Selection of Optimum Machinery in Construction Project Using Artificial Neural Network Technique

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Abstract— Selection of machineries in construction projects is a central element in the planning phase of the life cycle of the project. Appropriately selected machineries are the lifeblood of any multistoried construction project and contribute largely to the efficient, timeliness, and profitability of the project. An error in selection can lead to large and unnecessary expenses arising from operational inadequacy or failure, and can produce an unsafe working environment. Decision to select particular machineries depends on the factors such as project size, project terrain, size of the structure being erected as well as economy, safety, and weather conditions and their variability are considered for selection of machineries. Machineries operators perform large amount of work on machineries based on the limited information they obtain from the site. Engineers are increasing their risk by relying on this limited information for the optimum selection of machineries, which leads to huge amount. It is expected that optimum selection of machineries lower the risk and costs associated with the machineries.

Selecting machineries 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, and guidelines on methods of calculating production output, labor resources and equipment requirements. Parameters mentioned above are qualitative, and subjective judgments implicit in these terms cannot be directly incorporated into the classical decision making process. Some of these factors are partially quantified and often entangled with personal opinions and seldom based on scientific analysis. These considerations are handled using fuzzy logic techniques.

This paper presents a fuzzy logic approach to aid the contractor in the proper machineries selection. From expert's opinions in terms of membership values of fuzzy sets are aggregated by modified pessimistic aggregation procedure and final selection will be achieved by Dominance Matrix.

Index Terms— Construction Industry, Fuzzy Logic Approach, modified pessimistic aggregation, Optimum Machineries

I. INTRODUCTION

Construction industry plays an important role in the development of the nation. With the development of advanced technology and growing use of machinery in the construction of large civil works, it has become necessary for a construction manager to be familiar with the various techniques and their procedure that are used for selecting optimum modern construction machineries. On a large project, a contractor may have an assortment of various machineries for different purposes. Choice of type, number, and location of machineries to be used in construction of a high-rise building is a focal issue in planning the construction operations. Selection of correct machineries in construction projects is a central element in the planning phase of the life cycle of the project (Shapira and Marat 2007). Appropriately selected machineries is the lifeblood of any multistoried construction project and contributes largely to the efficient, timeliness, and profitability of the project. (Beavers et al. 2006). An error in selection can lead to large and unnecessary expenses arising from operational inadequacy or failure, and can produce an unsafe working environment. (Bhasker et al. 2001).

Selecting machines depends greatly on skilled judgment that accounts for every likely involved variable. Much information is available to assist in this process in the form of work study data, manufacturers' machine performance specifications, and guidelines on methods of calculating production output, labor resources and equipment requirements. Unfortunately this information is incomplete and generally requires the user to make bold decisions on job conditions and categories of machines for a particular situation leading to unavoidable mistakes and perhaps costly decisions. Selection of machines requires prediction of the consequences of the choice that is to be made. A wrong decision is likely to have significant effect 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.

Selection of an appropriate crane for construction projects generally involves two classes of factors or considerations. The first class comprises tangible, quantitative, which include technical specifications of the equipment, physical dimensions of the site and constructed facility, and cost calculations and are termed hard factors for considerations. The second class covers a large array of other factors, which are mostly intangible, qualitative, and informal in nature. Random examples include safety considerations, company policies regarding purchase/rental, market fluctuations, and environmental constraints. Many of these parameters are qualitative, and subjective judgments implicit in these terms cannot be directly incorporated into the classical decision making process. Translating these qualitative factors into mathematical measures, to aid the decision maker and to select a best crane using fuzzy logic approach is the aim of this research work.

