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TOOLS AND TECHNIQUES FOR INTELLIGENT PROJECT MANAGEMENT INFORMATION SYSTEMS: HERALDING A NEW PROJECT MANAGEMENT PARADIGM

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ABSTRACT

The focus of this paper is on presenting methodologies, tools and techniques utilized for systematic inclusion of both quantitative and qualitative variables for holistic decision-making and optimization of project plans. These comprise neural networks (NN), fuzzy logic, multi-criteria decision analyzes and intelligent agents as well as an integrated information system environment that permit both quantitative and qualitative evaluations merged through a transformation process. The development of domain knowledge on which training of neural networks can initially take place has presented a challenge. Typically, and following the soft systems methodology, information used to develop decision models of soft nature need to be case-based. Most if not all projects are unique in terms of objectives, scope, time, business imperatives etc. What may be considered as insignificant in one project may be critical in another. In order to model this decision paradigm the authors have devised a method for capturing the domain knowledge within the road transport sector, known as the integrated hierarchical decision framework. This paper describes the procedures, tools and transformation functions utilized in this research project. It describes the major high-level variables and the respective indicators that are used to evaluate these variables through several technologies and techniques. The work presented is part of a major research project funded by the Australian Research Council over a 3-year period and is in progress at the Project Management Research Center, Department of Civil Engineering of The University of Sydney.

KEYWORDS

Hierarchical Multi-criteria Decision Model, Artificial Neural Networks, Fuzzy Logic, Intelligent Agents

1. INTRODUCTION

This paper follows on from another paper written by the authors titled "A Conceptual Model for Holistic Decision Making in Projects". It would be appropriate to consult this preceding paper before continuing on.

A holistic project management information system is researched by the authors and in time will be developed to assist in the overall decision processes. The core of the discussion is on an integrated project management system and its hierarchical multi-criteria decision framework, which is partially presented in this paper and is fully presented in the preceding paper. The framework is designed to deal with dynamic decision-making where several alternatives and several criteria (quantitative and qualitative) are at its focus.

The objective of this paper is not to present and validate the approach but to outline the tools and techniques, which are used to facilitate such a framework and system. First, the overall modeling approach and the project management approach are presented. Then the tools and techniques to aid development of the model will be presented showing their potential in these areas. This is followed by future research and recommendations.

2. MODEL OF THE INTEGRATED PROJECT MANAGEMENT SYSTEM

In basic terms the integrated project management system and approach in the research is to determine the most optimal project solution given qualitative and quantitative criteria. The system is to be used by project managers and team members in real time using the aforementioned tools and techniques implemented in the system. Figure 1 shows the integrated project management system's hierarchical decision model component only. To see details of the decision model consult the preceding paper in the proceedings.

