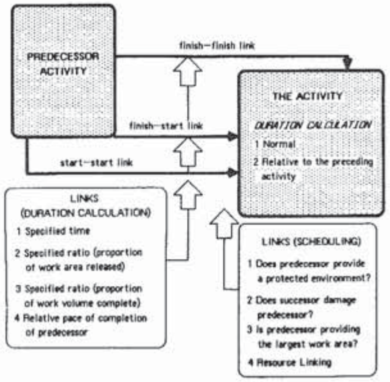

Figure 1 Data base structure for an activity

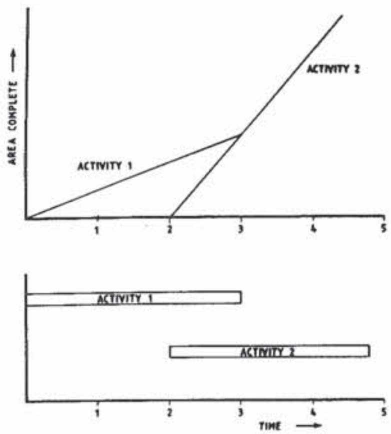

Figure 2(a) Activities scheduled at their earliest starts

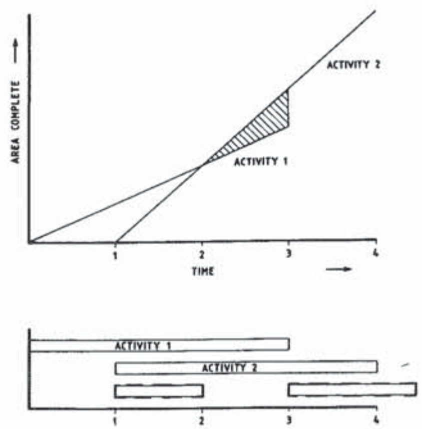

Figure 2(b) Activities scheduled to avoid interference

Knowledge-Based Expert Systems for Construction Risk Analysis

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KEYWORDS

Artificial Intelligence, Construction Industry, Decision-Making, Expert Systems, Risk Analysis.

ABSTRACT:

Construction engineering and management involves many complex decision-making problems in such areas as resource planning, cost estimating and control, design of construction process operations, risk management, and other construction management problems. Most of these tasks are highly dependent on engineering judgement. Contractors must use rules of thumb and subjective evaluations to solve the problems. Traditionally, construction management models are developed based on explicit algorithmic analysis and optimization programs. In these models the creative component of the construction management has been largely ignored. In the real construction world a large number of rules are not based on the mathematical laws, but they are based on the assumptions, limitations, rules of thumb, and management style of an expert who has a great deal of experience in construction operations, and can define the applicable conditions and corresponding actions. The main goal of this paper is to present a knowledge-based expert system for construction risk analysis which allows the unsophisticated field engineer to make decisions as if a construction field expert was providing advice and guidance based on long experience. The model describes how practitioners use, integrate, and combine elements of information and knowledge to develop an efficient and innovative management decision model.

Systèmes experts basés sur la connaissance pour l'analyse des risques de la construction.

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MOTS CLEFS:

Intelligence artificielle, Industrie de la construction, Prise de décision, Systèmes experts, Analyse de risques.

Sommaire:

