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A Fuzzy Approach for Delay Potential in Construction of Building

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Abstract—Delays in the construction projects are often unavoidable circumstances. The modelling for delay analysis in the construction of building assumes greater complexity due to the involvement of human perception in the evolution of decision making process. Further, the complex human perception is subjected to the physical surroundings, social environment and also to its own household structure over and above the economic constraints. The calculation of delay in the construction of building has a major bearing on the human decisions regarding the importance of the construction activities. Both the decision processes are complex with higher degree of subjectivity involved and therefore call for the analytical tools which can imitate this behavior and bring the results close to the reality. In the present study, the Fuzzy Rule Based System is developed to calculate delay status in the construction of building.

Index Terms— Fuzzy sets; Membership Grade function; α-cut, Fuzzy rule based system, Linguistic variables, Delay potential (DP).

1 Introduction

Construction industry has been in existence since the caveman started his dwelling. It has created many wonders in the world and produced many facilities for the benefit of the mankind. Project is a mission to create a unique facility, product or service within the specified scope, quality, time and cost.

Construction is an everlasting activity across the Globe. From Economic angle, the construction industry is that sector of economy that plans, design, constructs, maintains, alters and repairs physical immobile structures.

Contingency planning is a common practice in construction industry to prevent problems; however, many projects still exceed the predicted planned time for major tasks the main cause of project failure are inadequate project formulation, poor planning for implementation, lack of proper contract planning and management, lack of project management during execution.

Delay is one of the most common problems in the construction industry. Therefore, many techniques have been made to evaluate the different kinds of delays in the construction industry namely CPM, PERT, etc. But these techniques are not quite enough to incorporate with the Uncertainty of the human perception.

The traditional two-valued logical systems, crisp set theory and crisp probability theory are inadequate for dealing with imprecision, uncertainty and complexity of the real world. The uncertainty (predictive, prescriptive, etc.) has a pivotal role in any efforts to maximize the usefulness of systems models. Zadeh [15] first introduced the concept of fuzzy set theory through his paper and it is generally agreed that an important point in the evaluation of the modern concept of uncertainty was the publication of his seminal paper, even though some ideas presented in the paper were envisioned some 30 years earlier by the American philosopher Max Black (1937).

A fuzzy set can be defined mathematically by assigning, to each possible individual in the universe of discourse, a value representing its grade of membership in the fuzzy set. This grade represents the degree to which that individual is similar or compatible with the concept represented by the fuzzy set. Thus, an individual may belong in the fuzzy set to a greater or lesser degree as indicated by a larger or smaller membership grade. These membership grades are very often represented by real-number values ranging in the closed interval [0, 1]. The extreme values in these intervals 0 and 1, represent, respectively, the total rejection and confirmation of the membership in a given fuzzy set. As fuzzy logic deals with values between 0 and 1, it is also multi-valued logic. In other words, fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial - truth values between “completely true” and “completely false”. That is, propositions are true to a certain degree and false to a certain degree. In the extreme case, if a proposition happens to be completely true i.e., to a maximum degree, then it cannot be false in any amount i.e., it is false to a minimum degree. As its name suggests, it is the logic underlying modes of reasoning which are approximate rather than exact. The importance of fuzzy logic derives from the fact that most modes of human reasoning and especially common sense reasoning are approximate in nature [07]

Adriana V. Ordonez Oliveros and Aminah Robinson Fayek [02] presented a paper on fuzzy logic model that integrates daily site reporting of activity progress and delays, with a schedule updating and forecasting system for construction project monitoring and control. This model developed assists in the analysis of the effects of delays on a project’s completion date and consists of several components.

Albert P. C. Chan et al. [03] aims to comprehensively review the fuzzy literature that has been published in eight selected top quality journals from 1996 to 2005.Fuzzy membership

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functions and linguistic variables in particular can be used to suit applications to solving problems encountered in the construction industry based on the nature of construction, which are widely regarded as complicated, full of uncertainties, and contingent on changing environments. Moreover, hybrid fuzzy techniques, such as neurofuzzy and fuzzy neural networks, can be more widely applied because they can better tackle some problems in construction that fuzzy set/fuzzy logic alone may not best suit.

Sou-Sen Leu, et al., [14] says activity duration is uncertain due to the variation in the outside environment, such as weather, site congestion, productivity level, etc. A new optimal resource-constrained construction scheduling model is proposed in this paper, in which the effects of both uncertain activity duration and resource constraints are taken into account.

H. M. Al-Humaidi and F. Hadipriono Tan [06] described construction projects often suffer from material unavailability, which results in failure to meet set schedules. They described that Fuzzy logic can be used to describe the relationship between material availability and the likelihood of project delay. This paper applies fuzzy modus ponens deduction techniques to model material availability and related project delay by incorporating Baldwin's rotational fuzzy-set models.