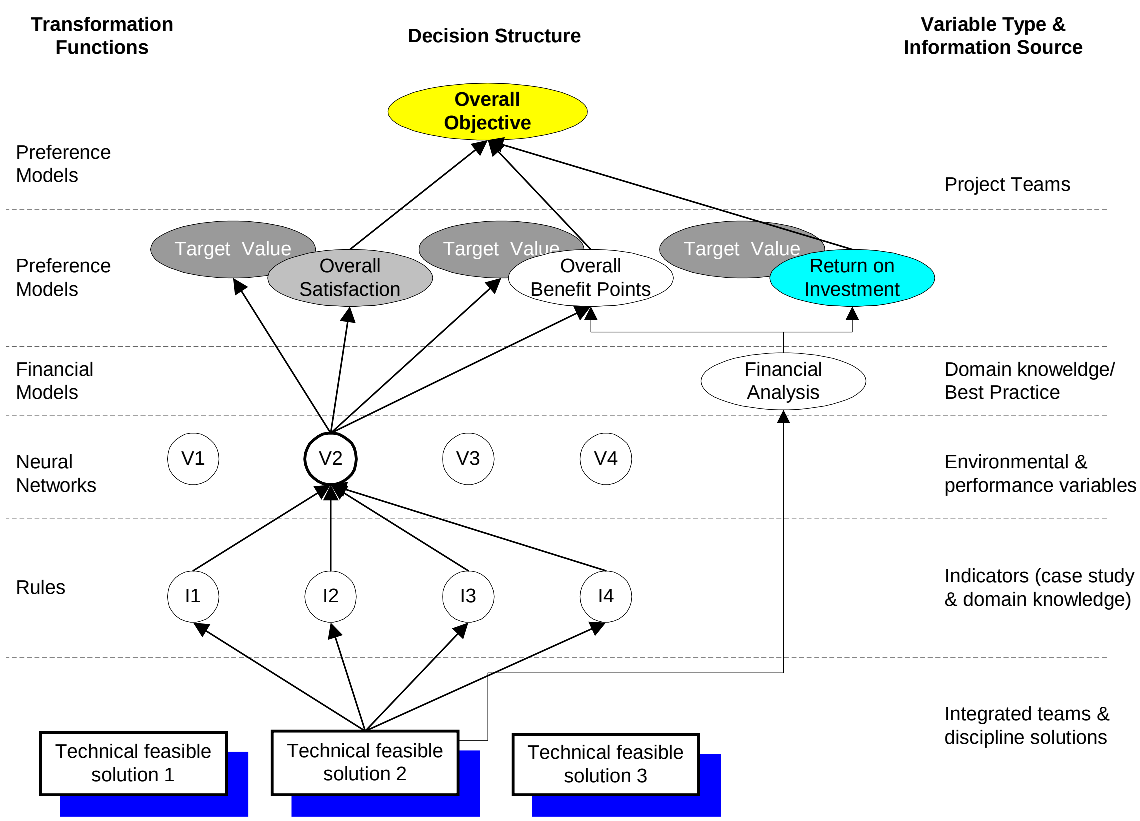

Figure 1: Project Decision Model Hierarchy and Information Sources

2.1 How to Achieve the Optimal Solution?

Figure 2 depicts the flow process on how to achieve the optimal solution. As can be seen, there will be a user interface module to allow the PM to set up various alternative solutions. For each solution there will be predefined indicators for each of the environmental variables in the road infrastructure domain. For the variable, no questions will be asked of the user on how the variable was perceived by the host community. The values for the variables will be predicted by using a neural network, which would have to be initially set up within the overall system. Data for the neural network(s) will be procured from various experts in the field by conducting a survey. Another set of networks will map environmental variables to the overall project's satisfaction level. Therefore, all environmental variables that are qualitative are modeled using neural networks. Note that analysis of quantitative variables based on a whole of life financial modeling has already been successfully researched and developed (see Jaafari and Manivong, 1999; Manivong, 2000). At the multi-criteria decision level, total benefit points, internal rate of return (IRR) and overall satisfaction level will be traded-off using preference modeling. Therefore one has several alternative solutions with specific qualitative and quantitative criteria. The system should be able to output the optimal solution depending on the decision makers' preferences. Further details of neural networks and preference modeling and their application will be described in the next section.