II. PAST STUDIES

There are numerous works regarding the choice of construction equipment. These are given in Table 1 chronologically. As can be seen in these past researches, fuzzy logic is an ignored solution tool except the study of Hanna and Lotfallah (2003) in the selection process of construction machines. On the other hand, Tam et al. (2003) investigated concrete vibrators which have very different features and criteria when compared. In addition, this study included 5 criteria, all of them of a quantitative nature. Although Tam et al. (2004) examined concrete pumps, their method is different from fuzzy logic and they solely consider quantitative criteria. Moreover, 10 concrete pumps, which characteristics vary in a very large spectrum, were investigated. In reality, this is incongruous with the basic MCDM logic because of the fact that MCDM is a useful and reasonable device employed when there are little differences between the characteristics of alternatives and thereby when the selection process is a tough and indecisive work.

Gray et al(1985.) developed a systematic approach to the selection of an appropriate crane for a construction site. They described the process and criteria for the selection of two categories of crane, namely, tower cranes and mobile cranes. The selection process was in the form of decision flow charts. A computer based expert system was developed and used to simplify the selection process and is named CRANES.

Anil Sawhney et al. (2002**)** has stated that due to the central role of cranes in construction operations, specialists in the construction industries have cooperated in the development of structured methods and software for crane selection. Most of these software tools are for crane model selection, and integrated systems that handle both crane type and model selection are not readily available. In this paper they presented the crane type selection features of IntelliCranes, a prototype integrated crane selection tool that assists in both crane type and crane model selection based on a set of inputs describing the construction operation under consideration. By using historical data and advanced artificial intelligence computing tools such as artificial neural networks,

IntelliCranes automates crane type selection. Crane type and crane model selection are seamlessly integrated in a comprehensive crane selection tool, and consistency in the selection of cranes for similar situations is increased.

Tam et al.(2003) developed genetic algorithms and an artificial neural network model (GA-ANN) for predicting tower crane operations and site layout. However, only limited attempts have been made to determine the optimal number and location of tower cranes based on a graphical programming environment.

Shapira et al (2007) said that, cranes play crucial roles in construction industry, especially mobile cranes due to their high capacity in respect to construction assembly operations on-site. Crane operation is critical to implementing projects in the construction industry because it strongly influences successful project completion for modules' installation without potential site errors such as spatial collision which could lead to reduce productivity by increasing cost and time.

Crane application has improved the construction industry's efficiency dramatically in recent decades, making prefabrication and on-site installation possible. Efficient crane use also improves work productivity and quality with cost and time savings. After modules are manufactured in a factory, they are delivered to construction sites for assembly.

Warszawski (1990) developed a knowledge-based system LOCRANE to assist the construction planner in selecting and locating a crane for a construction site. This system was developed using a commercially available shell (SAVOIR). The system asks the user to input all information related to building geometry and possible for application for the proposed crane. The system outputs, most appropriate alternative from a set of cranes available.

After studying all the previous paper related to selection of construction machineries it can be concluded that the proper selection not only fasters the operation but also affects the different resources.

Table 1: Previous papers concerning the selection problem of construction machines

Author	Type of equipment	Selection method
Chan and Harris (1989)	Backhoe/loader	Electronic spreadsheet
Jayawardane and Harris (1990)	Earthwork equipment	Linear programming
Amirkhanian and Baker (1992)	Earth-moving equipment	Expert system
Hanna (1994)	Crane	Expert system

Touran et al. (1997)	Dozer	Empirical charts
Hanna and Lotfallah (1999)	Crane	Fuzzy logic
Naoum and Haidar (2000)	Opencast mine equipment	Genetic algorithms
Sawhney and Mund (2002)	Crane	Neural networks
Tam et al. (2003)	Concrete vibrator	ELECTRE III
Tam et al. (2004)	Concrete pump	Superiority and inferiority ranking
Al-Hussein et al. (2005)	Mobile crane	Optimization algorithm
Goldenberg and Shapira (2007)	Concreting equipment	Analytical hierarchy process
Schabowicz and Hola (2007, 2008)	Earth-moving machinery	Mathematical-neural networks
Sivilevicius et al. (2008)	Asphalt mixing plant	Simple additive weighting
Zavadskas and Vaidogas (2008)	Protective equipment	Bayesian approach

