Expert Systems for Construction Planning and Scheduling - An Integrated Approach

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ABSTRACT

This paper presents an integrated software approach to the development of a computerized knowledge based system for construction planning and scheduling. The system, ESCHEDULER embraces hybrid methodology to make use of and to build on available experiential knowledge in construction planning, and to enhance currently available project management software and other computing algorithms. It integrates through an expert system building tool (ESBT), relational databases, knowledge bases and their control functions, a traditional network analysis software and two interfacing programs written in Fortran language. The main program is written in the language provided by the ESBT, and DOS batch commands control the process of consultation and integration. This prototype system uses a micro-computer based hybrid artificial intelligence (AI) environment and has some interesting features: the determination of job logic for the activities entered through an end-user interface and a set of stand alone nested expert system modules to modify activity duration with respect to different site conditions. At the end of the consultation, ESCHEDULER prepares a realistic 'as possible' schedule. An example application is presented to illustrate the essential features of ESCHEDULER. The system can successfully be applied to other domains in construction management and its modular architecture allows further enhancement and expansion.

Key Words: expert systems, construction, planning, scheduling, productivity, construction management.

1. Introduction

Construction planning and scheduling is an important task in the management of construction projects. Current construction planning relies upon manual formulation of plans and is usually performed in an intuitive and unstructured fashion with considerable reliance on engineering judgement. The need for engineering judgement is necessitated by the uncertain but predictable variables which dynamically affect the work tasks. Assessment of their impact is a complex problem, since they are dynamic in nature and dependent on project conditions, location and the calendar dates when the activity will be performed.

Currently many computerized algorithmic scheduling systems are available in the software market. These traditional systems require the complete input of the activity description, precedence relationships, duration and the allocation of resources for each activity. As planning and scheduling is usually performed in an intuitive and unstructured fashion with considerable reliance on engineering judgement these systems are widely acknowledged as deficient planning and scheduling aids (McGartland and Hendrickson 1985). They are unable to interpret the qualitative and subjective information so prevalent in the construction environment and cannot be used without human experts to provide the required experiential knowledge for the process of planning and scheduling.

This paper presents a prototype of a computerized hybrid knowledge- based system to automate the generation of realistic schedules, along with an example application to illustrate its essential features. The potential application of the system in other domains of construction management are also explained.

2. Expert Systems

Recently, expert system (ES) technology has been introduced in an effort to improve the deficiency in traditional tools. Construction scheduling utilizing knowledge based expert systems (KBES) has been the subject of considerable research in recent years (Ashley and Levitt 1987). Systems for schedule updating (Levitt and Kunz, 1985), schedule analysis and evaluation (O'Connor et al, 1986), activity duration estimation (Hendrickson et al, 1987), construction planning (Hendrickson et al, 1987a), prediction of cost and time of construction (Gray, 1986) and project network generation (Navinchandra et al, 1988) have been described in the literature.

These systems have been implemented under different expert system development environments. Though each has somewhat different focus, they generally address the process of developing and analyzing schedules. Except O'Connor's system none of the above makes use of the widely used business computing software. These systems are being developed in total AI environments, that are optimized to run AI languages, which are not familiar to the construction industry. One of the major concerns regarding the implementation of the above systems, is the elimination of project scheduling algorithmic programs which are currently in use.

Several important trends in the business of ES have emerged over the past few years (IEEExpert, 1988), and the integration of ES technology with "traditional technology" is one of them. Whether or not a system is fully embeddable in other systems, and is therefore capable of autonomous operation is becoming increasingly important, now that ES are moving from prototypes to being fielded (Gevarter, 1987). If consideration is not given to incorporating existing software in any future system, the economic loss will be heavy as their past investment in automation is not put to full use. The industrial impact of ES technology can be better realized through an evolutionary approach in which existing computer systems gradually absorb the most practical aspects of the new technology and coexist with them and supplement them. Future implementation of successful ES will depend on how well they can integrate with existing systems (Richner 1986). In the construction industry, personal computers (PC) are the most popular machines used as the industry consists mainly of small and medium size contractors, who cannot afford to invest in sophisticated computers and their associated peripherals. It has been found that access to a PC offers an environment in which people are most willing to participate in the ES development process (Finn and Reinschmidt 1986).