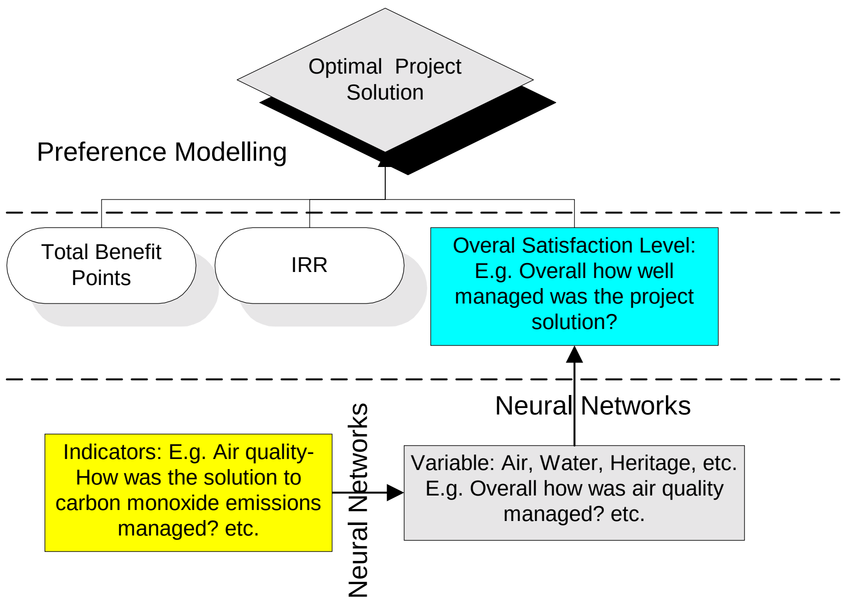

Figure 2: Process on Achieving an Optimal Solution

3. OVERVIEW OF TOOLS AND TECHNIQUES AND THEIR APPLICATION

3.1 Artificial Neural Networks (ANNs)

ANN's are computational models based on the structure of the human brain. They are parallel-distributed information-processing structures consisting of processing elements (neurons) interconnected with connections that permit unidirectional signals to be transmitted (axons and synapses of neurons in the human brain). The role of the network is to learn the mapping between the input and output patterns of data. In doing so they are equipped to predict the outputs for new inputs, which they may not have seen before.

In the decision model, neural networks would be used to learn the required set of relationships between the high level variables, lower level variables and their associated indicators. To establish the network(s), a survey, using questionnaire, has already been conducted to obtain the set of data points needed. The key is to obtain enough data points, which can generically model the relationships between project environmental indicators and variables, for road infrastructure projects. There are two sets of neural networks that need to be trained: one is for the mapping of indicators to lower level variables (such as air quality, water/hydrology quality, biodiversity, etc.), and the other for mapping of lower level variables to the higher level variable (overall satisfaction level). Essentially neural networks will predict the values of the variables using their associated indicators in the decision framework. In terms of the ongoing use of neural networks, as the project gets further defined, and as the model is used on more projects, there will be an accumulation of data sets that can be utilized. Each data captured will be used to automatically retrain the neural networks for more accurate prediction of the variables. This way neural networks will be predicting results along the lines of recent trends in road infrastructure projects.

3.2 Fuzzy Logic

Fuzzy logic is all about the relative importance of precision: How important is it to be exactly right when only an estimate will do? In the fuzzy world values range from 0 to 1, 1 being 100% true. Linguistic variables have values described in words, e.g. very good, good, excellent, etc. These are assigned to a degree of membership (0 to 1) which is the "degree of truth" of the fuzzy statement. Fuzzy 'if-then' rules can be applied where antecedent and consequents are propositions containing these linguistic variables, e.g. 'if the food is nice and service is fast then tipping is average'. In fuzzy logic, relationships between imprecise concepts are evaluated instead of mathematical equations. Thus fuzzy logic mimics the remarkable ability of the human mind to summarize data and focus on decision-relevant information (Zadeh, 1994)

Application of fuzzy logic can be seen in various engineering fields (Furuta, 1994; Subramaniam et al, 1996). The application of fuzzy logic in this model is only partial. As mentioned previously, preference modeling, including fuzzy preference modeling techniques, would be used in the determination of the optimum solution (see the next section for details on preference modeling).

3.3 Multi-Criteria Decision Analysis (MCDA)

This section presents an overview of just a few MCDA techniques and does not compare them in any way. The overview is only to provide insight and the way forward to apply such methods for the integrated project management system and the hierarchical multi-criteria decision model (Fig. 1).

MCDA is a major part of decision theory and analysis. It refers to making decisions in the presence of multiple usually conflicting criteria. By exploring these in the context of a problem, it guides decision makers to identify the preferred course of action. Fuzzy preference models are part of the MCDA family. They deal with linguistic variables as independent variables representing subjecting ratings (e.g. "good") to combine these ratings into an overall preference. Aggregation and exploitation are two main steps in modeling: aggregation defines an outranking relation indicating the global preference between every ordered pair of alternatives (with different points of view); exploitation involves transforming the global information about the alternatives into a global ranking of them.

