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Applying The Analytical Hierarchy Process To Select The Transmission Lines Type In Telecoms

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Abstract: - In real life, many practical troubles occur in the volatile environments, particularly in cases involving human self-assessment. Decision making has always been a difficult process, based on various combinations of objectivity and subjectivity. Objectivity refers to scientific tools were used, while subjectivity is considered that decisions at the end are made by people, with their strengths and weaknesses. This paper represents a multi-criteria decision making in telecom companies to select the best suitable transmission lines. The technique will be used is based on the analytic hierarchy process (AHP) method. Six criteria were identified such as Installation cost, capacity, Security, immunity to noise, issue of latency, and distance for getting the best type of transmission lines among the three alternatives options which are fiber optic, VSAT, and microwaves under consideration.
Keywords: - *Alternatives, Criteria, Decision making, Fiber optic, Transmission media, VSAT,*

I. INTRODUCTION

The physical path over which the information flows from transmitter to receiver is called the transmission medium or the channel. The transmission media that are used to convey information can be classified as guided or unguided. Guided media provide a physical path along which the signals are propagated; these include twisted pair, coaxial cable, and optical fiber. while Unguided media or wireless includes infrared, radio, microwave and satellite transmission.

The characteristics and quality of a data transmission are determined both by the characteristics of the medium and the characteristics of the signal. In the case of guided media, the medium itself is more important in determining the limitations of transmission. For unguided media, the bandwidth of the signal produced by the transmitting antenna is more important than the medium in determining transmission characteristics. One key property of signals transmitted by antenna is directionality. In general, signals at lower frequencies are omnidirectional; that is, the signal propagates in all directions from the antenna. At higher frequencies, it is possible to focus the signal into a directional beam. A number of design factors relating to the transmission medium and the signal determine the data rate and distance are demonstrated as follows:

i. Bandwidth: All other factors remaining constant, the greater the bandwidth of a signal, the higher the data rate that can be achieved.
ii. Transmission impairments: Impairments, such as attenuation, limit the distance.
iii. Interference: From competing signals in overlapping frequency bands can distort or wipe out a signal. Interference is of particular concern for unguided media but is also a problem with guided media.

The Analytic Hierarchy Process (AHP) deals with solving complex problems, and quite often is referred to Saaty method. It is popular and widely used in decision making and in a wide range of applications such as technology choice, evaluation of new telecommunications services, and strategic planning. The basic procedures are as follows:

i. Decompose the decision-making problem into a hierarchy.
ii. Make pair wise comparisons and establish priorities among the elements in the hierarchy.
iii. Synthesise judgments (to obtain the set of overall or weights for achieving your goal).
iv. Evaluate and check the consistency of judgments.

There are 3 steps to arrive at the consistency ratio:

i. Calculate the consistency measure. This step includes two mathematical operations.

a. Multiply each column of the pair wise comparison matrix by the corresponding weight.
b. Divide of sum of the row entries by the corresponding weight

ii. Calculate the consistency index (CI).

$$CI = (\lambda_{max} - n)/(n - 1) \qquad (1)$$

Where : n is a number of criteria,
λ_{max} is the maximal eigenvalue.

iii. Calculate the consistency ratio (CI/RI where RI is a random index).

The CI is a random index chosen from table 1 that derived from Saaty's book, in which the upper row is the order of the random matrix, and the lower is the corresponding index of consistency for random judgments.

Table 1: Random index (RI) for the factors used in the decision making process.

n	1	2	3	4	5	6	7	8	9
CI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

II. METHODOLOGY

The problem which will be discussed in this section is to choose the most suitable transmission line type according to different criteria; the criteria include both qualitative as well as quantitative criteria. Qualitative criteria include security where as quantitative criteria include installation cost, capacity, immunity to noise, issue of latency, and distance. These are the criteria against which the alternatives have to be compared. The alternative which suits in all the ways is chosen as the best resulting solution. The parameters for optimal choice of the transmission lines are as under:-

1. Installation Cost : The initial cost required to construct the system.
2. Capacity : The maximum data rate that can be attained over a given channel.
3. Security: Is the discipline of preventing unauthorized interceptors from accessing telecommunications in an intelligible form, while still delivering content to the intended recipients.
4. Immunity to noise: The ability of an apparatus or system to perform its functions when interference is present.
5. Issue of latency : Essentially any delay or lapse in time. In general, it's the time it takes for a packet to cross a network connection, from sender to receiver.
6. Distance : Signals are transmitted over long distances over air, cable, and radio communications lines.

