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COMPUTERIZED MULTIPLE CRITERIA DECISION MAKING MODEL FOR PROJECTS PLANNING AND IMPLEMENTATION

1. ABSTRACT

Projects are initiated and implemented to promote investment and maintain the competitiveness of the company. For the project to be successful the company management must come up with best decisions during the implementation phases of these projects. In this paper a computerized multi-criteria decision making model based on Analytical Hierarchy Process (AHP) has been developed to assist in decision making for projects. This process incorporates the quantitative and qualitative aspects of the decision making and provides a measure for determining the consistency of the decision maker. A survey has been conducted to gather information that influence the decision for ranking and evaluating telecommunication projects alternatives. To demonstrate the usefulness and application of the model, it has been applied on a telecommunication project for a major industrial company using the criteria that resulted from the questionnaires.

2. INTRODUCTION

Projects are implemented to achieve certain goals, which may include increasing company's profit or enhancing its competitiveness to survive in future. In order for projects to be successful, the company must come up with best project alternatives to achieve its objectives. During preliminary engineering study the decision making team is faced with a dilemma in its decision making process, in which more than one objective needs to be satisfied. To satisfy these objectives simultaneously order of preference is a major factor. The projects goals though defined in abstract, are elusive and in unclear manner.

Often, project owners consider cost only when comparing project alternatives, or do a traditional cost-benefit analysis. Problems that might be encountered during decision making process may include: complexity of the decision, inconsistency of the decision maker, political favor and hidden agenda by decision maker, overlooking the objective of the project, conflicting between the individuals, and variation of perception from one individual to another. To avoid these problems and improve the decision making process, a structured and comprehensive Computerized Multi-Criteria Decision Making Model based on Analytical Hierarchy Process(AHP) that assist in selecting the best project alternative is presented in this research. The model will help the decision maker focus on main objective of the project. Projects involve environmental, political, social and other intangible factors, which are usually ignored in the cost-benefit analysis. Decisions dealing with cost-benefits only are inadequate decisions that may lead to failure of a project.

The report will consider only telecommunication projects. Factors considered in the decision making model are those that influence the decision making with regard to the system selection and the project. These factors are obtained from literature review and previous telecommunication projects.

2.1. Problem Statement

During the preliminary engineering phase of the project, there is an array of possible alternative solutions to any project, deciding on which alternative to select is difficult. Often, owners do not consider alternatives to their investment projects for comparison, when they do; they may compare cost only or conduct the type of cost benefit analysis.

However, projects involve environment, political and other intangible factors, which are usually ignored in the cost benefit analysis. Such decisions with cost benefit are inadequate. During the decision making process, conflict may exist between the decision maker because of their different concerns and goals which may not match the stated organizational objectives. New technology to one might not be the same for another.

Problems might be encountered if specific requirement of the organizations are not consider that will affected project

By following structured and comprehensive approach, the team can quantify the subjective measurements, proceed logically and come up with the most feasible solution.

2.2. Research objective, Scope and Limitation

The objective of this research is to develop a computerized decision support model based on multi-criteria decision making approach to assist in decision making. This model will be applied to a case study to demonstrate its feasibility. The research will consider telecommunication projects implemented in Saudi Aramco. Factors considered in the decision model will be the factors that influence the decision making with regard to the system selection and project implementation.

2.3. Research Methodology

2.3.1. Determine the evaluation criteria for selecting projects alternatives from literature review and documentation of previous projects.