III. FUZZY DEFINITION

Fuzzy means blurred, indistinct in shape or outline, frayed or fluffy Oxford University 1993. In modern mathematical society, fuzzy is defined as a branch of modern mathematics that was formulated by Zadeh (1965) to model vagueness intrinsic in human cognitive process and to solve ill-defined and complicated problems because of ambiguous, incomplete, vague, and imprecise information that characterize the real-world system. It is appropriate for uncertain or approximate reasoning that involves human intuitive thinking Zimmermann (2001) because much of our natural language is fuzzy in nature, for example, it was

―very hot‖ yesterday; 100 is ―much larger‖ than 10; I ―like‖ watching TV; you drive ―too fast,‖ please keep it ―slower;‖ and he is not too ―old.‖

It is generally accepted that two fundamental fuzzy concepts are: (1) fuzzy set; and (2) Fuzzy logic. Fuzzy set uses linguistic variables and membership functions with varying grades to model uncertainty inherent in natural language Zimmermann (2001).

Fuzzy relation can be defined as more or less vague relationships between some fixed numbers of objects, and it can formally be treated like fuzzy sets Bandemer and Gottwald (1995). Fuzzy logic is a superset of Boolean conventional logic that has been expanded to handle the concept of partial truth and true values between ―completely true‖ and ―completely false‖ Zimmermann (2001).Fuzzy control can be defined as the application of fuzzy logic Lin and Pang (1994). In general, the design and setting of fuzzy controllers consist of defining three parameters, including:

1. Defining the domain for the input and output of linguistic variables for each fuzzy controller;

2. Defining the set and the type of membership function for each linguistic value-input of every fuzzy controller. The relations between inputs and outputs of linguistic values have to be provided in the form of fuzzy rules, which represent logical inference; and

3. Defining the fuzzy logic operators for each IF-THEN sentence, as a base for final inference Lah et al. (2005).

Two Fundamental "Fuzzy Concepts" Applications in Construction Management Research

Two fundamental ―fuzzy concepts,‖ including fuzzy set and fuzzy logic, are extensively applied in construction management research. It should be noted that fuzzy set is the basis of fuzzy logic and they are highly associated with each other in that fuzzy logic is a reasoning system that uses fuzzy sets. In fact, both fuzzy set and fuzzy logic are intended to deal with a different type of uncertainty than probability theory, that of vagueness and imprecision. Since these two concepts are increasingly applied to construction management discipline, they are described in the following subsections in greater detail, and their applications in construction management research will be further discussed after the section ―Fuzzy Research in the Past.‖

A. FUZZY SET

As mentioned before, fuzzy set theory FST is a branch of modern mathematics that was formulated by Zadeh (1965) to

model vagueness intrinsic in human cognitive process. Since then, it has been used to tackle ill-defined and complex problems due to incomplete and imprecise information that characterize the real world systems Baloi and Price (2003). In fact, Zadeh stated that when the complexity of a system increases, the ability for human beings to make precise but significant statements about their behavior diminishes. This will continue to happen until a threshold is reached beyond which precision and significance becomes mutually exclusive—the principle of incompatibility.

Therefore, it follows that modeling complex or ill-defined systems cannot be made precisely. However, FST was not intended to replace probability theory, but rather to provide solutions to problems that lack mathematical rigor inherent to probability theory Baloi and Price (2003). FST is an extension of the classical Boolean or binary logic. The main problem with binary approach is that it fails to convey information effectively, that is, the states between full and non-membership are ignored but they are very vital. Meanwhile, most real-world systems are extremely complicated and ill defined.

B. FUZZY LOGIC

Fuzzy logic is a superset of Boolean-conventional logic that has been extended to handle the concept of partial truth and truth values between completely true and ―completed false‖

Zadeh (1965); Lin and Pang 1994; Lah et al. 2005_. Fuzzy logic should be seen as a data analysis methodology to generalize any specific theory from ―crisp‖ to ―continuous.‖

Fuzzy modeling opens the possibility for straightforward translation of the statements in natural language—verbal formulation of the observed problem into a fuzzy system. Its functioning is based on mathematical tools. The basic operations of the set theory are intersection, union, and complement extended for the purpose of fuzzy logic.