BilalM.Ayyub and Achintya Haldar [04] determined Probabilistic methods that are being used increasingly in construction engineering. They explained when a parameter is expressed in linguistic rather than mathematical terms; classical probability theory fails to incorporate the information. The linguistic variables can be translated into mathematical measures using fuzzy set and system theory.

Abdulaziz A. Bubshait and Michael J. Cunningham [01] studied three delay measurement processes. These procedures were employed to measure delay impact, utilizing computerized critical path method (CPM) analyses, performed on genuine construction schedules. Results indicate that outcomes of delay analyses are not predictable, nor can one method be used universally. However, in given circumstances, one procedure can be more beneficial than another. Guidelines for the utilization of each method have been presented.

Gary R. Smith and Donn E. Hancher [05] developed a conceptual model for evaluating precipitation impact. This method utilizes a Markov process for prediction of rainfall events, combined with an impact evaluation utilizing basic fuzzy-set operations.

Pasit Lorterapong and Osama Moselhi [11] developed a new network scheduling method based on fuzzy sets theory. This method incorporates a number of new techniques that facilitate: (1) the representation of imprecise activity durations; (2) the calculation of scheduling parameters; and (3) the interpretation of the fuzzy results generated. Two network examples are worked. Out to illustrate use of the proposed method, and to compare its capabilities with Monte Carlo Simulation. The results indicate that the proposed method is capable of providing schedules that can appropriately account for the nature as well as the type of uncertainties normally encountered in construction projects.

Michael R. Finke [10] discussed the reasons for the superiority of the window method. The possible results of a window analysis are evaluated and graphically presented.

Saied Kartam [13] presented a written exposition of a generic methodology for analyzing delay claims. This methodology has been developed and successfully used, by the writer, in various projects to resolve delay claims.

Jonathan Jingsheng Shi et al. [09] presented a method for computing activity delays and assessing their contributions to project delay. The method consists of a set of equations, which can be easily coded into a computer program that allows speedy access to project delay information and activity contributions.

J.K.yates, [08] discussed the industrial participation in the development of DAS (delay analysis system) program, its technical parameters, usage, and the program output. A sample case study is also presented that demonstrates how the program is utilized and the type of output it provides.

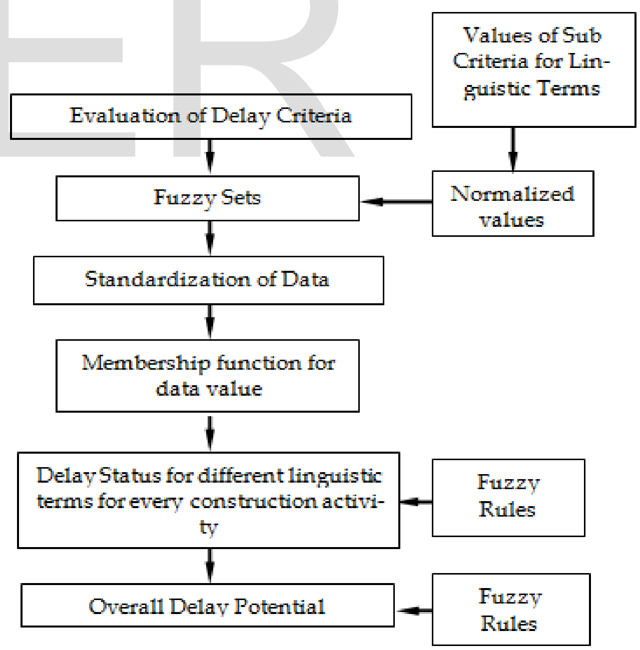
2 METHODOLOGY

Research Approach*:*

In the present study, the Fuzzy Rule Based System is developed to calculate delay status in the construction of building. A flow diagram of fuzzy model is developed in accordance with more understanding about present invention and features.

Figure 1 shows flow diagram of Delay Potential fuzzy model for Delay Status in Construction of Building.

Figure 1: A flow diagram of Delay Potential fuzzy model for



Delay Status in Construction of Building

In this study, the fuzzy model Delay Potential (DP) is oped to determine delay potential at every stage of construction activities and also for overall delay potential status of construction of residential and commercial building. The delay status will help to decide rescheduling status of further activities.

The first step was the identification of experts. Experts were from the field of civil engineering as top level managers, Senior Civil Engineers and Professors.

To develop the Fuzzy rule base system, expert's opinion has been taken for different criteria to arrive at status of the following construction activities for defining delay potential of construction of building:

Excavation delay potential status: Excavation upto hard strata (with carting away of materials) and Dewatering.

Foundation base delay potential status: PCC and waterproofing.

