DECISION MAKING MODEL FOR PROJECTS

ABSTRACT

Companies initiate and implement projects to promote investment and maintain their competitiveness. To ensure success, management must make positive decisions during the planning and implementation phases of these projects. In this report a Computerized Decision Making Model (CDMM) based on the Analytic Hierarchy Process (AHP) is presented, to assist in making decisions on all aspects of a project. This process incorporates the quantitative and qualitative aspects of decision problems and performs a consistency test of the decision-maker's judgment. An example is illustrated using hypothetical but representative data to rank the alternatives involved in a major industrial company's telecommunications project.

INTRODUCTION

Projects are implemented to achieve certain goals. These goals may include increasing the profit of a company or enhancing its competitiveness to ensure its future survival. In order for projects to be successful, the company must implement the best project alternative to achieve its business objectives.

At the time of the preliminary engineering study, the decision making team is faced with a dilemma in which more than one objective needs to be satisfied in its decision making process. The need to satisfy these objectives simultaneously is a major factor in determining the order of preference for the available project alternatives. Selecting an inadequate alternative will result in an incorrect decision, thereby causing loss of time and money for the company. Although the project goals are defined, it is unclear how these goals can be measured or achieved. They are usually stated in an abstract, elusive and unclear manner, (8).

Quite often, project owners consider cost only when comparing project alternatives, or do a traditional cost-benefit analysis. Unfortunately, projects involve environmental, political, social and other intangible factors, which are usually ignored in the cost-benefit analysis, because they can not be measured in monetary units. Decisions dealing with cost-benefits only are inadequate decisions that may lead to failure of a project.

Other problems that might be encountered during the decision making process may include: complexity of the decision, inconsistency of the decision maker, political favors and hidden agenda by the decision maker, overlooking the project objective, conflict, and variation of the perception from one individual to another, just to name a few. To avoid these problems and improve the decision-making, a structured and comprehensive computerized multi-criteria decision-making model based on the Analytic Hierarchy Process (AHP) that assists in the decision making of all aspects of the project is recommended and presented in this paper. The model will help to focus the decision-maker's attention on the main objective of the project and ensures that the judgments are consistent. It has been applied to a case study to demonstrate its usefulness and viability.

This report will consider only telecommunications projects. Factors that are considered in the decision model are the factors that influence the decision-making with regard to system selection and the project. These factors have been obtained from a literature review, questionnaires, and previous telecommunications project documentation. The questionnaires were distributed to selected professional who play a major role in telecommunications project decision-making to seek their opinion regarding these factors.

The next section explains the AHP methodology. The application of the method is illustrated via hypothetical but representative data to rank the alternatives available to a telecommunications project. The program structure is presented through the application example and, finally, the summary and concluding remarks are presented.

Analytic Hierarchy Process (AHP)

Dr. Thomas Satty developed the AHP, (1977, 1986). It is a robust and flexible multi-criterion decision-making approach used for prioritizing alternatives and determining trade-offs among them. A hierarchical structure models the system of interest and an intermediate objective is to determine the influence that the alternatives in one level in the hierarchy exert on the next higher level, (26).

It aids in the decision-making analysis and it is designed to solve complex problems involving multiple criteria. It has been used in the analysis of decisions involving both tangible and intangible criteria to rank alternatives on the basis of cost, benefits and risk.

It has been applied in many areas where it was used to solve highly complex and elusive decision problems. Areas where the AHP has been used include economics and planning, energy policies, health, conflict resolution, arms control, material handling and purchasing, manpower selection and performance measurements, and marketing and consulting (25). All these areas share one problem, a decision problem, which has to do with rating decision alternatives, selection or prediction.

The decision 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 selection relative to each criterion. The output of the AHP is a prioritized ranking indicating the overall preference for each of the decision alternatives.

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:

The AHP consists of the following four steps:

1. *Develop the decision hierarchy by breaking down the decision problem into a hierarchy of inter-related elements.*
2. *Perform the pairwise comparisons of the decision elements.*
3. *Use the eigenvalue method to estimate the relative weights of the decision elements.*
4. *Aggregate the relative weights of the decision elements to arrive at a set of ratings for the decision alternatives.*

Methodology Application

A major industrial company has decided to replace its current communications system, infrastructure and end-user equipment with a new state-of-the-art system. This project is viewed as a big investment for the company which will enhance its production and place it on the competitive edge.

Three system alternatives were investigated. These are: 1) replacing the current system with a new analog system. [This alternative has been tried, field proven and used by other entities]; 2) replacing the current system with proprietary system architecture, [there is a possibility of discontinued support after commissioning due to the use of non-standard equipment]; 3) replacing the current system with open system architecture, [this alternative has potential cost and schedule risks due to the unavailability of the product in the market on a larger scale].

The next section describes how the AHP and the developed program can be used to assist the company in ranking these 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. The criteria are divided into three categories, these are: project-related, equipment-related and vendor-related.

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 criterion includes all the costs associated with system installation, replacement, operation and maintenance, system upgrade and decommissioning.

