COMPUTERIZED CRANE SELECTION FOR CONSTRUCTION PROJECTS

Sabah Alkass, Mohamed Alhussein, and Osama Moselhi

School For Building, Concordia University, Montreal Canada

This paper describes a methodology for crane selection for construction projects. The methodology is incorporated into an integrated computer system capable of advising users on the selection of appropriate cranes for their construction projects. Expert's knowledge has been captured, classified and coded in the system's knowledge-base. The system integrates a knowledge-base with algorithmic programs, and commercially available tools such as: database management, spreadsheet applications, graphics and simulations. The system utilizes Object Oriented Programming characteristics of the abstraction, inheritance, modularity, and encapsulation of data. The system allows for the stored data and knowledge to be accessed by all parties involved in the crane selection process. It is also capable of facilitating user friendly interface. Description of the methods and current practices used for crane(s) selection for construction projects is also presented. A case example is presented, to demonstrate the effectiveness of the system.

Keywords: cranes, database management, spreadsheet applications, graphics and simulations

INTRODUCTION

Material handling is an important part of the delivery process of construction projects, and cranes are the most important resources used in achieving this, specially on a building construction site. Selection of type(s), number(s), and location(s) of crane(s) to be used in constructing a high-rise building is a focal issue in planning the construction operations. Selecting cranes depends greatly on skilled judgment that accounts for all likely involved variables. Much information is available to assist in this process in the form of: work study data, manufacturers' machines performance specifications, guidelines on methods of calculating production output, labour resources and equipment requirements. Unfortunately this information is incomplete and generally requires the user to make bold decisions on job conditions and categories of cranes for a particular situation leading to unavoidable mistakes and perhaps to costly decisions. Selecting a crane, requires prediction as to the consequences of the choice that is to be made. A wrong decision is likely to have significant effects in terms of high cost and possible delays. The ability to predict and make decisions grows out of knowledge and experience gained during many years of work on construction sites. Most of the time this knowledge is not available to the decision maker when needed. This makes the knowledge-based systems valuable tools to be used as decision supporting system during the crane selection process.

Conventional algorithmic programs are unable to manipulate heuristic and qualitative knowledge necessary for the equipment selection. On the other hand Knowledge Based Expert System (KBES) are not robust in numerical data manipulation, while being very effective in declarative knowledge manipulation and handling of logical

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inferences and reasoning. Therefore, expert systems and conventional programming can be combined to support effective decisions for crane selection.

With this respect an integrated computer system called capable of advising the users on the selection of appropriate cranes has been developed. Experts knowledge has been captured, classified and coded in the system's knowledge-base. The system integrates a knowledge-base with algorithmic programs, and commercially available tools such as: database management, spreadsheet applications, graphics and simulations.

The system incorporates two main modules. The first being a Knowledge-Based module that contains experts knowledge, heuristics and rules of thumb related to cranes selection. The second is a Case-Based module containing information on various cases representing already constructed buildings with pre selected crane(s). In addition to the knowledge-base, the system integrates procedural algorithms for performing routine calculations and graphics to support the crane selection process, in three other modules: geometry calculations, graphical validation, and cost estimation. All these modules share a global database containing information on a number of already constructed buildings, information on problems related to cranes used in their construction, and data on a large number of commercially available cranes, that includes their types, specifications and costs.

LEVEL 5 as an Object-Oriented Expert System shell, has been used to develop the system [1]. The system allows for the stored data and knowledge to be accessed by all parties involved in the crane selection process. It is also capable of facilitating user friendly interface.

Knowledge based systems and their various applications in construction have been extensively described in the literature, [2, 3, 4, 5]. They have been used for equipment selection [6, 7, 8, 9, 10, 11, 12].

Very few attempts in developing computer modules for crane selection and their use have been reported in the literature [13, 14, 15, 16, 17].