A popular type of MCDA is the Analytical Hierarchy Process (AHP) developed by Saaty (1980). AHP aims at quantifying relative priorities for a given set of alternatives on a ratio scale, based on judgment. It stresses the importance of intuitive judgments as well as the consistency of the comparison of alternatives in the decision process. Either subjective or objective components can be assessed without compromising any of these perspectives. It also permits qualitative data to be transformed into pairwise comparison data. AHP is a framework within which the decision maker can express a complex problem using a hierarchical or network structure. The basic framework involves constructing different levels of decreasing priority or aggregation starting from a top-level objective/goal. Pairwise comparisons are used to establish relations between elements of the structure and to develop a matrix of pairwise ratios. The pairwise approach is based on a fundamental principle that it is more complicated to evaluate n elements ($n > 2$) simultaneously than to compare two elements at a time. AHP has been widely applied in planning, optimization and resource allocation and project management. One application of AHP has been to pre-qualify contractors researched by Al-Harbi (2001).

Another type is the Evidential Reasoning (ER) method in which qualitative and quantitative assessments are combined using uncertain and imprecise information/data (Yang and Singh, 1994). It uses the concept of degree of belief to elicit the decision maker's preferences. Put in another way, individuals evaluate decision criteria by using their degree of belief, which indicates their expectation that an alternative will yield a certain outcome. Degree of belief is the individual's knowledge and experience. ER is based on an evaluation analysis model and the evidence combination rule of the Dempster-Shafer theory. In the ER framework, the objective/goal of the problem is assessed by a set of grades (e.g. best, good, bad, etc.). An algorithm then carries out the transformation of several criteria assessments to the top-level objective. It essentially collapses several criteria into one so individuals can rank all the alternatives in order of preferences (Yang and Singh, 1994).

ELECTRE (Elimination and Choice Translating Reality) is one method, which deals with outranking relations by using pairwise comparisons among alternatives under each criterion separately. By using physical or monetary values of the alternatives and introducing discrimination thresholds for the difference, the decision maker may state that they are indifferent between the alternatives. They can also state that they have a weak or a strict preference for one of the two. As well, they may be unable to express any preferences. Weights are assigned to the criteria in order to express their relative importance (Triantaphyllou et al, 1998). Concordance and discordance information shows if the amount of evidence to support the conclusion that one alternative outranks/dominates or is worse than another. The method then yields a system of binary outranking relations between the alternatives. It then produces a core of leading alternatives and eliminates less favorable ones (Lootsma, 1990).

SMART (simple multi-attribute rating technique) prescribes that each alternative is rated on each criterion. Each criterion is assigned to a measure of importance to the decision maker, and a summary score (the highest is the best option) for each alternative is calculated as a weighted average of the ratings. The weights represent the relative importance of the criteria. The assumptions in SMART are that there exists no uncertainties and that there are no interactions between attributes. Goodwin and Wright (1991) provide a detailed discussion on SMART.

The hierarchical multi-criteria decision framework (Fig. 1) will be developed based on information provided by future case studies. It is decided preference modeling (Fodor and Roubens, 1994; Cvetkovic and Parmee, 1999) such as the techniques described above will be used at the highest level in the decision model.

It is not the scope of this paper to go into detail about the reasoning behind the chosen technique adopted, however, the authors have considered the following attributes which such a technique should possess: able to handle uncertainty in preferences on criteria; able to handle several criteria measures (cardinal, deterministic, fuzzy, etc.) and adapt to the subject’s choice; able to derive the optimum solution based on uncertain data, i.e. choice of the best alternative; able to process unlimited criterion and alternatives; able to be implemented into a computer program integrated into the current prototype system; and compensation effect, that good performance of an alternative on one criterion compensates for a bad performance of the same alternative on another criterion. As seen above, ER and ELECTRE are potential candidates.

3.4 Intelligent Software Agents

Software agents are autonomous software entities that can interact with its environment. A simple software agent is an Internet search engine, which looks for information, and reports the information requested by the user. Agents have the ability to be: autonomous – initiates and operates without intervention; mobile – transport itself from one platform or environment to another; proactive – goal oriented and purposeful; intelligent – state is formalized by knowledge; able to learn – changes its behavior based on experience; and adaptive/reactive – sensing and acting, responds in time to changes in the environment.