5. 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, makeing 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.

Equipment Related Factors

1. Operation Characteristics

Equipment operation characteristics include reliability, availability, 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 its working, economical and 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 .

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 (21).

The Developed Program

The program has been developed in Visual Basic, which is linked to data base files in Microsoft Access. The following is the flow chart of the program:

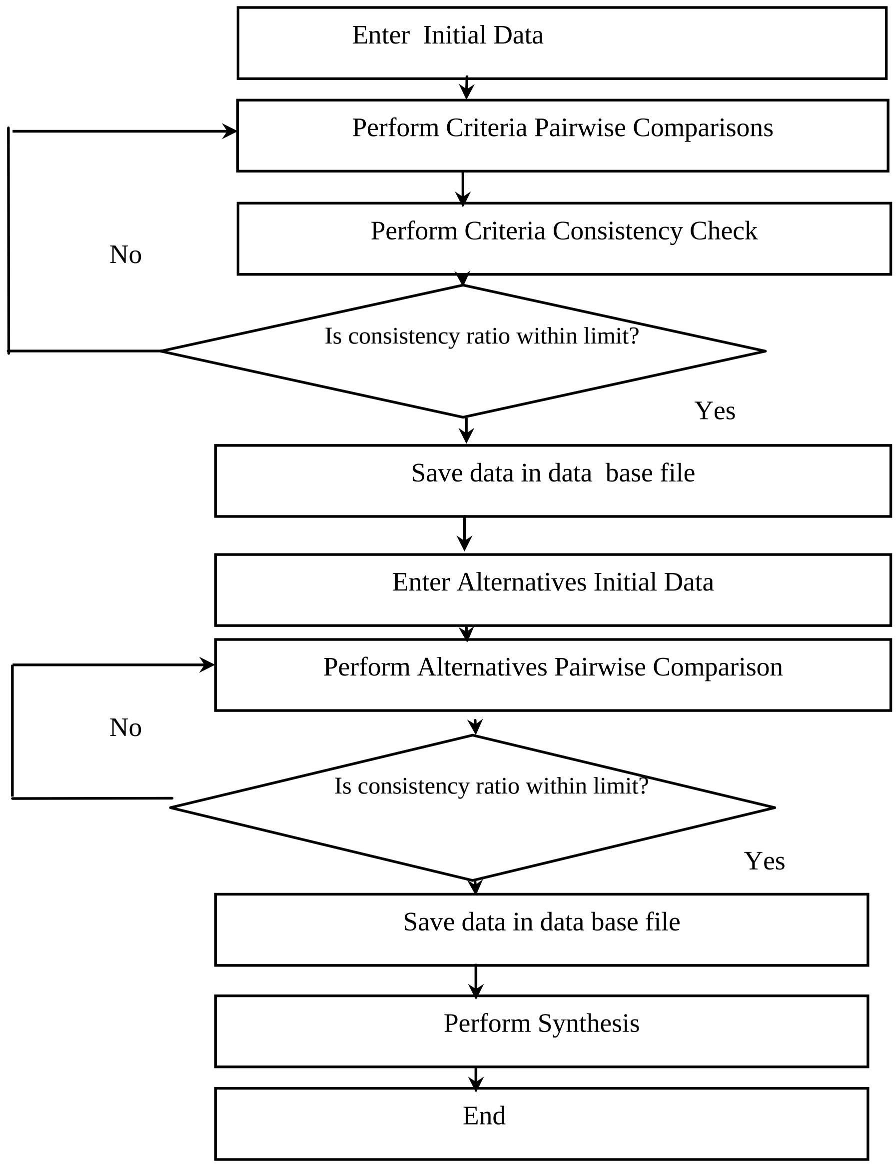

Figure one (1), illustrates the decision hierarchy. It has four (4) levels. At the top of the hierarchy lies the most general objective of the problem, such as the objective of making the best decision or selecting the best alternative. The more general, more risky and uncertain the decision elements, the higher the levels are. The elements in each level are influenced or controlled by the elements in the level immediately above. In the example the main objective is to “ *select the best telecommunications system that can support the company operation* ”.

Influence is distributed downwards from the top, which is the main objective. The main objective has the greatest influence with a value of one. This value is divided among the decision elements of the second level and the values of each level down below down to the level of alternatives, the last level in the hierarchy.

The degree of influence is measured on a nine-point scale: one (1) for equal importance of the two evaluated elements, three (3) for moderate importance, five (5) for strong importance, seven (7) for very strong importance and nine (9) for extreme importance of one element over the other. Numbers 2, 4, 6 and 8 are used for compromise and reciprocals for the inverse comparison. Nodes in the hierarchy represent main criteria that may have sub-criteria or decision alternatives in the immediate lower level to be prioritized.