2.3.2. Present the selected method and discuss its mathematics and applications

2.3.3. Develop a computerized model based on the selected method

2.3.4. Apply the computerized model on real project to demonstrate is usefulness and application

3. PREVIOUS STUDIES

Previous studies were found in literature that talked about methods of selecting projects alternatives in value engineering. Al-Sughaiyer conducted a study, (1987) on public construction projects in Saudi Aramco. In the value engineering study, alternatives are compared by using weighted evaluation to help in selecting the best alternative. This method comprises of two processes, the paired comparison criteria weighting process and the evaluation matrix

Under the paired comparison criteria weighting process criteria influencing the decision making are listed. Each criterion depending upon its importance to the decision maker is assigned a letter. When selecting between two criteria, the degree of importance of one criterion over another can be:

- Major (3 points)
- Medium (2 points)
- Minor (1 point)
- No Preference (0 point)

For instance if criterion (A), is considered less important than (D), then criterion (A) receives a score of 2. Hence, the comparison between (A) and (D) in the criteria-scoring matrix is recorded with the notation A-2. If it is not possible to decide between two criteria, each one will receive one point, & the notation will be recorded in the matrix as D/B.

Raw score of all the criteria is then adjusted to a scale of 1-10 with, 10 assigned to the criteria with the highest raw score and others adjusted accordingly. Once the criteria elements and their weights have been established, they are entered in Evaluation Matrix as shown in fig2. First each criterion is ranked against each alternative.

A scoring of 1-5 is used as follows:

- Excellent = 5
- Very Good = 4
- Good = 3
- Fair = 2
- Poor = 1

Then the rank of each alternative with weight of criterion is multiplied and the result is entered in the matrix. After that, the total score is summed up for each alternative and ranked for selection. The alternative with the highest total score is the one to be selected

Fig.2

	A	B	C	D	E
A					
B					
C					
D					
E					

Criteria	Raw Score	Assigned Score
Criteria A		
Criteria B		
Criteria C		
Criteria D		
Criteria E		
Criteria F		

Figure 2.1 The Paired Comparison

Alternative: The Evaluated Alternatives

Criteria	Weights	Excellent	V.Good	Good	Fair
Criteria A					
Criteria B					
Criteria C					
Criteria D					
Criteria E					
Criteria F					

This method can handle only a few or limited number of decision criteria and is sometime difficulty to use. Restricting its scale to 5-point scale is a disadvantage.

Zedeh in 1965 initiated Fuzzy Set Theory using Fuzzy Multi-criteria concept for comparing projects. In this theory, values are assigned a membership from 0 to 1 in the sets, where 1 indicates membership in the set and 0.5 means that it is equally likely to be in set or out of the set.

Grandzol and Gershhon in their study entitled Multiple Criteria Decision Making; developed Criteria for evaluating the alternatives by assigning weights and alternatives rankings. The team used Electra Technique which compares a pair of alternative actions and ranks them by weighted scores for criteria for which a given alternative action is better (discordance). Alternatives actions that are better in the weighted criterion and not too much worse in the other criteria rank highest. The study team decided on 0.8 level of concordance and a 0.2 level of discordance for alternative action to qualify. The formula for concordance and discordance calculation follows:

Concordance of two alternatives action i and j:

$$C(i, j) = \frac{\textbf{Sum of weights for the criteria where } i>j}{\textbf{Total sum of weights}}$$

Discordance of two alternative action i and j:

$$D(i, j) = \frac{\textbf{Maximum interval where } i>j}{\textbf{Total range of scale}}$$

4. ANALYTICAL HIERARCHY PROCESS (AHP)

4.1. Introduction

Under the utility function it is difficult to assign and estimate the weight of each attribute. Sometimes the decision making is based on subjective criteria, which cannot be qualified in the utility function. Goal Programming lacks a systematic approach to set priorities and trade off among objectives. Fuzzy set theory is difficult to implement. To overcome short-comings from Goal Programming & Fuzzy set theory, the AHP is recommended. The AHP is a robust and flexible multi-criterion decision making tool for prioritizing alternatives associated with a system and determining trade off among them.

Hierarchical structure models the system of interest and determines the influence that the alternatives in one leveling the hierarchy exert on the next level.

Analytic Hierarchy Process (AHP) was developed by Satty in 1977 and 1986. It aids in the decision making analysis and is designed to solve complex problems involving multiple criteria to rank alternatives on the basis of cost, benefits and risk. It has been used in economics and planning, energies policies, health, conflict resolution, arms control, material handling and purchasing, man power selection and performance measurements, marketing, consulting. All these areas share a common decision making problem, which has to do with rating decision alternatives, selection or prediction.

