FUZZY LOGIC IN CONSTRUCTION PROJECT SCHEDULING: A REVIEW

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Abstract – *Construction activities are mainly scheduled using the Critical Path Method (CPM) that depend on one another through network relationships and is deterministic on considering the duration assigned to the execution of the activities and the results thus produced. Unfortunately, construction activities are performed under uncertain conditions. Any risks in the project can cause variations in activity duration and in turn the entire network is affected by uncertainty. Thus activity duration can be represented by using fuzzy sets, and CPM network calculations can be done by fuzzy operations. Mathematical models allow the multi objective optimization of project schedules, considering constraints such as time and cost defined in the project, and unexpected materials shortages to determine the fuzzy aspiration levels of Decision Makers.*

Key Words: Scheduling, Construction materials, Fuzzy sets, Construction management, Mathematical model.

1. INTRODUCTION

Construction project scheduling has been developed as an influential and classy management tool. On the basis of the schedules developed during the early planning stages of projects, and taking all the possible scenarios into account, the construction management decisions are made. During the course of the project, many unpredictable events may occur. Therefore, in these situations the decision maker has to make decisions quickly during course of construction. The decisions are based on the expertness of decision managers who use software, but during the execution period, the assumptions may vary that were made during the planning stage of a project. However, the decisions which are made need to be aided by a risk management plan. In most of the situations, to minimize the risks in the planning stages, the allowances considered may not be enough to cover all the possibilities, and the planner will have to react accordingly when changes occur.

A case study, was made among schedule and duration of the project. The schedule of the project and sticking towards it is crucial to the success of any project. But real-life scenarios have got a lot of constraints (Weather, Labour availability, Material, etc.,) to complete the project in scheduled time. Spending the allocated budget is one of the primary objectives which should be studied and controlled at the stage of executing a project. This problem has been arisen to check whether the cost work ratio is in balance according to the forecast in the budget. It is evident that it is impossible to maintain cost-work ratio as predicted in the project. Some such as inflation, human workforce, natural calamities, accidents, etc., may result in possible increase or decrease in cost of the project. The actual time and cost of construction projects may be affected by the client, the project and same contract characteristics and in many cases can be very different from the contract time and cost. The substitution between the minority diverse phases of the project is a challenging job and planners are faced with numerous possible combinations for project delivery. Different evolution approaches are applied to optimize the multi-objective time and cost optimization problem.

The project without the proper plan and schedule will incur more cost and duration, which affect the project manager and client's fulfilment. The duration of the project is a result of the effective scheduling.

2. FUZZY LOGIC

2.1 Definition

In dictionary the word "fuzzy'' is defined as "blurred, vaguely, indistinct". Here the term "fuzzy logic" refers to a logic of approximation. Lotfi A Zadeh (1994) [20] said that fuzzy logic (FL) is a problem-solving methodology which can itself implement to a systems ranging from simple, small, micro-controllers to large, networked workstation-based data acquisition and control systems. Even it can be implemented in a combination of both hardware and software. FL provides an easy way to reach a definite conclusion based upon vague, ambiguous, noisy, or missing input information. FL mimics how a person would make decisions, in approach to control problems in a much faster way. Fuzzy logic imitates the logic of human thought, and it is much less stiff than the calculations computers generally perform. While Sivanandam et al. (2007) [18] defined fuzzy logic as a mathematical tool for dealing with uncertainty and also it provides a technique to deal with imprecision and information granularity.

2.2 Fuzzy Set Theory and Fuzzy Numbers

In general classical set theory, the membership of an element to a specified set is explained by two definite and opposite situations: belonging to the set (membership degree = 1.0) or not (membership degree = 0.0). Later, in fuzzy set theory, the membership of an element to a specified set is explained by the membership degrees with values between 0.0 and 1.0 (Zadeh 1965[20]). This provides an opportunity in modelling the uncertain expressions of real life mathematically, performing fuzzy set operations between these uncertainties and finally reaching fuzzy results that cannot be achieved analytically.

Consider a fuzzy set A of the universe U,
$A = \{(x, \mu_A(x)) | x \in A, \mu_A(x) \in [0, 1]\}$
where $\mu_A(x)$ is the membership function, and $\mu_A(x)$ exactly states the degree to which any element x in A is a member of the fuzzy set A.

This definition combines each element x in A with $\mu_A(x)$ in the interval [0,1] which is assigned to x. Larger values of $\mu_A(x)$ indicate higher degrees of membership.