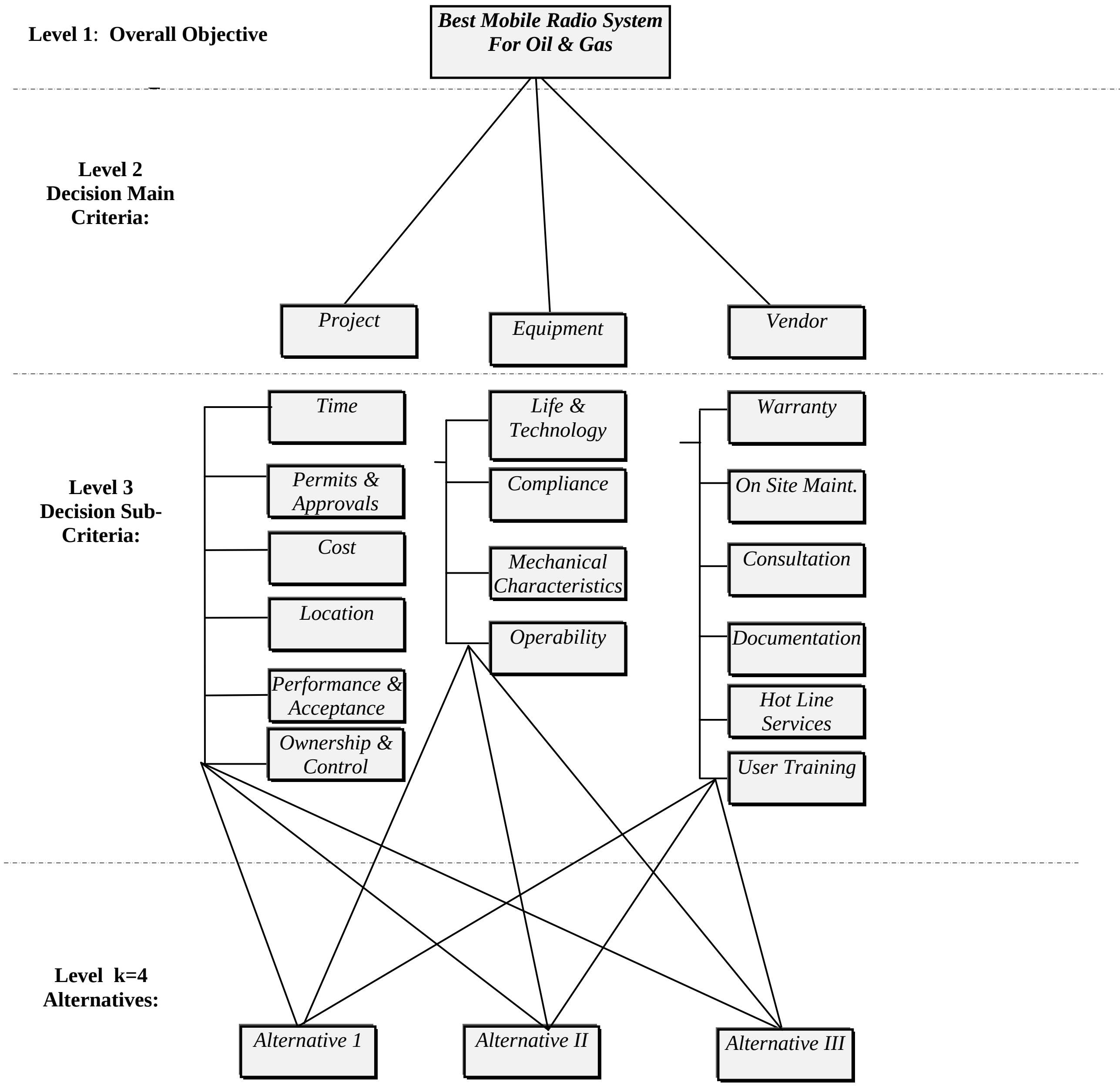

Figure 1: *Hierarchical Structure*

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 number of levels depends on the complexity of the problem and on the degree of detail.

The second step involves the pairwise 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 pairwise comparison. Pair wise comparisons are fundamental building blocks of the AHP.

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

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.

In the example, the first three main criteria at the second level are evaluated first. These are project, equipment and vendor.

$$\boldsymbol{A} = \begin{array}{r} \\ \textbf{Project} \\ \textbf{Equipment} \\ \textbf{Vendor} \end{array} \begin{bmatrix} \textbf{Project} & \textbf{Equipment} & \textbf{Vendor} \\ 1 & 1/6 & 1/2 \\ & 1 & 5 \\ & & 1 \end{bmatrix}$$

They are placed in a 3x3 matrix called matrix A. in the first row, equipment is evaluated between strongly more important and very strongly more important (1/6) than project. This is due to the fact that the equipment will survive after the project is completed; the owner will live with the system for the rest of its life. That is why it is given more importance than the project it self. Vendor is judged to be between equally more important and moderately more important than the project criterion. Again it is the vendor who should give support after the project is over, such as spare parts support, training, and on site maintenance.