La construction et la gestion comprennent un grand nombre de problèmes complexes qui demandent des prises de décision concernant la gestion des ressources, le calcul et le contrôle des frais, l'étude des procédés de construction, la prévision des risques, et divers autres problèmes associés à la gestion de la construction. La plupart de ces tâches dépendent en grande partie du jugement de l'ingénieur. L'entrepreneur, pour résoudre certains problèmes, se voit dans l'obligation d'utiliser des méthodes empiriques et des évaluations subjectives. Traditionnellement, les modèles de gestion de la construction sont basés sur des analyses algorithmiques explicites et sur des programmes d'optimisation. Dans le cas de ces modèles, l'élément créatif de la gestion de la construction a été grandement ignoré. Dans le monde réel de la construction, un grand nombre de décisions sont prises en se basant sur les suppositions, les limitations, les méthodes empiriques et le style de gestion d'un expert, et non sur des lois mathématiques. Cet expert possède une grande expérience des opérations de construction, est capable d'identifier les conditions existantes et de prendre les mesures appropriées. Le principal objectif de cet exposé est la présentation d'un système expert basé sur la connaissance en vue de l'analyse des risques de la construction, système qui permettra aux ingénieurs de chantier ayant peu d'expérience à leur actif de prendre les mêmes décisions que s'ils bénéficiaient des conseils et des directives d'un expert en construction. Le modèle décrit comment les professionnels utilisent, intègrent et combinent les éléments d'information et de connaissance dont ils disposent dans le but de développer un modèle efficace et innovateur concernant les prises de décisions en matière de gestion.

INTRODUCTION

A construction project is continuously influenced by uncertainty factors. These uncertainty factors have high financial and social impact on major parties involved in the project. Some of these uncertain or risk factors can be managed in advance. However, most of them can not be eliminated. Therefore, construction engineering and management involves many complex decision-making tasks under uncertainty (Ref. 1). Contractors use rules of thumb and subjective evaluations to analyze the uncertainty factors. A successful construction risk management system requires a significant amount of empirical knowledge from construction experts and specialists.

Traditional construction risk management systems are developed based on algorithmic analysis. In these models the creative component of the construction risk analysis has been largely ignored. In the real construction world, construction management rules are not based on mathematical laws, but are based on the contractor's assumptions, limitations, rules of thumb, and management style. The traditional algorithmic risk management models have not fully incorporated the significance of empirical knowledge. Emprical knowledge plays a major role at every stage of construction decision-making. Many risk analysis models have failed due to the lack of expert support for novice or semi-experienced model users (Ref. 2).

The objectives of this paper are to explore the application of expert systems in construction risk management, and to develop a prototype expert system for decision-making under uncertainty. This paper is focused on risk analysis from contractors viewpoint.

CONSTRUCTION RISK ANALYSIS

Risk is commonly defined as chance of injury, damage, or loss. Although these definitions are easy to understand, they are not suitable for risk analysis since they can be interpreted in different ways and are not explicit enough to allow measurement. The subject of risk is very complex and no single method of risk analysis is free of weakness. This paper defines risk as dispersion of outcomes around the expected value (Ref. 3).

The identification and effective evaluation of risk is an important requirement for successful project selection. Continued growth and complexity of construction projects require fundamental knowledge concerning the identification and evaluation of project risk by contractors. The construction industry is becoming a more changing, uncertain environment than before. As the underlying conditions are changing, the available information that indicates the trends, cycles, or seasonal fluctuations should be taken into account.

There are many reasons which justify expert system development effort in risk analysis. First, risks associated with construction projects are potentially serious and have significant financial and social impact on contractors; therefore, there is a reasonable possibility of high payoff when an expert system is developed. Second, for an inexperienced engineer an expert system can act as an advisor when the professional experts are unavailable. Expert systems are justified especially when significant expertise is being lost to a construction company through personnel changes (e.g., retirement, job transfers, etc.). Finally, expert system development in construction risk management is justified because of the dynamic, ill-structured, and high risk environment of construction field which requires quick decision-making.