The decision making process in the AHP context requires the decision maker to provide judgments about the relative importance of each criterion and then specify a preference for each decision for each decision alternative on each criterion. The output of the AHP is prioritized ranking indicating the overall preference for each of the decision alternatives.

4.2. The Decision Model Outline

1. Understand clearly the scope of the project.
2. Define the main objective of the project.
3. Determine the project alternatives.
    - 3.1 Literature review
    - 3.2 Market surveys
4. Determine all the criteria that influence the decision.
    - 4.1 Brainstorming sessions
    - 4.2 Questionnaires

5. Group the criteria that are related.

6. Use the AHP methodology to rank the project alternative:

4.3. The AHP Steps

The AHP consists of the following four steps:

1. Construction of decision hierarchy by breaking down the decision problem into a hierarchy of inter-related elements.
2. Performing pair-wise comparisons of the decision elements.
3. Estimating the weights if the decision elements by using Eigen-value method.

4. Aggregating the weights of the decision elements to provide a set of ratings for the decision alternatives.

Starting with the first step, the decision problem is formulated in a hierarchical structure. The decision problem is broken into a hierarchy of interrelated decision elements. Figure below illustrates such a hierarchy.

At the top of the hierarchy lies the most general objective of the problem such as the objective of making the best decision or selecting the best alternative.