The applicability of fuzzy logic in the field of construction management is quiet notable (Dubois 1980). Fuzzy logic allows expressing this knowledge with subjective concepts such as good weather and a little bit experienced contractor etc., which are mapped into exact numeric ranges. A number of practical and wide-ranging applications are available that fuzzy logic can bring about in the field of construction management (Ross 1997).

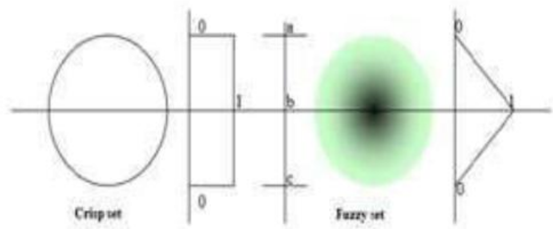

Fig 1: Demonstration of a crisp set and fuzzy set

IV. RESEARCH METHODOLOGY

Table 2. Summary of Literature Review of Fuzzy Set/Fuzzy Logic

	Decision making	Performance	Evaluation/ assessment	Modeling	Total
Fuzzy set	9	6	4	4	23
Fuzzy logic	1	2	5	0	8
Hybrid fuzzy techniques	5	6	4	6	21
Total	15	14	13	10	52

The research method used for this paper was to launch a comprehensive review of the related literature from 1996 to 2005.

The selection of literature was mainly based on the top quality journals in construction management and other related fields, which include: (1) Journal of Construction Engineering and Management, ASCE; (2) Journal of Management in Engineering, ASCE; (3) Construction Management and Economics; (4) Engineering, Construction and Architectural Management; (5) International Journal of Project Management; (6) Building Research and Information; (7) Building and Environment; and (8)Benchmarking: An International Journal. In fact, with reference to a research study on journal ranking in construction management conducted by Chau 1997 , the first six journals were assessed by respondents to have very high rankings among 22 relevant journal assessed. And the last two journals are widely perceived by academics to be first tier journals in construction related areas.

Keywords for ―searching‖ were ―fuzzy set,‖ ―fuzzy logic,‖ ―fuzzy control,‖ and other hybrid fuzzy techniques. These terms were well known of having been used in writing papers on fuzzy techniques.

The procedures for retrieving the fuzzy papers are as follows:

- The titles of the articles were scanned with the keywords. Altogether, there were 59 articles that contained one of the keywords in their articles' titles, which are either ―genuine fuzzy‖ papers or closely related papers.

- Seven articles were taken out as they were not in the context of construction management.

Metaanalysis is a statistical technique for combining the research findings from independent studies. The essential character of metaanalysis is that it is the statistical analysis of the summary findings of many empirical studies Glass et al. (1981). It can be understood as a form of survey research in which research reports, rather than people, are surveyed. A coding form is developed, a sample or population of research reports is gathered, and each research study is ―interviewed‖ by a coder who reads it carefully and codes the suitable information about its characteristics and quantitative findings Lipsey and Wilson (2001). Since the aim of this research study is to summarize and present a critique of the existing fuzzy literature so as to investigate which major categories fuzzy techniques are strong to analyze and provide a path for future research studies on some areas, content analysis, instead of metaanalysis, was deployed in this research study because it was not aimed at conducting statistical analysis by combining the research findings from a number of independent empirical research studies.