KNOWLEDGE ACQUISITION

The effectiveness of any knowledge based system depends on the amount and quality of knowledge stored in its knowledge base. This knowledge is acquired from experts and stored in the Knowledge-Base by the knowledge engineer during the knowledge acquisition stage of the system's development. Experts from the domain of crane selection were identified, their knowledge was solicited during interview sessions.

During this work, 30 professionals considered to be experts in the area of the crane selection, were classified into groups based on their areas of specialization: general contractors, rental companies, project managers, government authorities, training institutions and instructors, expert with academic and practical background, design professionals, crane operators, and crane manufacturers. This grouping simplified the process of accumulation and codification of the knowledge. Two methods of knowledge acquisition procedures were used: structured interviews, and prototyping.

Structured Interviews

Experts were asked to describe the crane selection process with the emphasis on the factors affecting their selection. It was found that, decisions made at various stages had to be tested in the light of discrepancies bound to arise between the experts. All decisions require prediction as to the consequences of the choice that is to be made. The decision could some times be restricted by the company's interests, making different experts to have different point of view in the process.

Prototyping

This involved the development of a knowledge-based prototype at an early stage of the knowledge acquisition process. Information and knowledge collected from experts were classified, coded, and represented in a prototype module. This module was presented to the experts for criticism, feed back and to test its effectiveness. The demonstration of the prototype proved to be valuable since it helped in revealing new knowledge. The procedure was repeated until the system was finally approved by the experts.

Knowledge Acquisition Findings

The objectives of this research work was to study the current practices of the crane selection used on high-rise building projects, investigating the factors affecting the crane selection, and modeling the process in a computerized integrated environment. The study included, general contractors, rental companies and engineering consultant companies [1].

CURRENT PRACTICE FOR CRANE SELECTION

Contractors generally aim at both profit and reputation when bidding for a job. To achieve reasonable profit, contractors try to minimize the cost of using equipment especially cranes on site. Normally they prefer to use the smallest size crane capable of completing the task. However, contractors rely on their in-house professional advice concerning the type of the crane to be used. Based on this, contractors can be classified into four groups: (a) General Contractors with in-house professionals and who own a number of cranes; (b) General Contractors with in-house professionals who rely on rental companies for the supply of cranes; (c) General Contractors who owns a number of cranes and depend on outside professional firm's advice on the crane selection; and (d) General Contractors who use outside professional firms for advice on crane selection and on rental companies for cranes supply.

This paper describes the process followed by the first group, (i.e. General Contractors with in-house professionals) who own a fleet of cranes. Experts use solutions to similar cases, involving crane selection they faced in previous projects in addition to heuristics and rules of thumb. Therefore analogical reasoning to identify most common cases is required in order to establish a methodology for crane selection process for high-rise building construction. Fig (1) illustrates the crane selection process followed by this group. It is noted that the crane selection is affected by the building's requirements that are included in the contract documents and drawings. The process starts with a report prepared by the Crane Manager, regarding a meeting held between experts in different areas (i.e. design professionals, architects, finance department representative). The crane manager's report may contain a recommendation for selecting a particular crane together with the factors considered during the selection process. Based on this report, and additional information on the construction requirements which include: (shape of the building, type of the structure, i.e. concrete or steel, construction program, site constraints, and the method of financing), and alternatives of similar cases from the company's previous work, the experts in their meeting would select the size and type of a crane (i.e. tower or mobile crane).

For a mobile crane the decision in most cases, is made between the crane manager, project manager, site supervisor, and crane operator to determine the type of a mobile crane, its attachments and location(s).

As is shown in Fig. (1), the final output consists of the number, type(s), positions of cranes, and operational costs. This output is further validated by studying the effect of the contractual and the economical factors such as: the availability of the selected crane, whether the selected crane can meet the construction program in terms of capacity and production rates, the effect of the selected crane on the structural and architectural design, and finally the cost of the selected crane.

In the case when changes to the construction requirements due to the crane selection is needed, the owner and/or his representative is notified, and the process is repeated for the new design.