A fuzzy number possesses two properties: convexity and normality. The convexity shows that the membership function has only one distinct peak, and the normality ensures that at least any single element in the set has a degree of membership equal to 1.0. These properties make the concept of fuzzy numbers more attractive and naturally appropriate for modelling imprecise fuzzy quantities such as "approximately one month," or "more or less than 30 days". In theory, fuzzy numbers can take different shapes. In modelling real-life problems, anyways, linear approximations such as trapezoidal & triangular fuzzy numbers are frequently used. Mathematical definitions and general shapes of triangular and trapezoidal fuzzy numbers are given below:

TRIANGULAR FUZZY NUMBERS:

Triangular fuzzy number with membership function $\mu_A(x)$ is defined as:

$$\mu_A(x) = \begin{cases} (x-a)/(b-a) & for\ a \le x \le b \\ (x-c)/(b-c) & for\ b \le x \le c \\ 0 & otherwise \end{cases}$$

TRAPEZOIDAL FUZZY NUMBERS:

Trapezoidal fuzzy number with membership function μA(x) is defined as:

$$\mu_A(x) = \begin{cases} (x-a)/(b-a) & for\ a \le x \le b \\ 1 & for\ b \le x \le c \\ (x-d)/(c-d) & for\ c \le x \le d \\ 0 & otherwise \end{cases}$$

3. LITERATURE REVIEW

In a construction industry, any changes to projects in future and potential uncertainties need be included in the schedule in the planning stage itself. These changes would generate extra cost and time if they are not considered during the planning stage. The ideal situation for Decision Makers (DMs) would be to find the right decision at the right moment. In order to do this, problems have to be analyzed using different approaches rather than just traditional Critical Path Method (CPM) schedules including mathematical models or optimization methods. Commonly used commercial software that is based on heuristic procedures are not based on rigorous mathematical modus operandi. In practice, optimization methods are not frequently used due to the time required to find optimal solutions. In contrast, most construction companies use commercial software such as Primavera Project Planner (P3), or Microsoft Project because they are easier and faster to use. Even though these generate solutions that are not optimal, they are usable solutions. Decision Makers aim to control the causes of cost overruns. Therefore, mathematical models with material constraints would be useful for identifying and analyzing different paths and rescheduling the project in case of material shortages.

3.1 Construction Network Scheduling Approach and Variations with CPM

Critical Path Method Schedules are an important technique that has been used since the 1950s and the construction industry benefits from their use in the planning and controlling of projects, when communicating plans, and when training new managers. Newer versions of CPM scheduling software make CPM techniques easier for practitioners to use them and this has increased efficiency in some construction projects.

Schedules that neglect material constraints could mislead planners and affect the control of projects (Yates, 1993[19]). Real life projects present a wide range of variables that are difficult to control due to the fact that resources are limited in construction projects; therefore, float calculated using CPM techniques will lose its significance and new critical sequences will be created (Kim and de la Garza, 2005[8]). Critical Path Method schedules show the critical path, or paths, of a project but resource profiles present fluctuations that are not desirable for the efficiency of projects.

Project managers, or decision makers, now use commercial project management software, such as Primavera Project Planner (P3) and Microsoft Project, which are based on heuristic methods to plan and control schedules. In the article "Project-Network Analysis Using Fuzzy Sets Theory", the authors discuss the use of different applications in project planning and control (Liberatore, Pollack-Johnson, and Smith, 2001[9]). They found that the construction industry mainly uses critical path analysis applications and that Primavera Project Planner is used most frequently. The research showed that two out of four companies use Primavera and one out of four uses Microsoft Project for scheduling. The authors had a sample of forty-two construction companies that responded to their survey out of two hundred forty companies. Uncertainties and methods to forecast activity durations were two of several issues that practitioners are inquiring about nowadays. Labor productivity improved by 6% when resources were considered in CPM and an additional 4-6% improvement was obtained when using computerized systems as stated in the PhD. dissertation, "A Framework for a Decision Support Model for Supply Chain Management in the Construction Industry", (Perdomo-Rivera, 2004[16]).

