itself. Each row is the same value and provides the local relative weights of individual sets of elements. The limit matrix of our problem is given below in the Appendix (Table A3).

5.2.3. Selection of best alternative

From the Limit matrix the final decision is taken. In the limit matrix the final priority 0.70, 0.11, 0.19 are found for Dhaka, Comilla and Gazipur. The priority of Dhaka is more than

Comilla and Gazipur. So a supplier who decides to supply mangoes from Rajshahi should supply mangoes Dhaka first.

6. FINDINGS AND RESULT ANALYSIS

Our main motivation of this case study is to find out the suitable facility location for supplying mangoes from Rajshahi city to different location of our country. In our investigation we have select three different locations Dhaka, Comilla and Gazipur and to find out the best location from which a businessman can earn maximum profit this our main objective. To find out the best location we use two MCDM techniques AHP and ANP and finally the suitable location Dhaka city is found because Dhaka has the maximum priority weight for both AHP and ANP method. So when a businessman wants to supply mangoes from Rajshahi, he or she should choice the Dhaka city first from these three alternatives. The final priority or result of the AHP and ANP method are different, because in ANP the criteria interdependency comparisons are calculated. It obvious ANP will give more precise value of priority than AHP. A comparison between the final result of AHP and ANP is given in the Table 6. Two bar chat are shown (Fig. 3) to demonstrate the differences of result of AHP & ANP techniques. These bar charts mainly demonstrate how the priorities of the alternatives fluctuate for AHP and ANP techniques.

Table 6: *Comparisons between the results of AHP & ANP*

Facility Locations (Alternatives)	AHP	ANP
Dhaka	0.64711660	0.7000000
Comilla	0.06793652	0.1100000
Gazipur	0.01530529	0.1900000

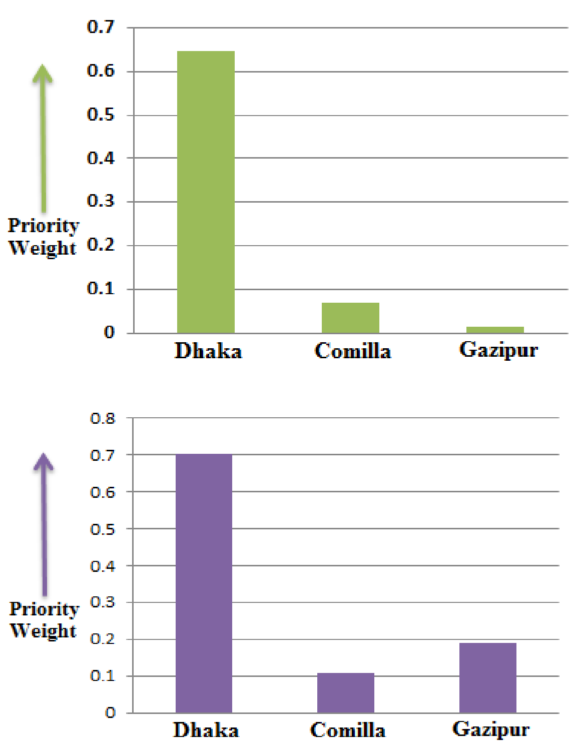

Fig.6. *(a & b) Priority weight versus Alternatives bar chart for AHP and ANP*

7. SUMMARY AND CONCLUSIONS

In this case study AHP and ANP both methods are used to solve a case. The differences between the two techniques appear in modeling the Facility location selection problem and evaluating the final priorities for the alternatives from ratio scales previously achieved. By studying the AHP and ANP, a strong knowledge of decision making is gained, because a lot of brainstorming is done for solving this problem. When selecting the criteria, a survey was done from different local mango businessman or supplier to know about their thought about mango supplying business. Based on their view the criteria are selected and the comparisons of the criteria are also done. Finally, the most profitable location is identified from the final priority vector. In this investigation the uncertainty of the decision makers were not taken into consideration when formulating the comparison matrices. But if decision makers have vagueness to compare two criterion or sub-criterion then AHP and ANP can't evaluate the best result. Then fuzzy logic concept can be employed to remove uncertainty of the decision makers.

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APPENDIX

Table A1: *Synthesized table for the optimal alternative selection*

Overall Criteria Weight (OCW)	Dhaka	Comilla	Gazipur	Weight Score of Alternatives=OCW * Alternative		
				Dhaka	**Comilla**	**Gazipur**
0.0456	0.1095	0.5812	0.3091	0.0049932	0.00290205	0.00089702
0.0113	0.7351	0.0653	0.1994	0.0083066	0.00054242	0.00010816
0.1021	0.6479	0.1221	0.2298	0.0661506	0.00807699	0.00185609
0.1444	0.6582	0.0598	0.2819	0.0950441	0.00568364	0.00160222
0.0618	0.6582	0.0598	0.2819	0.0406768	0.00243247	0.00068571
0.0131	0.6479	0.1221	0.2298	0.0084875	0.00103632	0.00023815
0.4061	0.6479	0.1221	0.2298	0.2631122	0.032126	0.00738255
0.2173	0.7379	0.0944	0.1675	0.1603457	0.01513663	0.00253539
Total Score				**0.6471166**	0.06793652	0.01530529
Decision				1st best location	2nd best location	3rd best location

Table A2: *The supermatrix*

			Selection criteria						Selection sub-criteria				
			Goal						C		T		
				P	C	T	Pol	D	E.C	W.B	M.T	R.C	Dis.
Goal			0	0	0	0	0	0	0	0	0	0	0
Sel. Criteria		P	0.0456	0	0.3913	0.0705	0.5316	0.17	0	0	0	0	0
		C	0.1134	0.5316	0	0.3682	0.1855	0.10	0	0	0	0	0
		T	0.2193	0.1855	0.1443	0	0.1855	0.30	0	0	0	0	0
		Pol	0.4061	0.1855	0.1443	0.193	0	0.41	0	0	0	0	0
		D	0.2173	0.0972	0.3199	0.3682	0.0972	0	0	0	0	0	0
Selection Sub-Criteria	C	E.C	0	0	0.1	0	0	0	0	0	0	0	0
		W.B	0	0	0.9	0	0	0	0	0	0	0	0
	T	M.T	0	0	0	0.65	0	0	0	0	0	0	0
		R.C	0	0	0	0.28	0	0	0	0	0	0	0
		Dis.	0	0	0	0.05	0	0	0	0	0	0	
Location		Dhaka	0	0.1095	0	0	0.6479	0.7379	0.7351	0.6479	0.6582	0.6582	0.6479
		Comilla	0	0.5812	0	0	0.1221	0.0944	0.0653	0.1221	0.0598	0.0598	0.1221
		Gazipur	0	0.3091	0	0	0.2298	0.1675	0.1994	0.2298	0.2819	0.2819	0.2298

Table A3: *The Limit matrix*

			Selection criteria						Selection sub-criteria				
			Goal						C		T		
				P	C	T	Pol	D	E.C	W.B	M.T	R.C	Dis.
Goal			0	0	0	0	0	0	0	0	0	0	0
Sel. Criteria		P	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
		C	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
		T	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
		Pol	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
		D	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
S. Sub-Criteria	C	E.C	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
		W.B	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
	T	M.T	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
		R.C	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
		Dis.	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Location		Dhaka	**0.70**	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
		Comilla	**0.11**	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
		Gazipur	**0.19**	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19