Equipment in the second row is evaluated as strongly more important than vendor. These values are entered in the program to calculate the weights and the consistency. As shown below, the first module of the program called “ initial input data”:

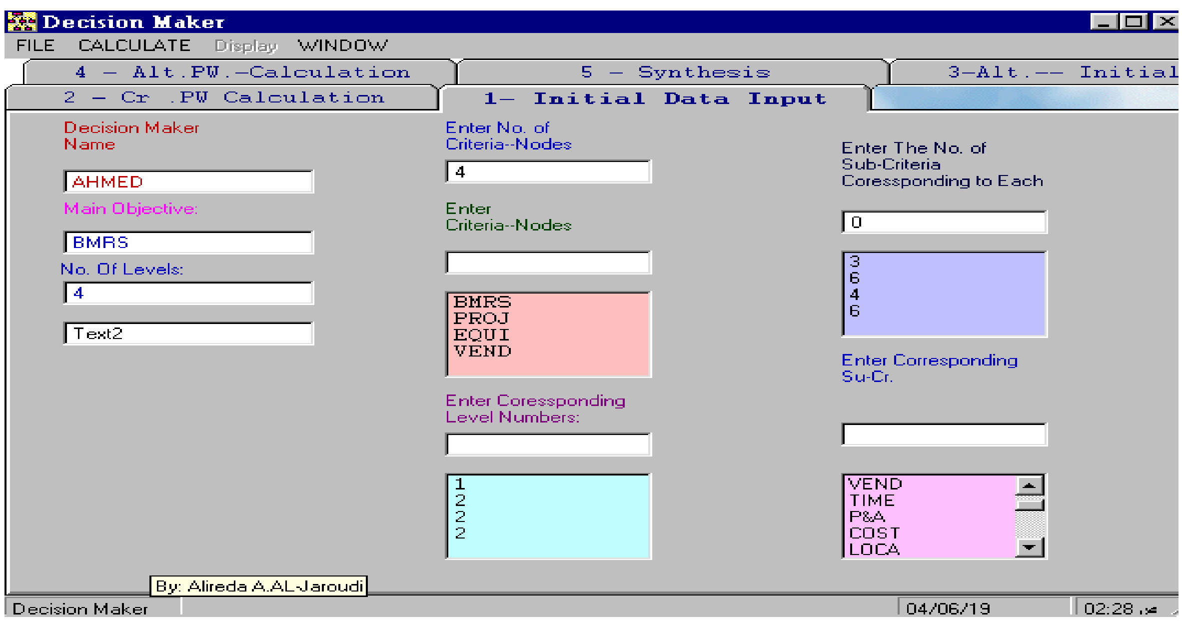

Figure 2. Initial Data Input

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:

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

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

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

where **A** is the observed matrix of the pairwise comparison; λ_{max} is the principal eigenvalue of **A**; w is its right eigenvector .

Perfect consistency is very difficult to achieve and some inconsistency is expected to exist in every pairwise comparison. To handle this, the AHP provides a method for measuring the degree of consistency among the pairwise 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 pairwise comparison judgment. A consistency ratio of 0.10 or less is considered to indicate a reasonable level of consistency in the pairwise 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, (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 pairwise 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.