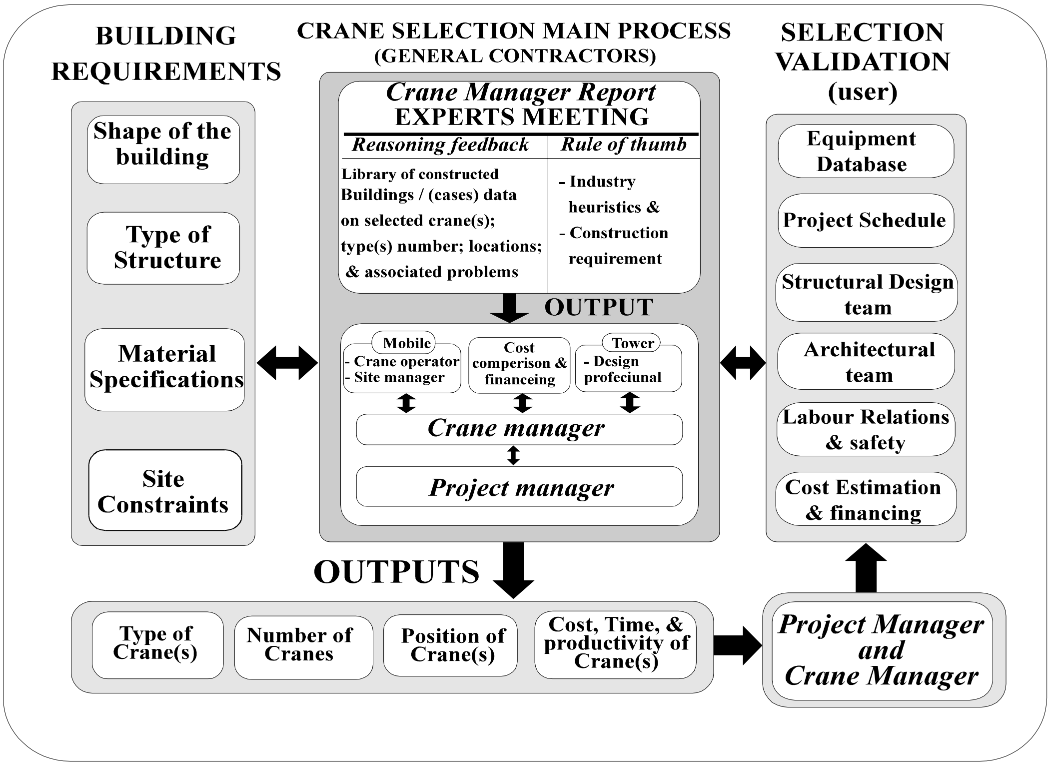

Fig. 1 Crane selection process followed by general contractor companies

FACTORS AFFECTING CRANE(S) SELECTION

Many factors need to be carefully considered when selecting cranes for building construction. They can be classified as technical, contractual and economical factors these which has been extracted during the knowledge acquisition stage of the system development factors are summarized in Fig. (2).

FACTORS AFFECTING CRANE SELECTION

Technical Factors

- Site constraints
- Site topography
- Access to the site
- Terrain condition
- Site layout and operational criteria
- Shape of the building
- Weight and size of material
- Cranes capabilitis

Contractual Factors

- Method of operation
- Construction schedule
- Building structure and method of construction

Economical Factors

- Size and number of cranes
- Cranes availability
- Running cost
- Purchase Vs rent
- Dismantling method

Fig. 2 Factors affecting crane selection

THE PROPOSED SYSTEM

The crane selection process is complex due to variety of factors including: buildings shapes, their structures, type and size of the material to be handled, along with the various crane types available in the market. The process requires expertise that might not be available to decision makers when needed. In an effort to facilitate this process and to make the expertise available to assist the decision makers during the crane selection process, experts knowledge have been captured, classified and coded in a computer system. The system is developed in a computer integrated environment capable of assisting owners, contractors, developers, design professionals, construction managers, and equipment suppliers in their decisions regarding the selection of appropriate crane type(s), number, and location(s) for high-rise building projects.