Construction of Footing delay potential status: Formwork, Steel work and Concreting.

Construction of Stub column delay potential status: Formwork, Steel work and Concreting.

Construction of Sub- structure delay potential status: Excavation, Foundation base, Construction of Footing and Construction of Stub-Column.

Construction of Plinth Beam delay potential status: Antitermite, PCC, Formwork, Steel fixing and concreting.

Construction of Grade slab/ PCC delay potential status: Antitermite, Polythene sheet, Formwork, Steel fixing and concreting.

Construction of Plinth work delay potential status: Construction of Plinth Beam and Construction of Grade slab/ PCC.

Construction of Column delay potential status: Formwork, Steel work and Concreting.

Construction of RCC wall delay potential status: Formwork, Steelwork, Concreting.

Construction of Beam & Slab delay potential status: Formwork, Steel work and Concreting.

Construction of Flat slab delay potential status: Formwork, Steel work, Laying of Tendons and Concreting.

Construction of OHWT/ LMR delay potential status: Construction of Column, Construction of bottom slab, Construction of Column & RCC wall and Construction of top slab.

Construction of Parapet wall delay potential status: Formwork, Steel work and Concreting.

Construction of RCC work delay potential status: Construction of Column, Construction of RCC wall, Construction of Beam & Slab, Construction of flat slab, Construction of OHWT/LMR and Construction of Parapet wall**.**

Construction of wall delay potential status: BBM, Plumbing & Electrical conduicting and internal Plaster.

Waterproofing delay potential status: Toilets & Balconies.

External & Internal Plaster delay potential status: Single Coat & Double coat.

Tiling delay potential status: Dado & Flooring.

Painting delay potential status: Internal & External Painting.

Tremix delay potential status: Internal & External Tremix.

Finishing Items delay potential status: Construction of wall, waterproofing, external & Internal Plastering, Tiling, Painting and Tremix.

Plumbing delay potential status: Internal & External Plumbing.

Electrical work delay potential status: Internal & External electrical work.

Heating, Ventilation and Air-conditioning (HVAC) delay potential status: Internal & External HVAC work.

Fire fighting delay potential status: Internal & External fire fighting work.

Mechanical, Electrical and Plumbing (MEP) delay potential status: Plumbing, Electrical work, HVAC and Fire fighting work.

Overall Civil Construction delay potential status: Construction of Sub-Structure, Construction of plinth work, Construction of RCC work, Finishing items and MEP**.**

Perception of experts, about the linguistic variables like Less, Average, Much and Very Much for the above selected sub criteria for getting Overall delay potential of construction of building, was obtained on the basis of their views through a questionnaire. The fuzzy sets like less, average, much and very much were developed for the determination of delay potential.

2.1 Membership Grade

The next step is the determination of membership grade at α-CUT. The first stage is normalization of field data. The field data can be normalized with respect to considerable limits. Then membership grade for respective delay potential at α-CUT can be calculated for every stage of construction activity.

2.2 Fuzzy Rules for Delay Potential of Construction of Building

After obtaining the fuzzy numbers with their corresponding α-CUT the rule base for the system is to be defined. A set of rules is required to be constructed for the delay potential in construction of buildings. Each rule has an antecedent proposition connected together using AND operator, resulting in some consequence. The assertions related to its antecedent part be obtained from the experts, are imprecise or fuzzy. Thus a fuzzy rule based system can be developed for the knowledge representation or reasoning process. Here, the partial matching is allowed and the analyst can estimate the extent to which the assertion satisfies the antecedent part of the rule contrary to the rule based system which examines as to whether the antecedent part is satisfied or not.

A hierarchical structure is developed for delay potential in construction of building resulting out of a set of rules.

Excavation, Foundation base, Construction of Footing and **Construction of Stub column delay potential status** can be judged in the first hierarchical level of knowledge base to arrive at **Construction of Sub- structure delay potential status**.

Construction of Plinth Beam and Construction of Grade slab/ PCC delay potential status can be judged in the second hierarchical level of knowledge base to arrive at **Construction of Plinth work delay potential status.**

Construction of Column, Construction of RCC wall, Construction of Beam & Slab, Construction of flat slab, Construction of OHWT/LMR and Construction of Parapet wall delay potential status can be judged in the third hierarchical level of knowledge base to arrive at **Construction of RCC work delay potential status.**

Construction of wall, waterproofing, External & Internal Plastering, Tiling, Painting and Tremix delay potential status can be judged in the fourth hierarchical level of knowledge base to arrive at **Finishing Items delay potential status**.

Plumbing, Electrical work, HVAC and Fire fighting work delay potential status can be judged in the fifth hierarchical level of knowledge base to arrive at **MEP delay potential sta-**

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tus.