A solution, then, to the problem of automating generation of schedules would be a micro-computer based hybrid system in which experiential knowledge and engineering judgement are represented using ES methodology and numerically intensive procedures such as critical path analysis and data storage and retrieval are left to available algorithmic methodology. The hybrid system, described in this paper, is developed in an effort to combine the above mentioned methodologies. Fig. 1 shows the basic architecture of such a system.

3. ESCHEDULER

EXPERT CONSTRUCTION SCHEDULER (ESCHEDULER) is a rule-based hybrid prototype ES for planning and scheduling of building construction projects. It is developed in **GURU** ES development environment, chosen on the basis of a set of selection criteria established by the authors (Moselhi and Nicholas, 1988). The basic architecture of the system consists of three knowledge base modules: **ACTIVITY TRANSLATOR (AT), JOBLOGIC HELPER (JH) and DURATION MODIFIER (DM)**. The AT module initiates the consultation process and checks whether the arbitrary activity description input by the user is system compatible. JH determines the physical precedence relationships among the activities input by the user, using a constraint-based approach with specific predecessor- successor relationship among activities. DM helps in modifying the unimpacted duration of an activity to a realistic one. To achieve greater modularity, DM is further sub-divided into five sub-modules, each containing knowledge on productivity levels at site, with respect to one of the five factors: weather, overtime, congestion,learning curve and re-assignment of labour. By consulting the necessary sub-modules the system modifies the standard durations of impacted activities.

ESCHEDULER makes use of the relational database management system provided by GURU and contains five databases: **LOGILIST** contains record on description of any two inter-dependent activities, commonly encountered in a building project. **WEATHER** contains the daily probable average temperature, humidity and wind speed for each day of the year for the City of Montreal. **CALENDAR** stores project calendar. **LISTACT** contains the list of activities along with their codes and durations. These raw data are entered by the user during the consultation with AT. The ES, JH creates this database during consultation and later retrieves data on activity description for precedence setting. **PROJREC** stores the project record extracted from the schedule report prepared by Primavera. DM creates this database prior to consultation. Creation of the last two databases is automated. Records for these two tables exist in an ASCII text data file before being transferred to respective GURU databases.

Apart from integrating the above modules, the system also interacts with a commercially available and widely used project scheduling software, **Primavera**. Its batch data entry system expedites the development of project schedules. Two interfacing programs written in **FORTRAN** are incorporated in ESCHEDULER to format the files to the requirements of the software tools used. Procedural language of the ESBT and its enhanced data management system are used for the flexible but tight integration of the various essential components of the prototype system. A DOS batch file was created to unify and run different software modules and their functions.

For detailed description of the above modules please refer Nicholas, 1989 and Moselhi and Nicholas, 1990.

4. An Example Application

The project considered is a multi-storey commercial plaza, to be built in the of the City of Montreal. It consists of ten storeys and houses underground parking facilities, two floors of shopping mall and eight floors of office space. Construction is to begin in April 1990. The input to the system are the description and duration of each activity. In this illustration, the application of ESCHEDULER in preparing an 'as possible' schedule is described. The system progresses through consultation as the user responds to questions posed by the system. In many cases, a simple yes/no (Y/N) response allows progression through consultation. Having received the answer to a question from the user or by accessing a database, the system locates the applicable rules by comparing the answer with the knowledge base and produces a decision or executes a function.

At the initial stage of consultation, ESCHEDULER prepares two batch files for Primavera with project information and instructions to perform network analysis, using the module AT. Then, module JH creates the database, LISTACT and stores the data entered by the user. It checks with the database LOGILIST for the existence of dependency between any two activities in LISTACT and sets the precedence by consulting its KB. The user is asked if he/she wishes to consider partial or conventional relationship between any two interdependent activities displayed on screen. If partial is chosen, the user will have to input the lag in number of days. Information on activities with activity description, duration and precedence record are written to another batch file.