System Architecture

As shown in Fig. (3), the system incorporates two main modules. The first is the Knowledge-Based module that contains experts knowledge, heuristics and rules of thumb related to cranes selection process. The second, is the Case-Based module containing information on various cases representing already constructed buildings with pre-selected crane(s). In addition to the knowledge-base, the system integrates procedural algorithms for performing routine calculations and graphic validation to support the crane selection process. These are incorporated in three modules: geometry calculations, graphic validation, and cost estimation modules. The first two of these modules calculate and validate the geometry of the selected crane(s) and their location(s) with respect to the building geometry and loads specifications. The cost estimation module provides intensive cost calculations for the selected crane(s). All the modules share a global database containing data on a large number of commercially available cranes: their types, their specifications, and cost data. The database also contains data on a number of already constructed buildings including information on problems related to cranes used in their construction.

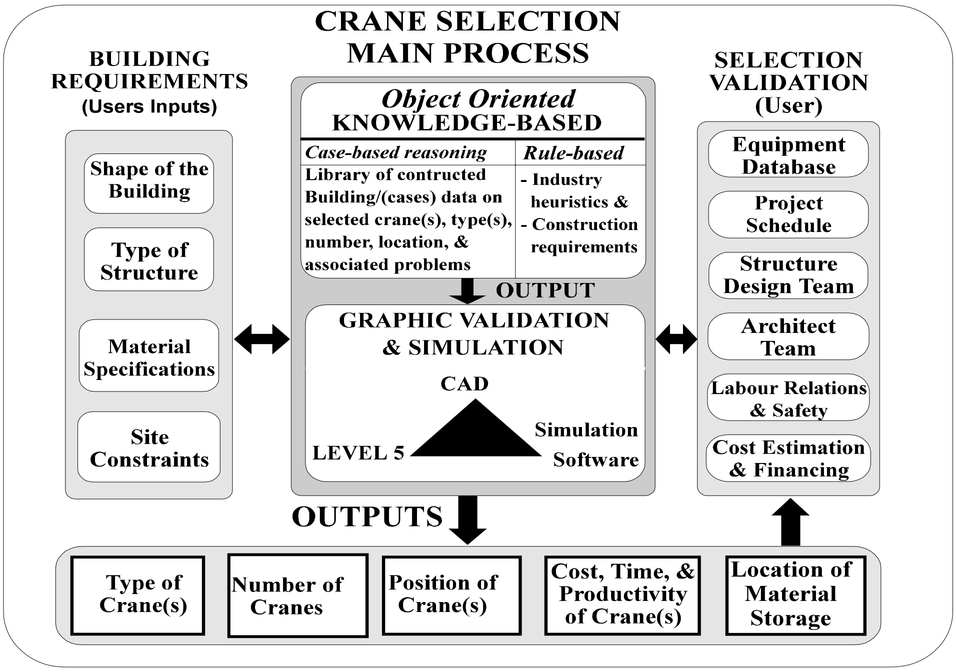

Fig. 3 Crane advisors main process

System's Strategy

When selecting a crane, in addition to heuristic and rules of thumb practitioners refer to solutions from similar cases, they faced in previous projects that involved crane selection. Therefore, identifying the most common cases is required in order to establish a methodology for crane selection for high-rise building construction. During the Knowledge Acquisition stage it was found that experts in the domain of crane selection use different strategies (explained in previous sections) to solve problems related to a crane's selection. These strategies have been incorporated in developing the system.

The system and the procedure followed during the selection process. The consultation starts, with the user, investigating the factors affecting the technical feasibility of a crane to be selected. This is based on the user's input as answers to a set of questions on different features of the project posed by the system, including: (shape of the building, type of the structure, i.e. concrete or steel, construction program, site constraints, and financing method). Based on the inputs, the system guides the user through the selection process using either the Knowledge-Based or/and the Case-Based modules. At the end of the session the user is presented with different alternatives of technically feasible cranes for the given building. These alternatives are thereafter, validated using graphical simulations, to establish the crane's position(s) and working range(s) on site. The system finally decides on the number, type(s), positions of crane(s), their operational methods and costs. This output is further checked for its compliance with the contractual and the economical constraints including: The availability of the selected crane(s), whether it can meet the construction program in terms of capacity and production rates, the effect of the selected crane(s) on the structural and architectural design, and finally the cost of operating the selected crane(s).