RISK ANALYSIS BY EXPERT SYSTEMS

To apply expert systems in construction risk analysis, first, the characteristics of uncertainty management must be explored. One of the most important characteristics is that people with an extremely high level of expertise exist in the construction management area. They have many years of professional construction experience, and can provide the knowledge necessary to build expert systems. Many of these people are able to articulate and explain the methods that they use to analyze risk. The second aspect which makes construction risk management appropriate for expert system is that risk management is cognitive, and does not require physical skills. The third characteristic is that risk analysis is not too difficult or too complex for a knowledge engineer to approach. Many sources of information (e.g., papers, books, and etc.) are available in this area which can establish the basic framework for knowledge acquisition. Therefore, it can be concluded that construction risk management is an appropriate area for expert systems since it requires symbolic reasoning, and it is heuristic in nature, that is, it requires the use of rules of thumb to solve problems. Risk management is not easy to model, it takes a human years of study or practice to achieve the status of an expert. Finally, it is of manageable size to be handled adequately by expert systems, and it has a practical value.

KNOWLEDGE ENGINEERING

Any intelligent analysis of risk requires appropriate knowledge. It can be said that knowledge is information that the computer can think about. The objective of this section is to present and describe the main components of the Micro Construction Risk Management Expert System.

The first step was to select an appropriate expert system shell. The next question was whether a large system designed to run on a large mainframe or a microcomputer shell program should be implemented. For many reasons it was decided to work with micro programs. The first reason was familiarity with micro systems. The second reason was low cost of resources, and the third reason was the type of application which was anticipated (Ref. 4).

Figure 1 shows a schematic view of the construction risk management expert system. The system helps contractors to identify the uncertainty factors, and provides a risk index for the overall project. The system is implemented in INSIGHT 2, a microcomputer knowledge engineering language for rule-based representation. The knowledge base systems created with INSIGHT 2 are complete knowledge and information processing systems capable of applying heuristic knowledge to direct the control and