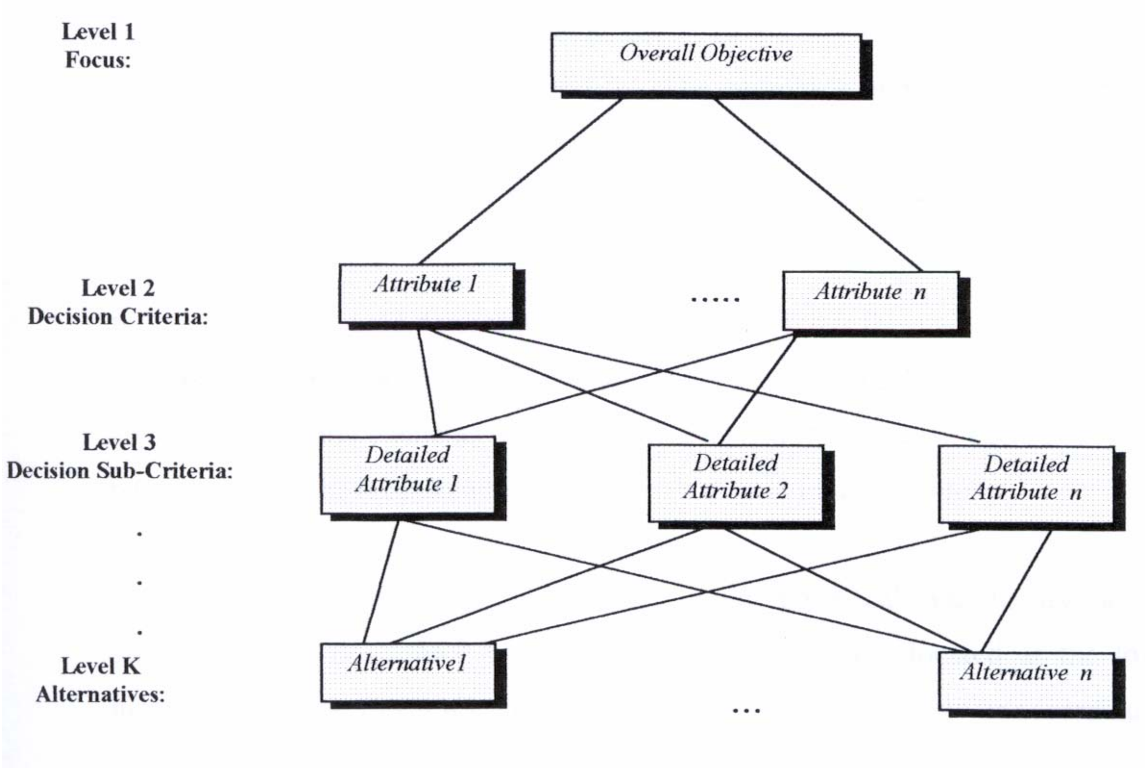


Figure 3.1: *Standard Hierarchical Structure*

The number of levels depends on the complexity of the problem and on the degree of detail. Each level of the hierarchy contains attributes or objectives that influence the decision. A node in the hierarchy represents the main criteria that may have sub-criteria or decision alternatives in the immediate lower level to be prioritized.

Each relationship is weighted according to the strength of influence an alternative or criterion at same level K exerts on alternative or criterion at level K-1, where K = 1, 2,3... N-1, N. The most general risky and uncertain the decision element the higher the level. The elements in each level are influenced or controlled by the elements in the level immediately above. Influence is distributed downward from the top.

The degree of influence is measured on nine-point scale.

The 1 to 9 scale is used as follows:

1. One (1) for equal importance of the two evaluated elements.
2. Three (3) for moderate importance of one elements over the other.
3. Five (5) for strong importance of one elements over the other.
4. Seven (7) for very strong importance of one elements over the other.
5. Nine (9) for extreme importance of one elements over the other.
6. 2, 4, 6, 8 for compromise.
7. Reciprocals for the inverse comparison.

The second step involves the pair-wise comparison of the decision elements for each group headed by a main criterion (node). The comparison is done in pairs and placed in matrix A of the following form; this is what we refer to as the pair-wise comparison. Pair wise comparisons are fundamental building blocks of the AHP.

$$\mathbf{A} = \begin{bmatrix} 1 & a12 & .. & a1n \\ 1/a12 & 1 & .. & a2n \\ : & : & :: & : \\ 1/a1n & 1/a2n & .. & 1 \end{bmatrix}$$

Each a_{ij} entry of **A** reflects the factor by which alternative i dominates alternative j as follows:

1. $a_{ij} = 1/a_{ji}$, for $a_{ij} \neq 0$

2. $a_{ij} = 1$, for i = j and i , j = 1, 2, ..., n.

Thus A is a reciprocal matrix. The evaluator has the option of expressing preferences between the two as equally preferred, weakly preferred, strongly preferred or absolutely preferred, which would be translated into pair-wise weights of 1,3,5,7 and 9 respectively, with 2, 4, 6, and 8 as intermediate values.

In the 3rd step the Eigen-value method is used to estimate the relative weights of the decision elements.

If the judgment of the evaluator is perfect in each comparison, $a_{ik} = a_{ij}a_{jk}$ for all values of i, j, k and **A** is referred to as a consistency matrix. The principal eigenvalue of **A** is used to measure judgment consistency, (26). The principal eigenvector of **A** is the ratio scale defining these weights and is defined as:

$w = [w_1 \ w_2 ... w_n]^T$

And it is the vector of the actual relative weights. In order to determine w, the following equations must be satisfied:

$A.w = \lambda max \ w,$ (1)

Where **A** is the observed matrix of the pair-wise comparison; λ_{max} is the principal Eigen-value of **A**; w is its right eigenvector .

Perfect consistency is very difficult to achieve and some inconsistency is expected to exist in every pair-wise comparison. To handle this, the AHP provides a method for measuring the degree of consistency among the pair-wise comparisons (judgments) provided by the decision-maker. If the degree of consistency is acceptable, the decision process can continue. If it is not acceptable, the decision-maker should revise the pair-wise comparison judgment. A consistency ratio of 0.10 or less is considered to indicate a reasonable level of consistency in the pair-wise comparison.