By using the content analysis method in this research study, four major categories of applications have been grouped under two broad fields. The two broad fields are: (1) fuzzy set/fuzzy logic; and (2) hybrid fuzzy techniques. The four major categories are:(1) decision making; (2) performance;

(3) evaluation assessment; and (4) modeling. The four major classifications of the area of application is mainly based on analyzing the contents of paper with particular reference to paper title, abstract, and keywords using the content analysis technique. The results show that 15 papers can be classified under ―decision making;‖ 14 papers under ―performance;‖ 13 papers under ―evaluation/assessment;‖ and 10 papers under ―modeling.‖ Content analysis is frequently adopted to determine the major facets of a set of data, by simply counting the number of times an activity happens, or a topic is depicted Fellows and Liu 2008 . The first step to conduct content analysis is to identify the materials to be analyzed. The second step is to determine the form of content analysis to be used, which includes qualitative, quantitative, or structural. The choice is dependent on the nature of the research project. The choice of categories will also depend upon the issues to be addressed in the research if they are known. In qualitative content analysis, emphasis is on determining the meaning of the data i.e., grouping data into categories .Quantitative content analysis extends the approach of the qualitative form to generate numerical values of the categorized data frequencies, ratings, ranking, etc. which may be subjected to statistical analyses. Comparisons can be made and hierarchies of categories can be examined Fellows and Liu 2008.

V. IMPLICATIONS FOR THE FUTURE RESEARCH DIRECTIONS

After conducting a comprehensive literature review on the applications of fuzzy set/fuzzy logic and hybrid fuzzy techniques in construction management research, some research areas have been identified for further study. First, it is recommended that fuzzy set/fuzzy logic can be incessantly adopted in the previously mentioned four major categories because they can assist in developing models to make decisions and to evaluate the performance in a wide range of areas when analyzing construction problems, which are often viewed as complicated, uncertain, and ill defined.

Fuzzy membership functions and linguistic variables, two of the major concepts associated with fuzzy set/fuzzy logic others including natural language computation, linguistic approximation, fuzzy set arithmetic operations, set operations, and fuzzy weighted average (Zimmermann2001); Zheng et al. (2005) can be especially adopted to suit applications to solve construction problems with reference to the aforesaid nature of construction. In fact, fuzzy membership functions enable one to perform quantitative calculations in fuzzy decision making Bharathi-Devi and Sarma (1985) while the concept of linguistic variables serves the purpose of providing a means of approximate characterization of phenomena that are too complex or too ill defined to be amendable to description in conventional quantitative terms Cross and Sudkamp (2002) & Niskanen (2004).

VI. CONCLUSION AND DISCUSSION

This paper has conducted a comprehensive literature review on the application of fuzzy techniques in construction management discipline. Although fuzzy techniques have been increasingly applied in the research area of construction management during the last decade, no paper has attempted to draw up a holistic commentary of the existing fuzzy literature. To fill up this research gap, this paper provides a comprehensive review on the fuzzy literature that has been published in eight selected top quality journals from 1996 to 2005. It has been found that fuzzy research, as adopted in the construction management discipline over the past decade, can be divided into two broad fields, encompassing:

(1) Fuzzy set/fuzzy logic; and (2) hybrid fuzzy techniques, with their applications in four main categories, including: (1) decision; (2) performance; (3) evaluation/assessment; and (4) Modeling. The applications of fuzzy techniques on these categories are very effective and practical because they can help to develop models to make decisions and to evaluate the performance in a wide range of areas when analyzing problems encountered in the construction industry, which are widely regarded as complex, full of uncertainties, and contingent on changing environments. Having conducted a comprehensive overview on the applications of fuzzy techniques in construction management research, it puts forward new directions for fuzzy research and its application in construction management research. It is suggested that future research studies on fuzzy set/fuzzy logic can constantly be applied on the four major categories mentioned

previously. Fuzzy membership functions and linguistic variables can be particularly employed to suit applications to tackling construction problems facing the aforesaid nature of construction. In addition, hybrid fuzzy techniques, such as neuro-fuzzy and fuzzy neural network, can be more broadly adopted because they can better solve some construction problems that fuzzy set/fuzzy logic alone may not best suit. For example, neural networks are strong in pattern recognition and automatic learning while fuzzy set and fuzzy logic are strong in modeling certain uncertainties. Their mixture can assist in developing models with uncertainty under some forms of pattern. Singh et al. (2007) it is believed that the application of fuzzy techniques will go beyond the construction management area into these disciplines as well.

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