CASE EXAMPLE

To validate the effectiveness of the system a case which consists of an office building with a composite steel and concrete construction was used. The building is 45 meters high, 45 meters long, and 45 meters wide. These dimensions fall in the group of mid-height, mid-length, and mid-width category of building groups. It is required to select a crane or cranes to be used in constructing this facility.

Facility type, kind and dimensions are determined first from the Facility Kind and Height Displays. Further the 3D Facility Main Display is activated.

The 3D Facility Main Display provides the user with information on the selected case based on the user's previous responses to questions posed by the system. The type of the facility, i.e. Office Building, and its group is displayed as shown in Fig. (4). At this stage the user can activate other options or make changes to his/her previous responses by choosing the command back to building types (BACK-type). Having selected a case from ALL Shapes Panel**,** which contains a list of other scenarios, for further evaluation the system activates the **2**D Plan Display option.

In the Facility (2D) Plan Display the actual case appears first showing that for this case one tower crane was selected as shown in Fig. (5). The shape of the building and the site constraints, as shown in Fig. (4), were the determinant factors in selecting this crane. The building has irregular shape, it starts with a wide section and continue with a single tower. The type of the selected crane, which is a large climbing tower crane with saddle jib, along with the load capacity chart for the selected crane, and additional information regarding the necessary reinforcement, slabs openings and the additional support for the slab to be able to bare the total crane's load, is presented in separate AutoCAD drawings.