In equation (1), the closer the value of λ_{max} is to n, the more consistent are the observed values of A. Thus the algebraic difference between λ_{max} and n is a measure of consistency. Saaty (1980) suggests the following consistency index:

$$C.I = \frac{\lambda max - n}{n - 1} \qquad (2)$$

And for consistency ratio (CR) as:

$$CR = (CI / ACI)*100, \qquad (3)$$

Where ACI is the average index of randomly generated weights (Saaty 1980). A CR value of 10% or less is acceptable. Otherwise, it is recommended that **A** be re-observed to resolve the inconsistency in the pair-wise comparison. The second section of the program does this calculation as shown below. The program performs a consistency check and displays the results as shown below.

If the judgments are consistent we can proceed with the analysis, otherwise we have to repeat the evaluation.

In the last step of the AHP the relative weights of various levels are aggregated. The results produce a vector of composite weights, which will serve as a ranking of the decision alternatives. The composite relative weight vector of elements at the kth level with respect to that of the first level may be computed by:

$$C\,[1, K] = \prod_{I=2}^{k} B_{i,} \qquad (4)$$

C [1,K] is the vector of composite weights of the elements at level k with respect to the elements on level 1, and $B_{i,}$ is the n_{i-1} by n_i matrix with rows consisting of estimated W vectors; n_i represents the number of elements at level i.

5. DECISION CRITERIA FOR THE SELECTION OF PROJECT ALTERNATIVES

5.1. Project-Related Criteria

1. Time

This is defined as the time required to place the system in operation. The time might be affected by delays on approvals of waivers, import permits, land use permits or delays in the construction of the other supporting facilities.

2. Permit & Approval

This criterion includes: 1) waivers for using non-standard equipment or non-standard installations; 2) equipment import permits; 3) land use permits. These sub-criteria may have a significant impact on the project duration.

3. Performance & Acceptance

This criterion includes satisfaction or acceptance of the proposed system by the owner (operating organization), the project management team (PMT), the end user, and the public.

4. Cost

This cost will be broken down into:

- Initial cost
- Operating and Maintenance cost
- Replacement cost
- System upgrading cost
- Leasing cost

- Decommissioning cost

5. Project Location

This specifies the location of the project. Some locations might not be thought desirable by the PMT or the owner due to site hardship or difficulty of accessibility. The location might be located in territories not belonging to the owner, making it an unattractive proposition. The location of any project might have an effect on its economic development.

6. Ownership and Control

This criterion considers the importance of ownership of the system and its control (13). The company may decide to lease the services from another entity, or government agency. The problem associated with this choice is the lack of system control by the company. If an outage happens somewhere in the system at certain time, repair might not take place immediately due to the differing priorities of the leasing entity. As a result, the company may incur loss of revenue due to unproductive downtime.

5.2. Equipment Related Factors

1. Operation Characteristics

Equipment operation characteristics include reliability, availability, and protection during failure, heat dissipation, power, and security of the system equipment.

2. Mechanical Characteristics

This criterion constitutes the dimensions, physical configuration and the weight of the equipment.

3. Compliance

Compliance is the ability of the system to interface with existing and future communications systems and the ability to conform to internationally known standards and protocols.

4. Life & Technology

This consists of system life, and system technology status. The life of the implemented system includes:

- Working life
- Economical life
- Technological life.

The working life is the duration of time in which the system is expected to operate. Some systems are expected to operate only for a certain period of time (i.e., a communications system built to support the construction activities of a major project). Economic life is the duration of time in which the system is expected to add to the revenue of the company. Technological life is dependent on the life expectancy of a communications system based on anticipated vendor support. Some vendors discontinue manufacturing certain products after several years, either due to bankruptcy or new products on the market.

System features:

The system features includes:

- Mandatory features
- Operational features

5. Equipments safety

This criterion is associated with the safety of the equipment. The evaluator needs to find out if the equipment is intrinsically safe. When it is confirmed then the equipment is approves to be operated in areas in which hazardous concentration of flammable gasses exists continuously, intermittently, or periodically.

6. Climatic and Environment Requirements

Ambient operating temperature and relative humidity are the conditions under which the system can be operated without affecting it performance.

7. Power requirement

The system should be operated at a specified power either at -48 VDC (nominal) or 120V AC, 60Hz or as specified. The system should be able to switch automatically to backup power in the event of main power failure.