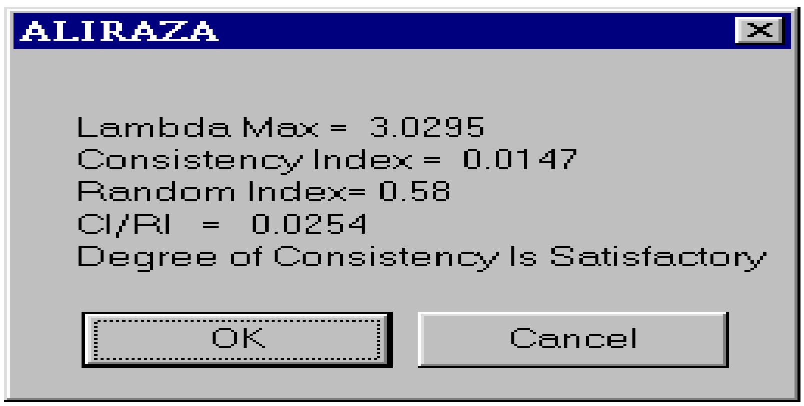

Figure 3. Consistency Check

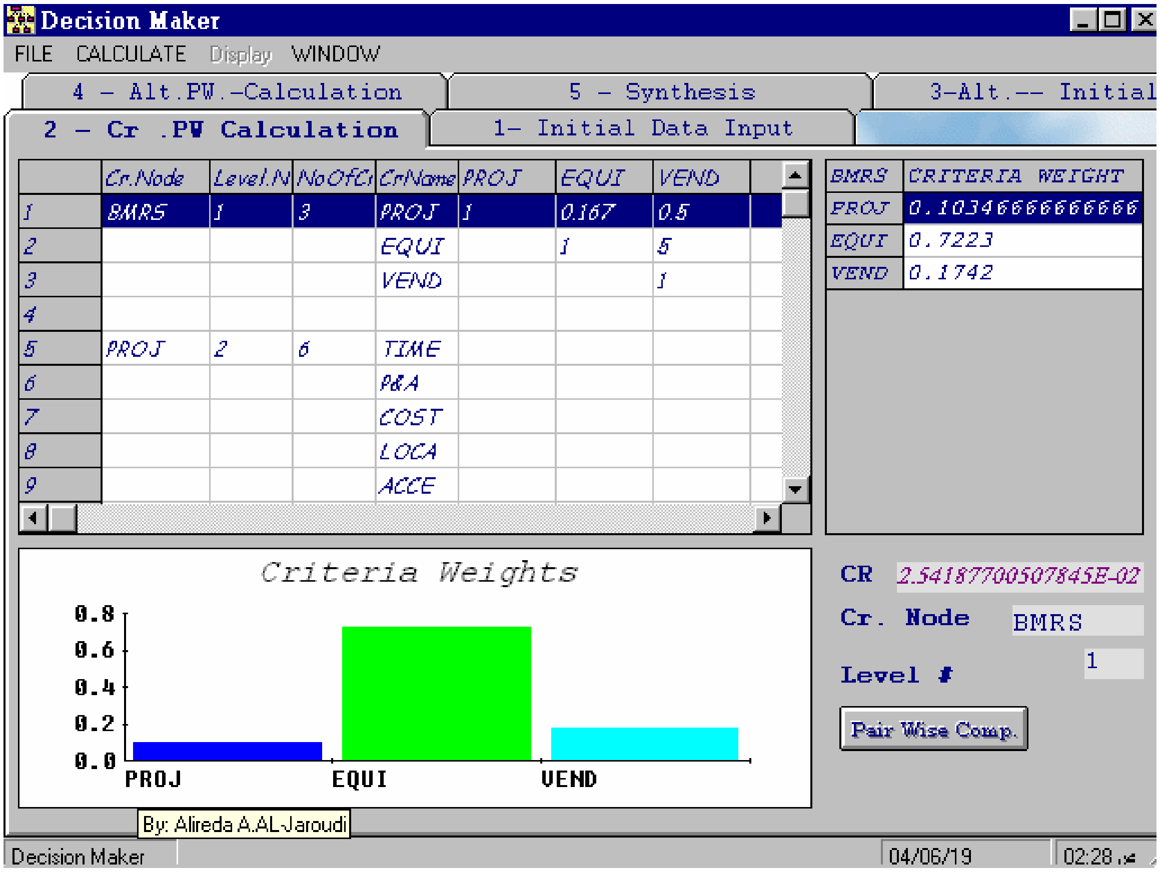

Figure 4. Criteria Pairwise Comparison and Ranking (Weights)

The weights for the main criteria are shown again in the following table:

Node	MCNAME	MCVALUE
BMRS	*PROJECT*	*0.103466666666667*
BMRS	*EQUIPMENT*	*0.7223*
BMRS	*VENDOR*	*0.1742*

Consistency: 0.0254------ **MCVALUE:** Main Criteria Value (Weight)

Table 1. Main Criteria Weights (Ranking)

Equipment criterion has the highest weight. The judgments are consistent, since the consistency ratio is within the limits. The pairwise comparisons for the other criteria will follow in the same fashion.

The weights for the sub-criteria are calculated as follows by the program. The abbreviations used are as follows:

SC2NAME: Sub-criteria name at second level.
SC2VALUE: Sub-criteria value (Weight) at second level
P&A: Permits & approval
LOCA: Location
ACCE: Acceptance
O&C Ownership & control
OPER: Operability
MC: Mechanical characteristics
COMP: Compliance
L&T: Life & technology
WARR: Warranty
OSM: On site maintenance
CONS: Consultation
DOCU: Documentation
HLS: Hot line support
UT: User training

Criteria Node	**SC2NAM**	**SC2VALUE**
PROJECT	*TIME*	*0.0942*
	P&A	*0.30905*
	COST	*0.16733*
	LOCA	*0.100983*
	ACCE	*0.12927*
	O&C	*0.19915*

Table 2. Project Sub-Criteria Weights

Name	SC2NAM	SC2VALUE
EQUIPMENT	*OPER*	*0.26445*
	MC	*0.0913*
	COMP	*0.28375*
	L&T	*0.3605*

Table 3. Equipment Sub-Criteria Weights

Name	SC2NAM	SC2VALUE
VENDOR	*WARR*	*0.277933*
	OSM	*0.16593*
	CONS	*0.149083*
	DOCU	*0.20717*
	HLS	*9.003E-02*
	UT	*0.1098*

Table 4. Vendor Sub-Criteria Weights

Next the initial input data and weights for the alternatives are entered in the program as shown below.