Once precedence setting is completed ESCHEDULER exits GURU and loads Primavera and processes all three batch files and prepares an 'as planned' schedule (Fig.2). The user is requested to prepare a schedule report in ASCII format using the facility provided by Primavera. The system again enters GURU to modify the duration of activities expected to be affected by conditions at job site. DM uses a FORTRAN program to format the ASCII output from Primavera and attaches it to PROJREC in GURU. It queries the user on site conditions, particular to the factor(s) chosen (Fig.3), and modifies activity duration in accordance with the appropriate productivity related factor(s) contained in the system. After completing consultation with DM, ESCHEDULER accesses the scheduling software and prepares the 'as possible' schedule. Similar application on an actual project was carried out to validate the system (Nicholas and Moselhi, 1989).

5. Potential Application of ESCHEDULER

The application of ESCHEDULER can be easily extended to other problem domains in construction management. It can also be used to train field engineers for further assignments. Its possible application in three areas of construction management are briefly mentioned below.

Claim Analysis: In delay claims, the analysis method requires the identification of the events that caused the delays. A refined and properly validated ESCHEDULER can be used in claims defence by inputting the delay-causing events during modifying the duration of an activity to arrive at a legally accepted, quantifiable delay period. This task is similar to preparing an 'as possible' schedule, but entering the actual site conditions.

Schedule Update: ESCHEDULER can be used to forecast the duration of activities and the possible project completion time. This replaces intuitive reviews of duration estimates and permits less experienced personnel to forecast activity duration with a degree of accuracy and consistency.

'What - If' Analysis: It can also be used to analyse a schedule, prior to or during construction, to study the impact of changing the project environment on project duration and cost. The effects of accelerating a project can also be studied by choosing the factors which are generated by this action, such as overtime, congestion, or re-assignment of labour.

6. Conclusion

The development of a hybrid expert system, ESCHEDULER is presented and its essential features are illustrated through and example application. The potential application of the system in other areas of construction management are also briefly described. There are several notable features in this system such as the ES for precedence setting. What is to be noted more is the basic architecture which allows flexible expansion of the system. Unlike other expert systems developed in this domain, ESCHEDULER integrates, builds on, and makes full use of current industry practice and its available traditional software such as the one used for project scheduling. It can be clearly seen that ESCHEDULER proves the feasibility of an integrated KBES.

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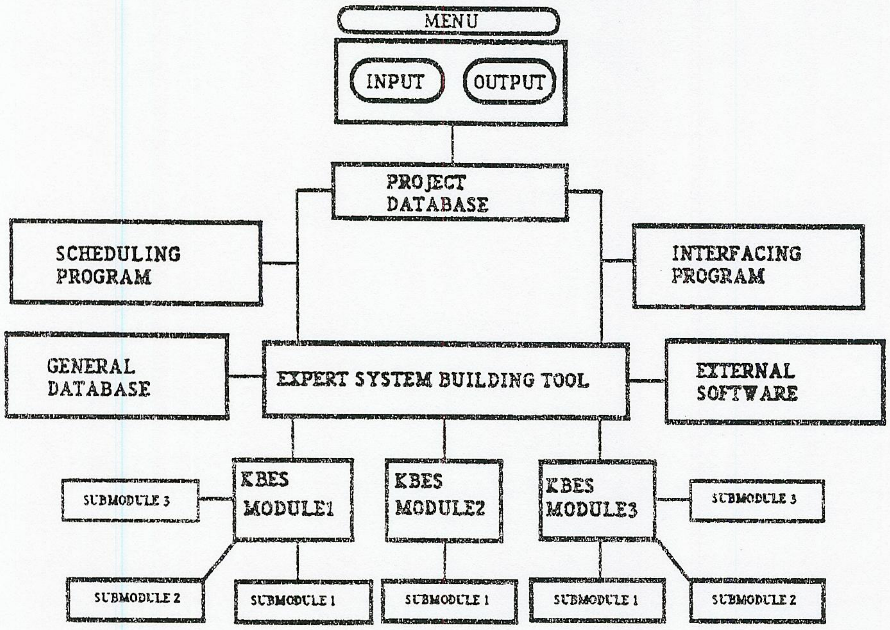