The first step in the AHP method is to develop a graphical representation of the problem in terms of the overall goal, the criteria, and the decision alternatives as shown in Fig. 1.

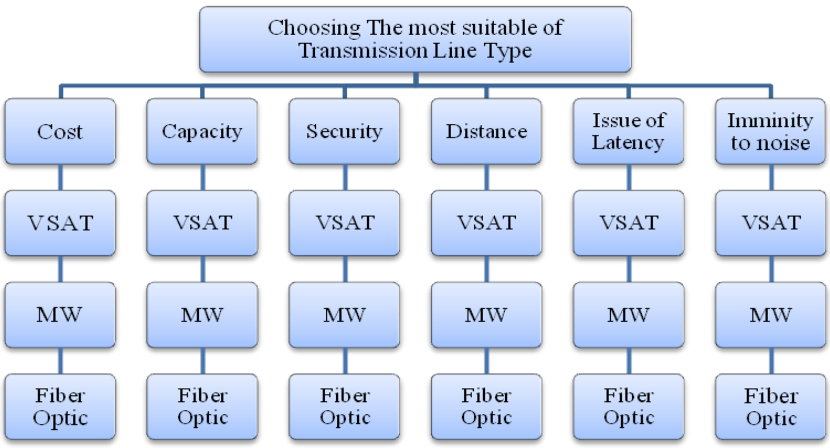

Figure 1: AHP hierarchy of goals, objectives and alternatives.

It's essential to construct a matrix expressing the relative values of a set of attributes. For example, what is the relative importance to the management of this firm? Risk owners are asked to choose whether for instance, capacity is very much important, rather more important, and as important, and so on down to very much less important, than issue of latency. Each of these judgments is assigned a number on a scale. One common scale is shown in Table 2.

Table 2 : AHP importance scale

Scale	Degree of Preference	Explanation
1	Equally preferred	Two factors contribute equally to the objective.
3	Moderately preferred	Experience and judgment slightly favor one over the other
5	Strongly preferred	Experience and judgment strongly favor one over another
7	Very strongly preferred	An element is strongly favored and its dominance is demonstrated in practice.

9	Extremely preferred	The evidence favoring one element over another is one of the highest possible order of affirmation
2,4,6,8	Inter mediate value	Comprise is needed between two judgments

According to the reciprocal axiom, if capacity for example is absolutely more important than distance and is rated at 7, then distance must be absolutely less important than capacity and is valued at 1/7.
The second step in the AHP procedure is to pair wise comparisons for criteria and establish priorities among the elements in the hierarchy:

2.1 Pairwise comparison of alternatives for each criteria :

The alternative in the row is being compared to the alternative in the column for each applied criteria. If the criteria in the column is preferred to the criteria in the row, then the inverse of the rating is given.

Table 3: Pairwise Comparison Matrix

(1) Installation Cost

Installation Cost	VSAT	MW	Fiber Optic
VSAT	1	0.33	0.14
MW	3	1	0.2
Fiber Optic	7	5	1
Total	11	6.33	1.34

(5) Immunity to Noise

Immunity to noise	VSAT	MW	Fiber Optic
VSAT	1	3.00	0.20
MW	0.33	1	0.17
Fiber Optic	5	6	1
Total	6.33	10.00	1.37

(2) Capacity

Capacity	VSAT	MW	Fiber Optic
VSAT	1	0.25	0.11
MW	4.00	1	0.17
Fiber Optic	9	6	1
Total	14.00	7.25	1.28

(5) Issue of Latency

Issue of Latency	VSAT	MW	Fiber Optic
VSAT	1	0.20	0.13
MW	5	1	0.25
Fiber Optic	8	4	1
Total	14	5.20	1.38

(3) Security

Security	VSAT	MW	Fiber Optic
VSAT	1	3	0.20
MW	0.33	1	0.17
Fiber Optic	5	6	1
Total	6.33	10	1.37

(6) Distance

Distance	VSAT	MW	Fiber Optic
VSAT	1	5	9
MW	0.20	1	3.00
Fiber Optic	0.11	0.33	1
Total	1.31	6.33	13.00

Table 3 shows the preferable matrix between the three alternatives. For example, in case of capacity criteria matrix; fiber optic is 9 times as important as VSAT which means fiber optic is extremely preferred than VSAT comparing to capacity, and fiber optic is 6 times as important as MW, while MW is 4 times as important as VSAT.