3.2 Modified CPM as a Tool for the Decision Making Process

Most decisions at construction sites are made based on the project schedules. This situation may be critical if suddenly a planned schedule has to be changed due to any type of delay. Decision Makers (DM) should have enough expertise, and the availability of previous information from similar situations, that will help them to make sound decisions. Some authors have analyzed this situation and presented a modified CPM to improve the decision making process. For instance, in the study "Construction Decisions Support System for Delay Analysis", the author, Dr. Yates, integrates commercial project management software packages based on CPM schedules with compatible software called The Delay Analysis System (DAS). In this software, a simulated project environment is created and possible alternative situations are analyzed by the computer. This model gives decision makers valuable alternatives to prevent, or minimize, the effects of probable delays. The Delay Analysis System presents clear and detailed information that could be used during any stage in a project. In addition, the information processed is stored creating historical databases that help support future DM (Yates, 1993[19]). This research gives practitioners an opportunity to consider historical information and have a more realistic approach to decision-making processes.

3.3 Optimization Models in Construction Networks

Optimization models have been used in construction projects, but they have not been successful for large networks. Networks with more than 100 activities could not be handled due to computer hardware limitations. Critical path method techniques, with discrete information instead of continuous membership functions have proven to be more efficient and they provide not optimal, but useable solutions. (Molder J., 1993[11]). However, some optimization techniques present the opportunity to analyze more than one objective at a time and this permits a more realistic approach. On the other hand, other authors analyze the uncertainties in a project by using fuzzy sets.

The principal objectives in a network project are to minimize completion time and cost. During the literature review only a few articles that concentrated on construction networks using goal programming were located. In the article "An Application of Fuzzy Goal Programming to a Multi-objective Project Network Problem" an analysis of the optimization of a project network facing two constraints simultaneously is presented. Unlike other optimizing methods, the optimization is made using nontraditional mathematical modeling, called Fuzzy Goal Programming (FGP). Therefore, having two constraints and the fact that the two objectives are presented in different terms such as time and cost, make the optimization project more difficult. Subjective judgments made by the Decision Maker (DM), and the fuzziness of the objectives, are the basis of the Fuzzy Set Theory (FST). Fuzzy Goal Programming is used to achieve an optimal solution while considering two objectives at the same time and using membership functions (Arikan and Gungor, 2001[2]). In their article "Project-Network Analysis Using Fuzzy Set Theory", Lorterapong and Moshelhi (1996) [10] present a practical network scheduling method for construction projects based on Fuzzy Set Theory (FST), which allows the consideration of uncertainties coming from diverse project settings. The authors emphasize that this method is more pragmatic than using stochastic or probabilistic techniques and does not show sophisticated computational calculations. However, the authors state that when a project consists of large networks a common spreadsheet package will facilitate the process. Consequently, taking into consideration uncertainties to decide possible completion times for each activity in a network makes this contribution a useful optimization tool for decision makers and researchers.

3.4 Approach of Using Optimization for Construction Management

Considering possible material shortages in construction helps project managers to evaluate different situations and make high-quality decisions. Furthermore, traditional mathematical models may generate optimal solutions, but even if they are single objective-oriented or multi-objective models they do not consider fuzziness as is possible in Fuzzy Mathematical Methods. Nowadays, powerful and fast computers can process complex fuzzy mathematical models that provide a more realistic approach to finding the optimal trade-off between cost and time for network projects in construction.

3.2 Fuzzy Logic in Project Scheduling

Considering the wild range of applicability of fuzzy logic and its flexibility in answering complex decision making problem, it can be accepted in construction project scheduling. Fuzzification and defuzzification are the two main phases in fuzzy logic mathematical modelling. There are some membership functions under fuzzy logic and out of which two are being used (Muhamed s. 2016[12]). The study explained the use of fuzzy mathematical model and concluded with a fuzzy mathematical model. Optimizing the construction project schedule is easy using this mathematical model.

4. CONCLUSIONS

Fuzzy Logic provides a completely different, way to approach a control problem. Focus on what the system should do rather than trying to understand how it works. Fuzzy logic leads to quicker, cheaper solutions.

Fuzzy mathematical models allow the inclusion of time and costs in the analysis process. In addition, material restrictions can be included as constraints that could determine more realistic solutions. The more constraints that are included in an analysis the more the analysis supports the decisions generated using fuzzy mathematical models.

Primavera Project Management (P5) does not directly perform cost-time trade-off calculations. For crash cost comparison purposes, the baseline of a project must be first created with regular cost, and then generate the crash cost on resources, activities, etc. to compare the baseline costs with the current schedule. It then encompasses a process in which schedules are revised again and again. Finally, this information is exported to Excel to create the cost-time trade-off graphics. These processes to create the cost-time trade-off graphics make the Primavera Project Software not practical in terms of this aspect. Mathematical models can be used to directly perform cost-time trade-off analysis.

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