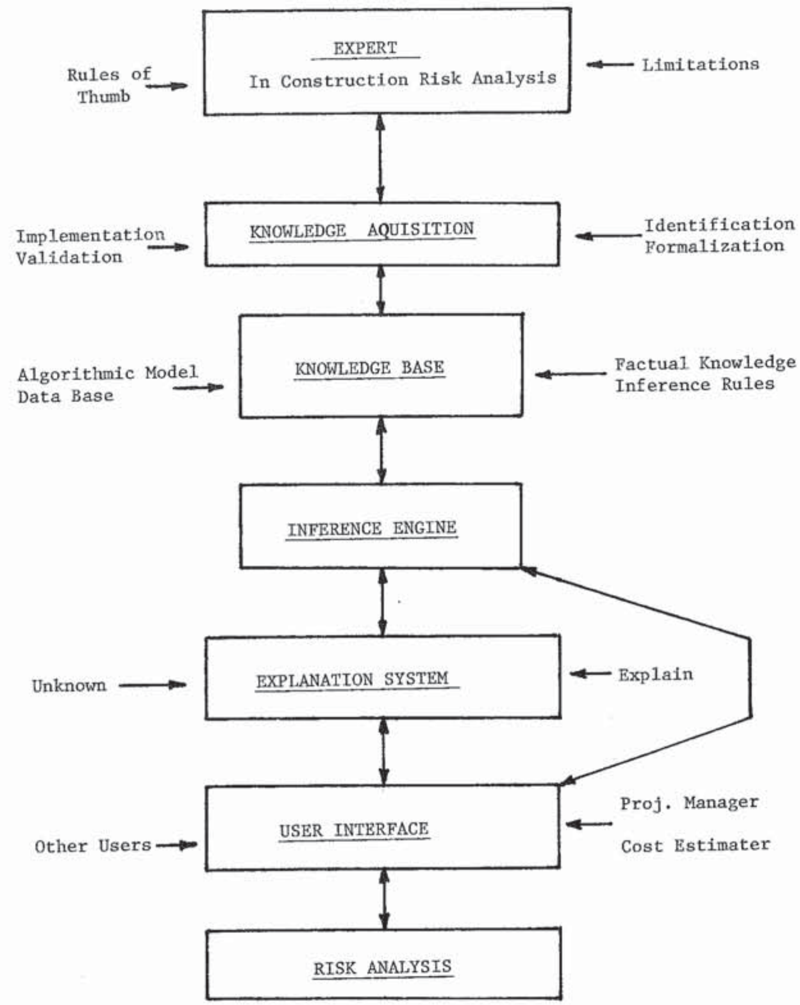

Fig. 1- General Feature of Risk Analysis Expert System

management of conventional programs with data bases. The system's control structure makes use of backward and forward chainings. Numeric data can be expressed as real numbers and variables and can be manipulated with the basic relational and arithmetic operations. Each supporting condition and conclusion of a rule can have its own confidence factor. Each knowledge base has a variable threshold of acceptability which is used to evaluate the viability of a path of reasoning. The system provides the facility for the activation of other programs written in any language during the execution of a knowledge base. The system also contains an interface to a Pascal programming environment which is extended to support direct access to dBASE II data base files. Through this interface, the system provides a rule-based expert system the capability to use the power of Pascal (or other languages) for complex algorithmic computing as well as relational data base access and manipulation. The system is capable of handling up to two thousand rules which is considered sufficient for risk analysis. A portable microcomputer was used during the interviews with contractors and bonding companies to get feedback from experts.

KNOWLEDGE BASE

One of the major components of a construction risk management expert system is the knowledge base. The knowledge base as shown in Figure 1 is that portion of expert system that contains the knowledge (information) of risk management. The knowledge was collected from various sources such as: interviews with contractors, journal papers about construction risk analysis, and text books. The basic framework was established based on the last two parts, and the system was modified by contractors. At the beginning, a small system was developed, and then incrementally a significant testable system was built. First, the specification of goals, and constraints was defined. Second, a general description and classification of construction risk, in terms of hypotheses, data, and intermediate reasoning concepts was constructed as shown in Figure 2. Third, the identified elements were represented in a rule-based (IF-THEN) format (Refs. 5, 6, and 7). Then, the system was tested against more complex and real cases. Many adjustments of the elements and their relationships were a result of these tests.

All the contractors interviewed had at least ten years of construction experience and a yearly volume of less than $50 million. One of the most important considerations of every firm was the amount of time allowed by the owner for completion as related to the type and amount of liquidated damages in the contract. A contract with heavy liquidated damages combined with a very short time allowed for completion presented a large and almost unacceptable risk. Another item was the client/contractor relationship. A good strong client relationship was highly valued and sought after when the contractor is considering new work. Such a relationship will mitigate or dramtically lessen a contractor's risk in such areas as poorly written contract language or vague project drawings. Other contractor considerations also included existing workload, repeat clients, and project location.

The foremost consideration of the surety companies is the financial stability of the general contractor. A contractor wishing to become