2.1.1 Normalization

This step is to normalize the matrix in table 3 by totaling the numbers in each column. Each entry in the column is then divided by the column sum to yield its normalized score. The sum of each column should equal to 1. For instance, in case of installation cost criteria, the normalized value for VSAT, MW, and fiber optic in the first row of table 4 is calculated as 1/11 = 0.09, 0.33/6.33 = 0.05, 0.11/1.28 = 0.11 respectively. Eigenvector for VSAT is equal to 0.09+0.05+0.11 = 0.25, where as Normalized Eigenvector is equal to 0.25/3 = 0.08. The same concept is done to the other criteria. It should be noticed that the Normalized Eigenvector denotes to scale of priority which means for instance fiber optic has high capacity than MW and VSAT with a ratio of 75%, 18%, 6% according to the result shown in table 4. Table 4 shows the calculations of normalized values, eigenvector, and normalized eigenvector for the six criteria.

Table 4 : Calculations of normalized eigenvector

Installation Cost	VSAT	MW	Fiber Optic	Eigenvector	Normalized Eigenvector
VSAT	0.09	0.05	0.11	0.25	0.08

MW	0.27	0.16	0.15	0.58	0.19
Fiber Optic	0.64	0.97	0.74	2.17	0.72
Total\Average	1.00	1.00	1.00	3.00	1.00
Capacity	VSAT	MW	Fiber Optic	Eigenvector	Normalized Eigenvector
VSAT	0.07	0.03	0.09	0.19	0.06
MW	0.29	0.14	0.13	0.55	0.18
Fiber Optic	0.64	0.83	0.78	2.25	0.75
Total\Average	1.00	1.00	1.00	3.00	1.00
Security	VSAT	MW	Fiber Optic	Eigenvector	Normalized Eigenvector
VSAT	0.16	0.30	0.15	0.60	0.20
MW	0.05	0.10	0.12	0.27	0.09
Fiber Optic	0.79	0.60	0.73	2.12	0.71
Total\Average	1.00	1.00	1.00	3.00	1.00
Immunity to noise	VSAT	MW	Fiber Optic	Eigenvector	Normalized Eigenvector
VSAT	0.16	0.30	0.15	0.60	0.20
MW	0.05	0.10	0.12	0.27	0.09
Fiber Optic	0.79	0.60	0.73	2.12	0.71
Total\Average	1.00	1.00	1.00	3.00	1.00
Issue of Latency	VSAT	MW	Fiber Optic	Eigenvector	Normalized Eigenvector
VSAT	0.07	0.04	0.09	0.20	0.07
MW	0.36	0.19	0.18	0.73	0.24
Fiber Optic	0.57	0.77	0.73	2.07	0.69
Total\Average	1.00	1.00	1.00	3.00	1.00
Distance	VSAT	MW	Fiber Optic	Eigenvector	Normalized Eigenvector
VSAT	0.76	0.79	0.69	2.24	0.75
MW	0.15	0.16	0.23	0.54	0.18
Fiber Optic	0.08	0.05	0.08	0.21	0.07
Total\Average	1.00	1.00	1.00	3.00	1.00

2.1.2 Consistency Analysis:

The main purpose for performing this step is to make sure that the original preference ratings were consistent. The consistency is computed for instance in case of installation cost as follows;

i. VSAT : (1*0.08 + 0.33*0.19 +0.14*0.72) / 0.08 = 3.0136553
ii. MW : (3*0.08 + 1*0.19 + 0.2*0.72) / 0.19 = 3.0427191
iii. Fiber optic : (7*0.08 + 5*0.19 + 1*0.72) / 0.72 = 3.1410816

Hence, $\lambda_{(max)}$ = (3.0136553+ 3.0427191+ 3. 1410816) / 3 = 3.0658187

Applying eq. 1, CI = (3.0658187 -3)/(3-1) = 0.033, where n is equal to 3 which is the dimension of the matrix. So, CR = CI/RI = 0.033/0.58 = 0.057, where RI is equal to 0.58 from table 1. The value of CR less than 0.1 indicates the judgments has an acceptable level. If unacceptable, pair wise comparisons should be revised. The same steps are implemented for the other criteria as shown in table 5.