Fig.1 Architecture of Integrated ES for Construction Planning and Scheduling

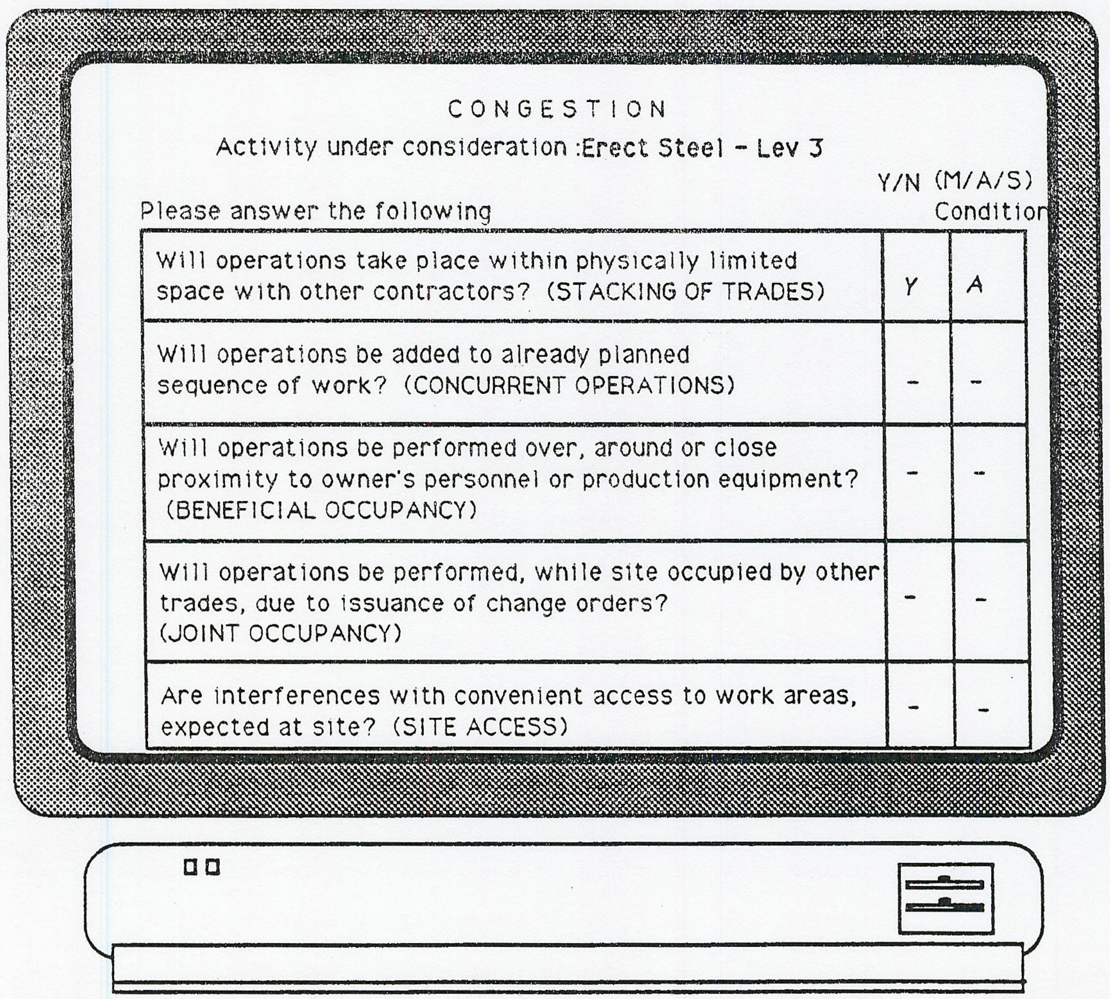