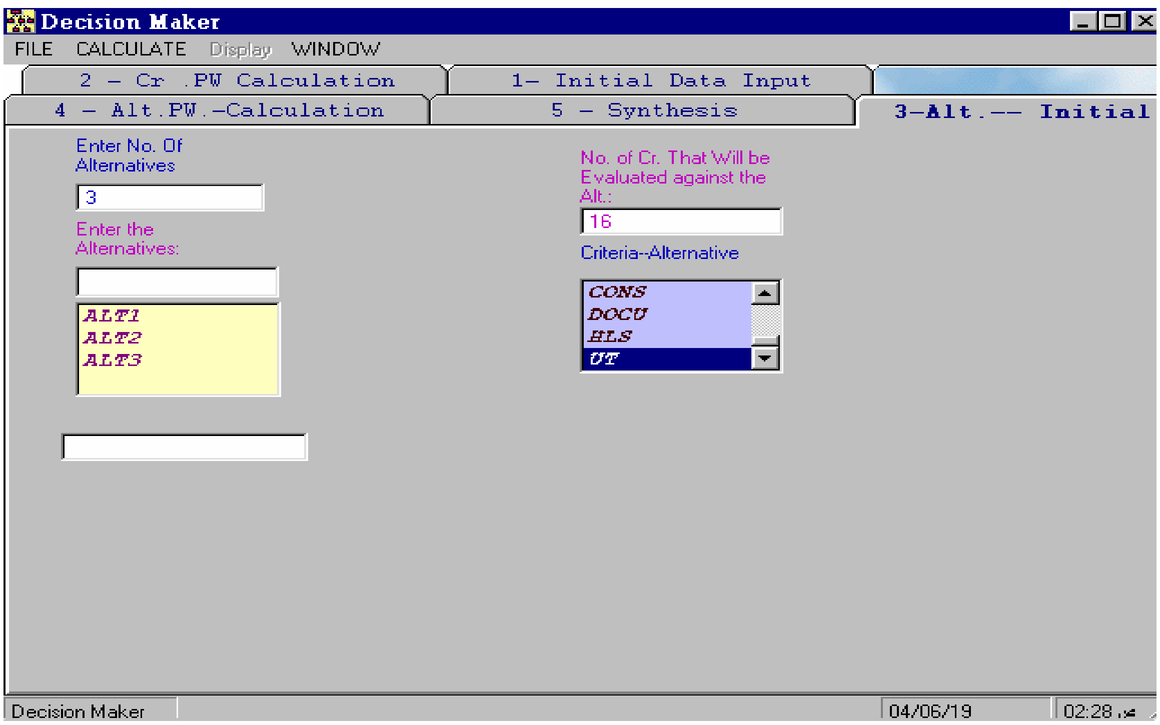

Figure 5. Initial Data Input for Alternatives

Each alternative is evaluated against each sub-criterion in the lowest level for each criteria group. As an example, refer to figure 6.0, the alternative pairwise comparison module.

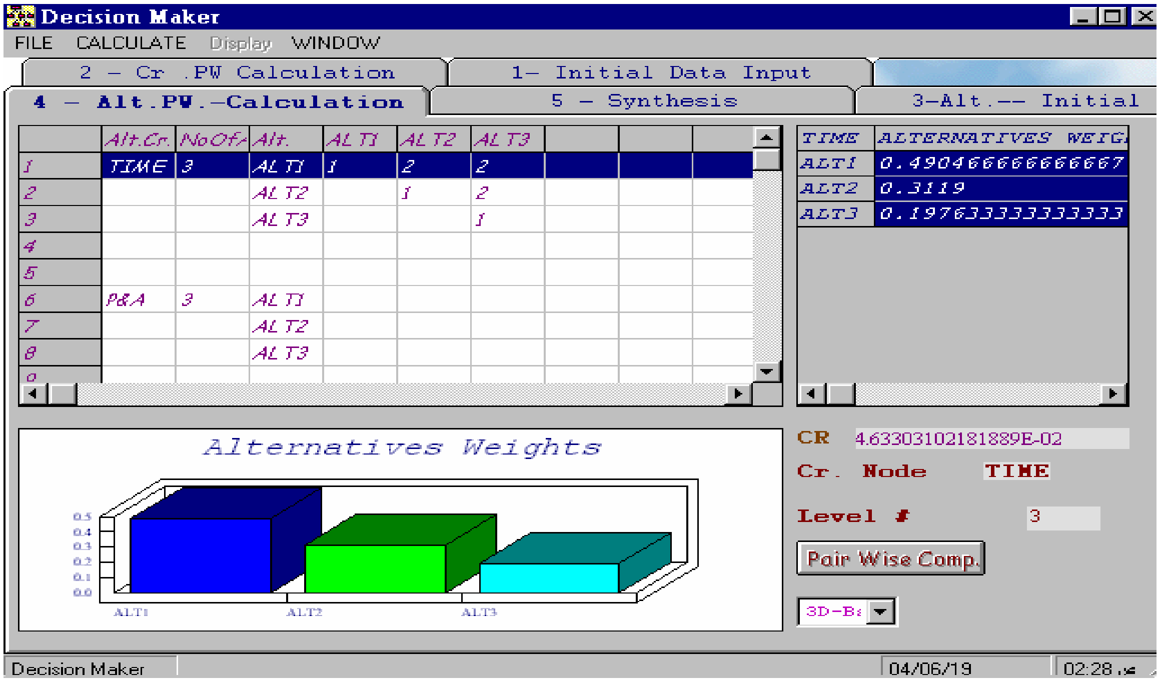

Figure 6. Alternatives Pairwise Comparisons and Ranking (Weights)