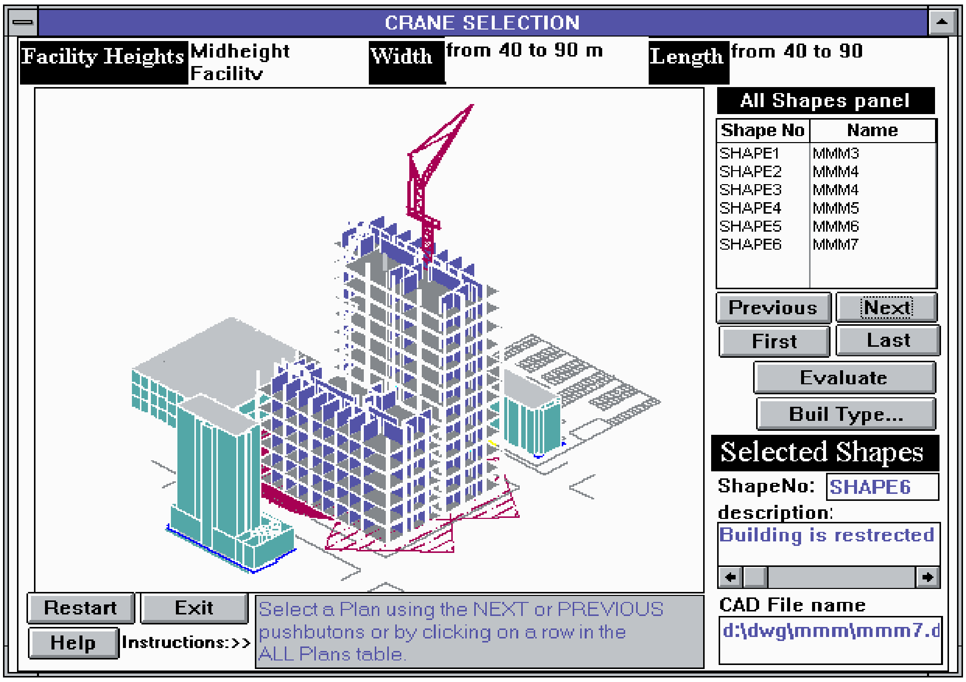

Figure (4) The selected tower cranes in 3D view

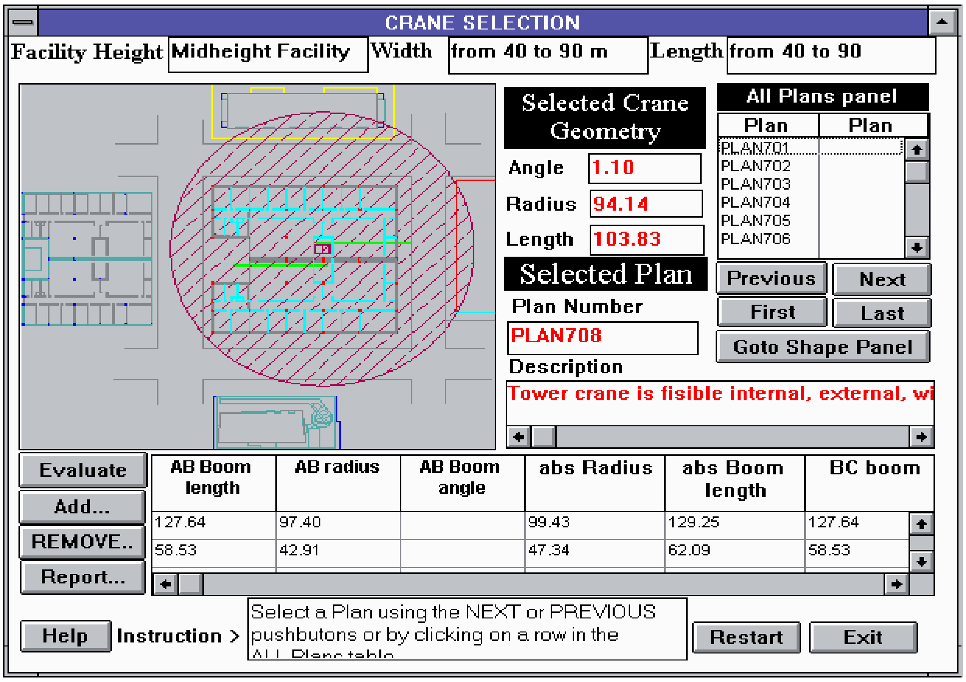

Fig. 5 Plan view of the tower crane

A consultation with the system using its knowledge-base revealed that two tower cranes are technically feasible. Fig. (6). The first crane is a static tower crane, with luffing Jib, located in the back area of the facility to serve the construction stages up to the completion of the

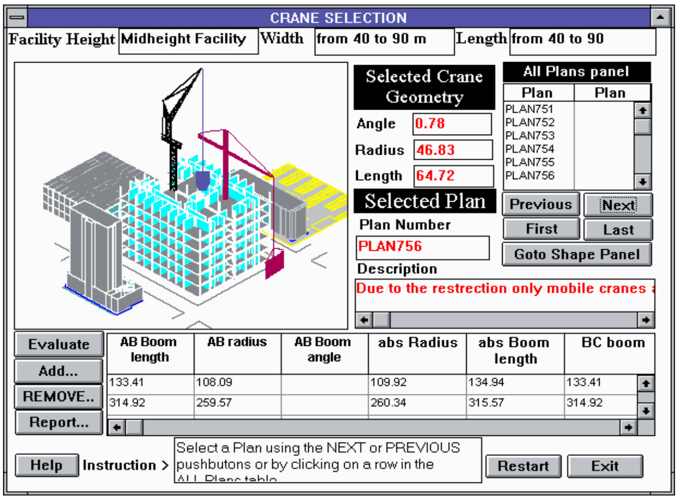

Fig. 6 Two tower crane suggested by the system

lower section, which has been designed for commercial spaces, and the other is a climbing tower crane to be located in the centre portion of the tower building (both jib configurations, Luffing and Saddle are accepted, in this case the saddle is selected). At this stage the user can activate other options or make changes to his/her previous responses by choosing the appropriate command from the screen, he/she can also investigate the site constraints by choosing NEXT, PREVIOUS, LAST or FIRST commands, revealing different constraints.