5.3. Vendor Related Factors

This criterion includes the vendor's experience and reputation; the vendor's ability to support its products through warranties, site maintenance, hot-line support, user training, consulting, and documentation.

6. COMPUTERIZED DECISION MAKING MODEL

6.1. Introduction

The computerized decision making model was created in visual basic. The program consist of six modules. These are:

1. Start Module
2. Initial Data Module
3. Criteria Pair-Wise Comparision Module
4. Initial Alternatives Data Module
5. Alternative Pair-Wise Comparision Module
6. Synthesis Module

All the input data and output data are automatically saved in a microaccess file called Alirezam.mbd. The input data is plotted immediately after performing the pair-wise comparision and obtaining the weights for the criteria. The consistency check is done everytime the pair-wise comparision is performed. The data must be entered in the initial data module and in the alternative initial data module and not in the access file.

The program has the apability to retrieve the files from the database via the pop-up menu. The print command prints the image of the sheet only.

6.2. Program Limitations

The program is limited to decision problems that have:

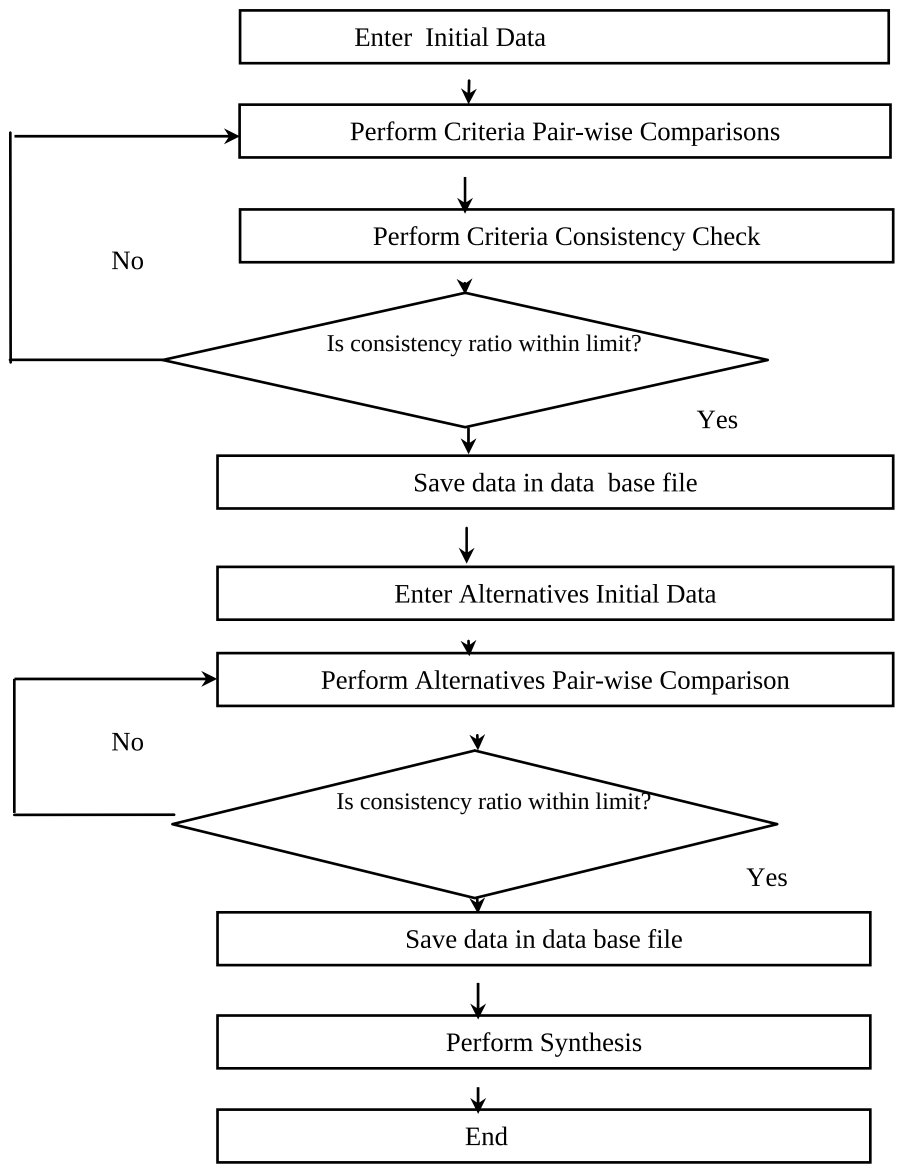
- Hierarchies of five level or less
- Criteria groups with ten sub-criteria or less