Therefore the intelligent aspect of the system will utilize software agents developed based on neural networks. The main function of the agent is to monitor the external environment of the project, during the life of the project, through sensing of the indicators, and to alert the project team to changes in the environment that may influence the optimality of project solution(s). In addition, the agent will provide the capability to forecast the state of the variables and future optimality of the solution(s) using past information. This all requires the project management system to be online, connected to the world-wide-web and other computers (corporate intranet) that the agents can talk to. This part of the research is in its infancy and will be considered in the next phase of this research. When this technology is implemented, then the project management system will be intelligent.

3.5 Object-Oriented Technology

Object-Oriented approaches have emerged as one of the most promising paradigms for developing integrated systems (Abdalla and Yoon, 1992). These approaches have gained popularity in a number of fields in computer science such as programming languages, databases, artificial intelligence, knowledge representation and CAD. The fundamental feature of the object-oriented approach is that an object conceptually includes both data about itself as well as the software that controls its behavior. This is different from the traditional software approach where software and data are viewed as existing independent of one another. Thus, each object has a unique identification code, and contains within it information and program codes which will enable it to interact with other objects through exchanging messages.

The current experimental project management system has been programmed using MS Visual C++ and C++ (see Manivong 2001 for further details on the applications developed). The backend project database and its graphical user interfaces have been designed and developed using object technology. In addition, object technology is well suited to program intelligent agents.

3.6 Databases

In general project management systems utilizes databases in the background to store, retrieve and manage project data/information in a timely fashion. In large projects it is often necessary to have a variety of people using and or updating the project plan. Project information can be shared across computer networks where a centralized database system can house the project data. This makes projects easier to coordinate, even when team members are working in different geographical areas. Also, having a central database will minimize the chances of users using outdated or inaccurate information. Data integrity is therefore greatly enhanced. The current experimental project management system is utilizing an object-oriented database management system.

There are three main functions for which the database management system is used:

1. Project data/information – Created by users and created by the processing functions in the PM system. The data have been pre programmed to meet the specific need of the system, e.g. financial analysis;
2. Indexing and management of documents – These data types are large project document files, i.e. sound, graphics, and so on that are needed to further convey and illustrate the project;
3. Project user and history data – These data are needed by the neural network engines and intelligent agents for them to be retrained and automated. There are also metadata in which these tools will be able to consult about a particular user and the history of their past actions.

The current experimental project management system utilizes an object-oriented database management system.

4. FUTURE WORK

This paper has outlined in broad terms the function and attributes of the hierarchical multi-criteria decision framework. Future work will take this plan and implement it into a prototype model in the already existing system. The upcoming challenges are as follows:

- Develop the user interface at the lower level in the model – This provides input to the neural networks. A series of questions will be provided for the user to enter their answers into the integrated project database;
- Develop and implement neural networks at the lower and middle level in the model – This provides the processing engine that results at the lower level variables. The lower level variables will then be used to derive the higher level variable, i.e. overall satisfaction level;
- Develop and implement the user interface and fuzzy preference model at the higher-level, i.e. using preference information on the qualitative and quantitative criteria and find the optimal solution from the alternative solutions.

Note that the above work is only a part of the research conducted on the intelligent project management information system. At the time of writing, this work is still in progress.

5. CONCLUSIONS

The authors have presented an integrated multi-criteria framework and decision model hierarchy and its physical entity the integrated project management system, which permit a holistic evaluation of project plans and solutions. The new perspective promotes a new understanding of the concept of “worth” for judging project decisions. The optimum solution is based on an effective trade off between the financial gains flowing to a project sponsor(s) and the corresponding social costs and or benefits accruing to the relevant stakeholders and the host community. The authors defined *overall satisfaction level* and *overall benefit points* respectively for representing the level of satisfaction achieved by the project solution and the benefits that accrue to stakeholders should the project proceed in accordance with that solution. These satisfaction level and benefit points are balanced against the overall return on investment or the projected net present value. It has been illustrated that current tools and techniques such as artificial neural networks, (fuzzy) preference modeling, object technology, databases and intelligent agents can be used to develop such a decision model and system. The work described in this paper is part of a larger research, attempting to develop a holistic and integrated intelligent project management information system.

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