Table 5 : Consistency Ratio Calculation

Installation Cost	Consistency	CI	RI	CR
VSAT	3.0136553	0.033	0.58	0.057
MW	3.0427191			
Fiber Op.	3.1410816			
λ(max)	3.0658187			
Capacity	Consistency	CI	RI	CR
VSAT	3.016195	0.055	0.58	0.095

Immunity to noise	Consistency	CI	RI	CR
VSAT	3.065392	0.048	0.58	0.083
MW	3.021038			
Fiber Op.	3.20098			
λ(max)	3.095803			
Issue of Latency	Consistency	CI	RI	CR
VSAT	3.0156716	0.048	0.58	0.082

MW	3.070062			
Fiber Op.	3.245972			
λ(max)	3.110743			
Security	Consistency	CI	RI	CR
VSAT	3.065392	0.048	0.58	0.083
MW	3.021038			
Fiber Op.	3.20098			
λ(max)	3.095803			

MW	3.079918			
Fiber Op.	3.1913043			
λ(max)	3.0956313			
Distance	Consistency	CI	RI	CR
VSAT	3.064936	0.015	0.58	0.025
MW	3.017345			
Fiber Op.	3.00555			
λ(max)	3.029277			

In practice, a CR of 0.1 or below is considered acceptable. Any higher value at any level indicate that the judgments warrant re-examination.

2.2 Pairwise comparison for all criteria :

It should now determine the ranking of each criteria together. It's an important step to construct the final decision.

Table 6: Ranking Criteria

No.	Ranking Criteria
1	Capacity is 9 times as important as cost
2	Security is 7 times as important as cost
3	Capacity is 5 times as important as security
4	Immunity to noise is 7 times as important as distance
5	Issue of latency is 4 times as important as distance
6	Immunity to noise is 3 times as important as Issue of latency
7	Capacity is 3 times as important as issue of latency
8	Capacity is 9 times as important as distance
9	Security is 3 times as important as distance
10	Immunity to noise is 8 times as important as cost
11	Immunity to noise is 4 times as important as capacity
12	Immunity to noise is 6 times as important as security
13	Issue of latency is 7 times as important as cost
14	Issue of latency is 3 times as important as security
15	Distance is 3 times as important as cost

2.2.1 Pairwise comparison Matrix :

Table 7: Pairwise comparison for all criteria

Factor	Installation Cost	Capacity	Security	Immunity to noise	Issue of latency	Distance
Installation Cost	1	0.11	0.14	0.13	0.14	0.33
Capacity	9	1	5	0.25	3	3
Security	7	0.2	1	0.17	0.33	3
Immunity to noise	8	4	6	1	3	7
Issue of latency	7	0.33	3	0.33	1	4
Distance	3	0.33	0.33	0.14	0.25	1
Total	35	5.98	15.48	2.02	7.73	18.33

2.2.2 Normalization Matrix :

Table 8 : Normalized values of table 7

Factor	Cost	Capacity	Security	Immunity to noise	Issue of latency	Distance
Installation Cost	0.03	0.02	0.01	0.06	0.02	0.02
Capacity	0.26	0.17	0.32	0.12	0.39	0.16
Security	0.20	0.03	0.06	0.08	0.04	0.16
Immunity to noise	0.23	0.67	0.39	0.50	0.39	0.38

Issue of latency	0.20	0.06	0.19	0.17	0.13	0.22
Distance	0.09	0.06	0.02	0.07	0.03	0.05
Total\Average	1	1.00	1.00	1.00	1.00	1.00

2.2.3 Calculation of priority (i.e., normalized eigenvector)

Table 9: Weight Matrix for all criteria

Factor	Eigenvector	Normalized Eigen	λ(max)
Installation Cost	0.16	0.03	6.195510632
Capacity	1.42	0.24	7.196378523
Security	0.59	0.10	6.239358495
Immunity to noise	2.55	0.43	7.111223899
Issue of latency	0.96	0.16	6.668120177
Distance	0.32	0.05	6.4264118
Total\Average	6.00	1.00	6.639500588

Eigenvector and normalized eigenvector are computed for instance in case of security criteria as the total sum of row 3 in table 8 as follows; Eigenvector (security) = 0.2 + 0.03 + 0.06 + 0.08 + 0.04 + 0.16 = 0.59, while normalized eigenvector (security) = 0.59/6 = 0.1

2.2.Calculation of consistency index (CI)

CI = (Lambda(max) - n)/ (n-1) = (6.639500588-6)/(6-1) = 0.127900118

2.2.5 Calculation of consistency ratio (CR)

CR = CI/RI = 0.127900118/1.24 = 0.103145256,

Hence, it's an acceptable level of consistency;

III. RESULTS AND DISCUSSION

Table 9 indicates that immunity to noise is the most criteria should be taken into consideration in making decisions. Capacity is the second one, while installation cost occupies the last one. This leads to consider installation cost is not a main issue to choose the different transmission system. Fig. 2 summarize the result of sequencing the assumed six criteria.