There is no restriction on the no of alternatives, but it is recommended that the number of alternatives should not exceed more than ten alternatives.

6.3. The Developed Program

Flow Chart of the program:

The following is the flow chart of the program. The program has mainly 12 steps. Once the program is loaded it initializes the output date files and then proceeds with the calculations after the user has input the data.



6.4. Program Step By Step Calculation

The different modules of the computerized model are shown below in Appendix A

7. PROJECT ALTERNATIVES EVALUATION PROBLEM CASE STUDY

7.1. Scope

In this section, a case study is presented to demonstrate the application of the developed Computerized Decision Making Model. The model is applied to rank the project alternatives. Under the scope of study, a major industrial company has decided to replace its current mobile communication system, infrastructure and end user equipments with a new state of Art Mobile Radio System.

7.2. Alternatives

Three mobile radio system alternatives were investigated. These are

1. To replace the current system with an analog system
2. To replace the current system with open architecture, this might end up in potential cost and schedule risk.
3. To replace the current system with proprietary system architecture, this may carry with it discontinued vendor support due to using non-standard equipment.

The next section describes how the AHP and the developed program can be used to assist in ranking the alternatives. The main objective of this decision making process is to determine the most viable alternative for implementating the project. The objective is located at the level one of the hierarchy as decipted in the next figure and is called the objective node. The factors are devided into three main groups.

Weights that reflect the influence of the major decision elements: the project, system and vendor which are the major key in overall decision can be assigned by performing the pairwise comparision at each level

7.3. Methodology Applications and Discussion

First Step: The decision problem if formulated in a hierarchical structure , (Appendix B) then it is broken into hierarchy of interrelated decision elements. The next figure shows the structure of the hierarchy based on the distribution of the decision elements per the related group. At the top lies the most important objective which is the selection of the most appropriate telecommunication project.

In the second level, the less controllable, the more risky and uncertain are listed. These are the project criterion, system criterion and vendor criterion.

Each of these criterion is broken down into sub-criteria in level three. Project criterion is broken in six (6) sub-criteria, namely Cost of project, Miscellaneous and time to implement, permits, approvals and acceptance of the project. The decision maker has to judge if any of these criteria has more importance than other.

System criterion is broken in four (4), Operatibility, Mechanical Characteristic, and Compliance of the equipments with standards & specification and Life & Techonology of the System.

Vendor criterion has three (3) sub-criteria, these are Vendor Reputation, Support during implementation and Support after commissioning.

The sub-criteria in level three are further broken into sub-sub-criteria: Cost is broken further in six (6) elements, Initial cost to engineer-constructing, testing and commissioning, Operation & Maintenance cost, Future system upgrade cost, Alteration and replacement cost, leasing cost, and Decommissioning cost.

Miscellaneous and time is broken into three (3), Time, Ownership & Controls and Location of project.

Under Permits and Approvals we have, Land use permit, equipment importation permit and waivers to use non-standard equipments or implementation/ construction methods.

In fourth level under project criterion the elements includes, Acceptance by the government, Acceptance by poject management team, Acceptance by the owner, by the end user and by the public.

Operation characteristics is broken into seven sub-criteria: Reliability, Equipment availability, Equipment protection during failure, Heat, Power, Climatic Criterion and Security of equipment during operation.

Mechanical criterion is broken into three elements that includes, Dimension of the equipment, Physical Characteristic and weight of the equipment.