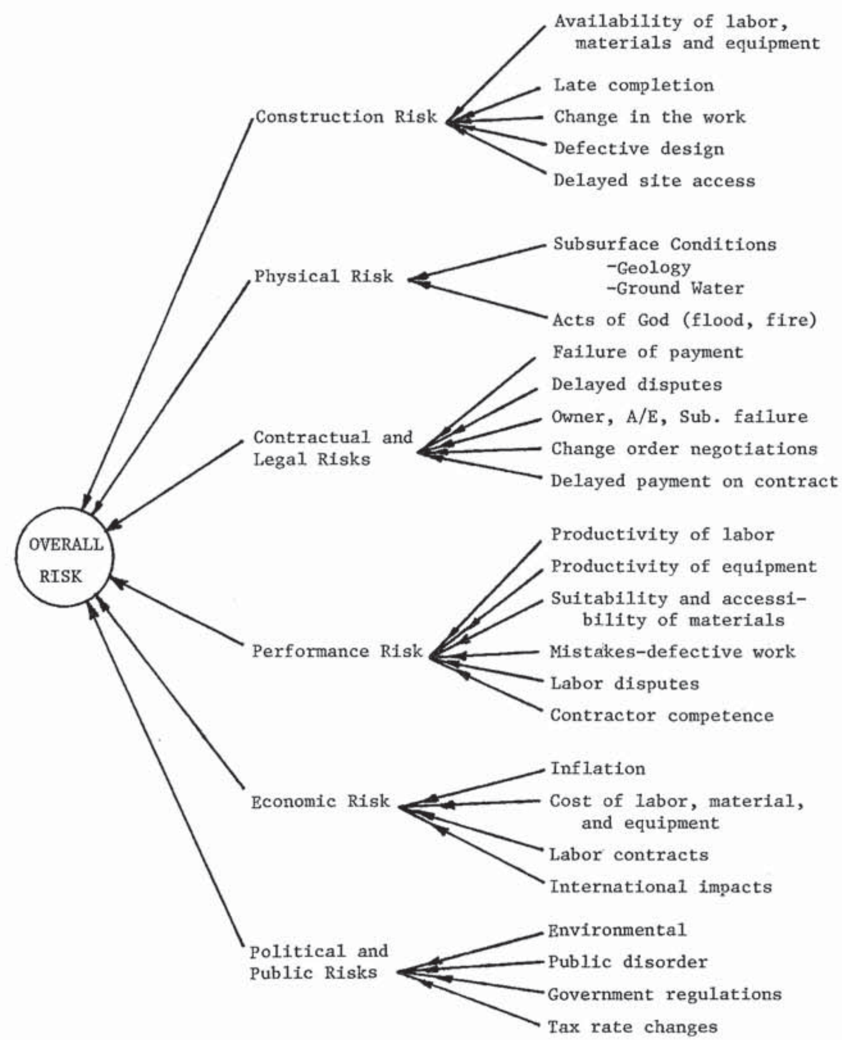

Fig. 2- Risk Management Inference Chain

bonded for a project or to increase his bonding capacity must furnish the surety with copies of his company's financial statements, letters or proof of credit, and tax records. Next, the surety looks at the company's performance on previous jobs, and size of jobs performed by the contractor over the last few years. The surety will then want to know who the general contractor will assign as the project supervisors for the job and their technical qualifications. The type of work is also another major element. The results of these interviews were then presented in rule-based format to enhance the risk management knowledge base.

MICROCOMPUTER APPLICATION

Primary motivations for implementing the construction risk management expert system on microcomputers were: 1) low cost of software programs; 2) availability of microcomputers by contractors in the field and main office; and 3) transportability of micros to construction sites (i.e., portable microcomputers). Overall, it appears that a primary advantage of implementing expert systems on microcomputers is that these computers provide potential users with a low risk opportunity to bring expert systems capabilities in construction site.

Although large scale expert systems have been providing themselves on minicomputers and mainframes for several years, AI developers are just beginning to develop programs for personal computers. Many micro expert system shells such as: Exsys (Exsys Inc.); Expert-Easte (Human Edge Software Corp.); Insight 2 (Level Five Research Inc.); KDS (KDS Corp.); KES (Software Architecture and Engineering Inc.); M.1 (Teknowledge Inc.); MicroExpert (McGraw-Hill Co.); Personal Consultant (Texas Instruments Inc.); and TIMM-PC (General Research Corp.) are commercially available (Ref. 8). These programs allow sophisticated users to build their own small expert systems without having to learn specialized programming languages such as LISP.

SUMMARY AND CONCLUSION

Expert systems are appropriate computer programs for construction risk analysis. These programs typically represent knowledge symbolically, examine and explain their reasoning processes, and address problem areas that require special education and experience. Expert systems will make it possible to develop quick answers for management problems. It will also help contractors to solve their productivity problems. Contractors can reorganize themselves into more efficient and effective organizations. Management will be able to monitor projects more effectively, and secure their profit by managing and forecasting the uncertainty factors. In summary, the construction industry will become much more rational. More information will be gathered, synthesized, and put into useful form more rapidly than has ever before been possible.

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