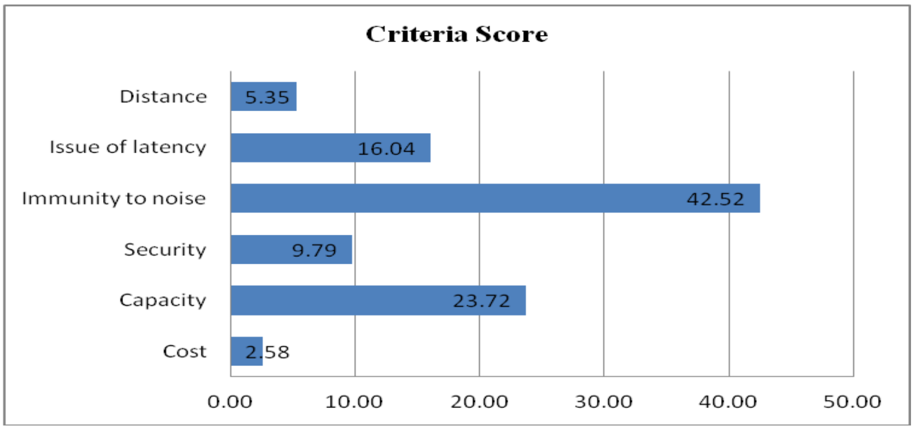

Figure 2 : The six criteria score

In order to obtain the final priority, multiplication matrix concept should be used. Normalized eigenvalue of all criteria should be multiply by criteria of alternative as shown in table 10.

Table 10: Final score calculations

Transmission type	Criterion	Criterion Weight	Transmission's weight	Weighted Score
VSAT	Installation Cost	0.03	0.08	0.002
	Capacity	0.24	0.06	0.02
	Security	0.10	0.20	0.02
	Immunity to noise	0.43	0.20	0.09

	Issue of Latency	0.16	0.07	0.01
	Distance	0.05	0.75	0.04
			Sum	**0.17**
MW	Installation Cost	0.03	0.19	0.005
	Capacity	0.24	0.18	0.04
	Security	0.10	0.09	0.01
	Immunity to noise	0.43	0.09	0.04
	Issue of Latency	0.16	0.24	0.04
	Distance	0.05	0.18	0.01
			Sum	**0.15**
FIBER OPTIC	Installation Cost	0.03	0.72	0.019
	Capacjity	0.24	0.75	0.18
	Security	0.10	0.71	0.07
	Immunity to noise	0.43	0.71	0.30
	Issue of Latency	0.16	0.69	0.11
	Distance	0.05	0.07	0.004
			Sum	**0.681**

It's obvious from table 10, fiber optic has high value which means it is the best choice to be selected according to the suggested criteria. VSAT and MW have second and third choice respectively as shown in fig. 3.

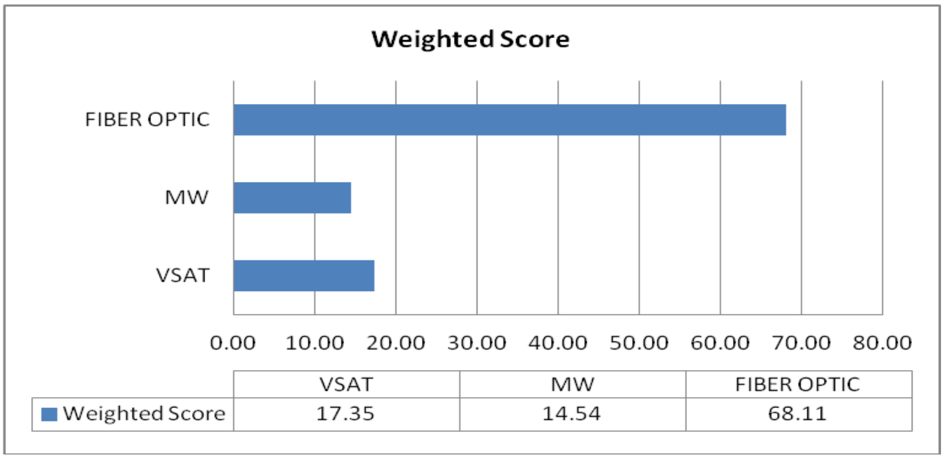

Figure 3: Sensitivity Analysis For Final Approach

IV. CONCLUSION

Telecoms companies are facing complex problems associated with transmission media. In this paper, AHP allows decision makers to model a complex problem such as selecting the best and suitable transmission lines type in a hierarchical structure, showing the relationships of the goal, objectives (criteria), and alternatives. Fiber optic is more reliable than the other media such as VSAT and microwaves system according to the six applied criteria. In addition, immunity to noise factor is the most important criteria to be taken into consideration. While installation cost criteria is not an obstacle issue to build up the system.

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