CONCLUSIONS

A computer system capable in assisting in crane selection has been developed. The system is currently undergoing detailed evaluation using major building projects to demonstrate its use and validity. The results. The system has a number of interesting features:

- Early trials with users indicate the advantages of using real cases within the system.
- The system also provides a disciplined method of transferring knowledge and expertise to inexperienced construction engineers.
- It assists in selecting cranes during the design and construction phases of a facility.
- It consists of database feature that contain constructed cases, presentation of the factors affecting crane selection, number of commercial types of equipment, and cost data.
- It facilitate integration within the systems' modules to perform a combination of algorithmic calculations and industry heuristics, forming a comprehensive crane selection process.

It must be emphasized that the system is strictly limited by the knowledge stored in its knowledge base and the information stored in its database.

REFERENCES

Al-Hussein, M, (1995-A) *A Computer integrated system for crane selection for high-rise building construction*, M.A.Sc. thesis, Centre For Building Studies, Concordia University.

Mohan, S. M. (1990) Expert system application in construction management and engineering, *Journal of Construction Engineering and Management*, ASCE, **116(**1), 87-99.

Moselhi, O., and Nicholas, M., (1990) Hybrid expert system for construction planning and scheduling, *Journal of Construction Engineering and Management*, ASCE, **116(**2), 221-238.

Alkass, S., and Harris F., (1988) An expert system for earthmoving equipment selection in road construction, *Journal of Construction Engineering. and Management.*, ASCE, **114**(3), 426-440.

Levitt, R. E., (1987) Expert system in construction: state of the art, M. L. Maher, (ed.), *Expert systems for civil engineers: technology and application*, New York: ASCE.

Alkass S., A. Aronian and O. Moselhi, (1993) Computer aided equipment selection for transporting and placing concrete, *Journal of Construction Engineering and Management***, 119(**3), 445-465.

Amirkhanian, S., and Baker, N., (1992) Expert system for equipment selection for earth-moving operations, *Journal of Construction Engineering and Management*, ASCE, **118(**2), 318-331.

Moselhi, O., and Gazal, N., (1992) A knowledge base approach for selection of earthmoving equipment, *Proceedings of the Canadian Conference and Exhibition on Industrial Automation*, Montreal, Canada, 1.9 - 1.12.

Alkass, S., and Aronian, A. (1990) Computer aided equipment selection for concrete placing, *Concrete Int.*, **12(**12), 39-45.

Christian, J., and Caldera, H., (1987) The development of a knowledge based expert system for the selection of earthmoving equipment, *AI-Civil-Comp, Proc., 3rd Int. Conf. on Struct. and Civil Engrg. Computing*, Edinburgh, UK, Civil-Comp Press, 55-59.

Bernel, L. E. (1986) Low level artificial intelligence and computer simulation to plan and control earthmoving operations, *Proc., Conf. on Earthmoving and heavy Equipment*, New York, ASCE, 156-165.

James M. Neil (1989) *Construction cost estimating for project control*, Englewood Cliffs: Prentice-hall INC.

Karl A. Raynar and Gary R. Smith, (1993) Intelligent positioning of mobile crane for steel erection, *Microcomputers in Civil Engineering*, **8**, 67-74.

Wrszawski, A., (1990) Expert system for crane selection construction, *Man and Economics*, **8**, 179-190.

Cooper C.N., (1987) CRANES- a rule-based assistant with graphics for construction planning engineers, *in the application of Artificial Intelligent Techniques to Civil and Structural Engineering*, Edinburgh: Civil Comp Press, , 47-54.

Gray, C. and Little, J., (1985) A systematic approach to the selection of an appropriate crane for a construction site, *Construction Management and Economics*, **3**, 121-144.

Furusaka, S. and Gray, C., (1984) A module for the selection of the optimum crane for construction sites, *Construction Management and Economics*, **2**, 157-176.