In this figure alternatives are evaluated against time criterion, and alternative 1 is better than alternatives 2 and 3 with respect to time. Stated differently, alternative 1 can be deployed faster to the site than the other alternatives, due to its availability in the market at a larger scale (i.e., it is off the shelve product). Alternatives 2 and 3 are still in the R&D stage.

Abbreviations used in tables 5 through 8 are as follows:

Cr. Nmae: Criteria Name

Alt. Name: Alternative Name

Alt. Value: Alternative Weight

Criteria Node	CrName	AltName	AltValue
Equipment	*OPER*	*ALTI*	*0.08093*
	OPER	*ALTII*	*0.29307*
	OPER	*ALTIII*	*0.626*
	MC	*ALTI*	*0.09817*
	MC	*ALTII*	*0.33393*
	MC	*ALTIII*	*0.56787*
	COMP	*ALTI*	*0.0963*
	COMP	*ALTII*	*0.2836*
	COMP	*ALTIII*	*0.6201*
	L&T	*ALTI*	*0.05977*
	L&T	*ALTII*	*0.27903*
	L&T	*ALTIII*	*0.6612*

Table 5. Alternatives Pairwise Comparisons with respect to Equipment Sub-Criteria

Criteria Node	CrName	AltName	AltValue
Project	*TIME*	*ALTI*	*0.70153*
	TIME	*ALTII*	*0.22667*
	TIME	*ALTIII*	*0.0718*
	P&A	*ALTI*	*0.07033*
	P&A	*ALTII*	*0.3465*
	P&A	*ALTIII*	*0.58313*
	COST	*ALTI*	*0.05977*
	COST	*ALTII*	*0.27903*
	COST	*ALTIII*	*0.6612*
	LOCA	*ALTI*	*0.3333*
	LOCA	*ALTII*	*0.3333*
	LOCA	*ALTIII*	*0.3333*
	ACCE	*ALTI*	*0.094*
	ACCE	*ALTII*	*0.16663*
	ACCE	*ALTIII*	*0.73933*
	O&C	*ALTI*	*0.12243*
	O&C	*ALTII*	*0.32103*
	O&C	*ALTIII*	*0.55653*

Table 6. Alternatives Pairwise Comparisons with respect to Project Sub-Criteria

Criteria Node	CrName	AltName	AltValue
Vendor	*WARR*	*ALTI*	*0.07343*
	WARR	*ALTII*	*0.2808*
	WARR	*ALTIII*	*0.64577*
	OSM	*ALTI*	*0.07707*
	OSM	*ALTII*	*0.35883*
	OSM	*ALTIII*	*0.56407*
	CONS	*ALTI*	*0.06867*
	CONS	*ALTII*	*0.27667*
	CONS	*ALTIII*	*0.65467*
	DOCU	*ALTI*	*0.3333*
	DOCU	*ALTII*	*0.3333*
	DOCU	*ALTIII*	*0.3333*
	HLS	*ALTI*	*0.0792*
	HLS	*ALTII*	*0.22907*
	HLS	*ALTIII*	*0.69173*
	UT	*ALTI*	*0.0886*
	UT	*ALTII*	*0.13487*
	UT	*ALTIII*	*0.77653*

Table 7. Alternative Pairwise Comparisons with respect to Vendor Sub-Criteria

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:

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

where 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.

The final step is dealt with in the last module of the program as demonstrated below:

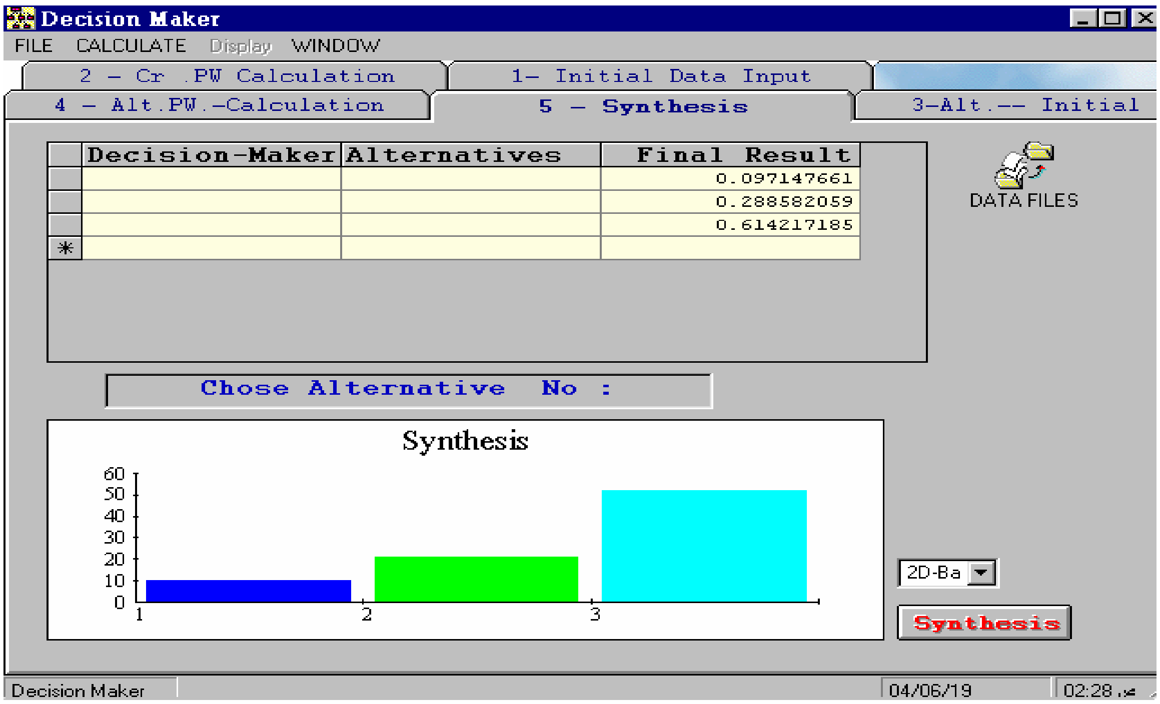

Figure 7. Final Results – The Synthesis

The following table shows the final results:

Alternatives	*Decision-Maker*	*Final Result*
ALTI	*ALIREDA*	*0.097147661*
ALTII	*ALIREDA*	*0.288582059*
ALTIII	*ALIREDA*	*0.614217185*

Table 8. Final Results -- The Synthesis and Ranking of Alternatives

The third alternative receives the highest weight, so the choice should be the third alternative.

The Benefits of the Decision Model

Not only can the computer based decision model provide the end-results pertaining to the decision problem, it can also provide a consistent, detailed, and systematic analysis of the decision problem. It provides a well-documented analysis of the decisions that can be traced at any time.

The model accelerates the decision process and provides decision-making in a timely manner which eliminates the overhead (O/H) cost for allocating resources to perform the decision-making process. Additionally it increases the likelihood of making sound decisions.

The model can be applied to all aspects of the project for alternative rankings and result predictions. The application areas may include ranking project alternatives, pre-qualification of contractors, ranking of bidders, employees' performance evaluation and ranking, project completion time and actual cost predictions. Additionally, it can be applied in the evaluation phase of value engineering (VE) studies..

Other advantages include the ability to incorporate tangible and intangible factors that influence decisions and the ability to test the consistency of a decision-maker's judgements.

The hierarchy of the decision can be standard for all decision situations involving telecommunications projects. In other words, the decision-maker does not need to develop another decision hierarchy every time. However, it can be altered to suit any decision situation. That applies to criteria pairwise comparisons. Also the comparisons can remain the same in subsequent decision situations unless the decision-maker feels that there is a need for re-evaluation. The result is a big saving of the time and resources required to collect data for decision-making processes.

SUMMARY AND CONCLUSION

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 a telecommunications system alternatives 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.

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Personal Biography

A A.A.AL-Jaroudi is currently working with Communications Project Management Team, Saudi Aramco. He has over sixteen (16) years of work experience in the area of telecommunications and project management. He worked with GTE Federal System Division, Virginia, and USA 1992-1993 where he worked on several telecommunications projects. He received his B.Sc. in Electrical Engineering from Valpariso University, Indiana, USA, in 1987 and M.Sc. in Construction Engineering and Management in 1998 from KFUPM. Mr. AL-Jaroudi is a member of Project Management Institute (PMI) and Institute of Electrical and Electronic Engineers (IEEE).

Dr. Sadi A. Assaf is professor of Construction Engineering and Management at King Fahd University of Petroleum and Minerals (KFUPM). He obtained his Ph.D. in 1982 from university of Illinois. His areas of specialization and interest are quantitative methods in construction, risk management, and life cycle costing. Dr. Assaf has 12 years of professional experience in the planning, design, and construction of major engineering and construction projects in the US, and has 16 years of experience teaching and researching construction management at KFUPM. He has received the Distinguished Research and Teaching Awards at KFUPM several times.

Dr. Mohammed Osama Jannadi is the Dean of College of Environmental Design at King Fahd University of Petroleum & Minerals in Dhahran Saudi Arabia. Dr. Jannadi received his Ph.D. from George Washington University in 1988. His main areas of interests are quantitative methods in construction management, safety and risk management. Dr. Jannadi has 10 years of experience teaching construction management at KFUPM and was chairman of the Construction Engineering and Management Department. He has published several papers in U.S. British and local Journals.