Compliance has six (6) sub-criteria, Compliance to internation standars, Compliance to owner standards, intrinsic safety, Compatibility to the existing system, Mandatory and optional features Compliance.

Under Life and Technology the sub-elements are, System migration ability to future upgrades and developments, Technology ststus of the equipment, System working life, System economical life, and System technological life.

Vendor reputation is further broken into, Availability of techinical literature, Responsiveness to customers, and consultation.

The sub-criteria for Vendor support during implementation are: Avaiability of techinical expertise, Quality of engineering work, and Site Support.

Vendor support after commissioning includes, Warrenties, On site maintenance, Documentation, Hotline support, and Users Training.

7.4. Criteria Pairwise Comparision

In this step the pairwise comparision (Appendix C) was carried out for all the criteria

7.4.1. Main Criteria Pairwise Comparision
7.4.2. Project Sub-Criteria Pairwise Comparision
7.4.3. System Sub-Criteria Pairwise Comparision
7.4.4. Vendor Sub-Criteria Pairwise Comparision
7.4.5. Cost Sub-Criteria Pairwise Comparision
7.4.6. Time & Miscellaneous Sub-Criteria Pairwise Comparision
7.4.7. Permits & Approvals Sub-Criteria Pairwise Comparision
7.4.8. Project Acceptance Sub-Criteria Pairwise Comparision
7.4.9. Operation Characteristics Sub-Criteria Pairwise Comparision
7.4.10. Physical Characteristics Sub-Criteria Pairwise Comparision
7.4.11. Compliance Sub-Criteria Pairwise Comparision
7.4.12. System Life & Technology Sub-Criteria Pairwise Comparision
7.4.13. Vendor Reputation Sub-Criteria Pairwise Comparision
7.4.14. Vendor Support during Implementation Sub-Criteria Pairwise Comparision
7.4.15. Vendor Support after commissioning Sub-Criteria Pairwise Comparision

8. SUMMARY CONCLUSION AND RECOMMENDATION

8.1. Summary

Industrial companies desire to stay ahead of their competitors. They seek to maintain their competitiveness and increase their profitability to ensure their future survival. To do so, companies must initiate and implement investment projects to increase production, improve quality, enhance performance or minimize production costs. The initial feasibility of such an investment must be determined at the early stage of the project. Conducting the initial feasibility studies usually requires the determination or selection of the best alternative for any investment project. This can be accomplished by the use of a multi-criteria decision making approach that considers the tangible and intangible decision criteria.

In this report a Computerized Multiple Criteria Decision-Making Model based on the AHP methodology has been presented. This model was applied to rank the available alternatives of telecommunications system for a major industrial company. The ranking of these alternatives will focus management attention on the best alternative and ensure that success of the project can be attained.

8.2. Conclusion

The developed Computerized Multiple Criteria Decision-Making Model gives the uses a structured and systematic decision making approach for evaluating and selecting projects alternatives. Additionally, this model can be used throughout the phases of the project. The areas in which this model can be applied include but, are limited to:

1. Preliminary engineering phase to:
    - Determine the initial feasibility of the projects.
    - Evaluate the technology alternatives.

    Contract development and bidding phase to:
    - Perform contractors pre-qualification
    - Evaluate technical bids.
2. Evaluation phase of the value engineering phase.

The application and use of this decision making approach is straightforward. However, the difficulty lies in construction of the decision hierarchy which depends mainly on the decision maker’s experience.

8.3. Recommendation for future research

Additional research on the developed Computerized Multiple Criteria Decision-Making Model should be conducted. This can include application of this model on the other aspects of project management such as the areas mentioned above.

It is recommended that this Computerized Model should be developed further to be part of an expert system that includes all the criteria that influence the various decisions for all aspects of the project. It should be noted that the developed model in this research is based on a deterministic approach to decision making. It does not consider uncertainties. Therefore, it is recommended that the future research incorporates such uncertainties.

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Appendix

Appendix A

Appendix B

Appendix C