Fig.3 Input to sub-module in DURATION MODIFIER

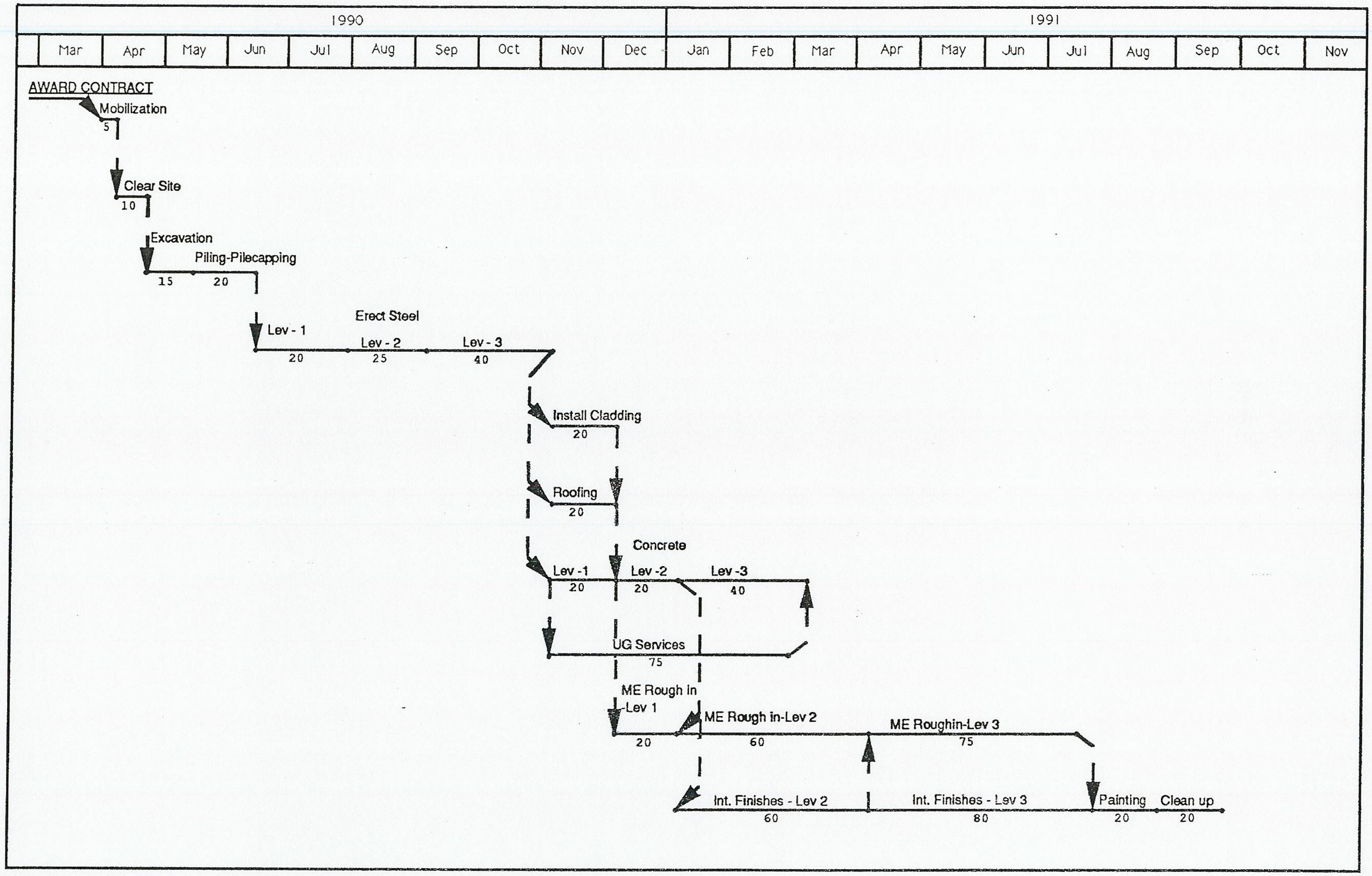

Fig.2 Time Scaled 'As Planned' Network