The final level characterizes Construction of Sub-Structure status, Construction of plinth work, Construction of RCC work status, finishing items status and MEP delay potential status to arrive at the Potential of Delay in **Overall Civil Construction as highly tolerable, tolerable, just tolerable and not tolerable.**

The Fuzzy rules were developed for all above construction activities. For example, If Excavation with carting away of material delay status is less and Dewatering delay status is less. Then, Excavation delay potential is less.

Simillarly, we have developed fuzzy rules for all other construction activities.

3 RESULTS AND DISCUSSION

For the determination of membership grade (Fuzzy Number: FN) at α-CUT, first the field data were normalized on the basis of considerable limits. Then membership grade for respective delay potential at α-CUT was calculated.Table 1 shows Fuzzy number of Field Data for Excavation.

Table 1 Fuzzy number of Field Data for Excavation

Scheme	Sub Criteria	Linguistic Terms			
		Less	Average	Much	Very Much
1	Excavation	0	0	1	0
	De-watering	0	0	0.8	0

Similarly, for all the activities the α-CUT were calculated.

The degree of certainty, of linguistic terms, less, average, much and very much for all the activities was calculated on the basis of Min-Max rules. Table 2 shows Fuzzy rules with Linguistic terms values for Excavation.

Table 2: Fuzzy Rules with linguistic terms values

Excavation delay status(FN)	De-watering delay status (FN)	Excavation delay potential status (Min. of 1 and 2)
Less (0)	Less (0)	Less (0)
Less (0)	Average(0)	Less (0)
Less (0)	Much(0.8)	Less (0)
Less (0)	Very Much(0)	Less (0)
Average(0)	Less (0)	Less (0)
Average(0)	Average(0)	Average(0)
Average(0)	Much(0.8)	Average(0)
Average(0)	Very Much(0)	Much(0)
Much(1)	Less (0)	Much(0)
Much(1)	Average(0)	Much(0)
Much(1)	Much(0.8)	Much(0.8)
Much(1)	Very Much(0)	Very Much(0)
Very Much(0)	Less (0)	Very Much(0)
Very Much(0)	Average(0)	Very Much(0)
Very Much(0)	Much(0.8)	Very Much(0)
Very Much(0)	Very Much(0)	Very Much(0)

From **Table2,** maximum value of the degree of certainty for linguistic terms Less, Average, Much, Very Much is 0, 0, 0.8 and 0 respectively.

The maximum value of the degree of certainty of linguistic terms Less, Average, Much, Very Much of Excavation potential for scheme 1 is as shown in **Table 3.**

Table 3 Excavation Delay Potential

Scheme	Excavation Delay Potential			
	Less	Average	Much	Very Much
1	0	0	0.8	0

Similarly, delay potential of different activities of sub-structure were calculated and shown in Table 4 to 6

.

Table 4 Foundation Base Delay Potential

Scheme	Foundation Base Delay Potential			
	Less	Average	Much	Very Much
1	0	0	0.9	0

Table 5 Construction of Footing Delay Potential

Scheme	Footing Delay Potential			
	Less	Average	Much	Very Much
1	0	0	0.8	0

Table 6 Construction of Stub column Delay Potential

Scheme	Stub column Delay Potential			
	Less	Average	Much	Very Much
1	0	0.2	0.6	0

On the basis of delay potential of Excavation, foundation base, footing and stub-column, the sub-structure delay potential was calculated (Table 7).

Table 7 Construction of Sub-Structure Delay Potential

Scheme	Sub-Structure Delay Potential			
	Less	Average	Much	Very Much
1	0	0	0.9	0

Similarly, the delay potential for other activities was calculated and the results are shown in Table 8.The following points were observed from the results (Table 8).

i) Delay status of Substructure shows much delay potential with degree of certainty 0.6, 0.6 and 0.8 respectively for scheme1, 2 & 3.

ii) Delay status of Plinth beam shows much delay potential with degree of certainty 0.9, 0.6 & 0.8 respectively for scheme1, 2 & 3.

iii) Delay status of RCC work shows average delay potential with degree of certainty 0.7, 0.9&0.7 respectively for scheme1, 2 & 3.

iv) Delay status of finishing items shows much delay potential with degree of certainty 0.8, 0.6 &0.8 respectively for scheme1, 2 & 3.

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v) Delay status of MEP work shows much delay potential with degree of certainty 0.8, 0.8 &0.8 respectively for scheme1, 2 & 3.

vi) Delay status of Overall Civil Construction work shows much delay potential with degree of certainty 0.6, 0.6 &0.7 respectively for scheme1, 2 & 3.

Table 8 Delay Potential Status for Scheme 1,2 and 3

	Delay potential			
SCHEME	LESS	AVERAGE	MUCH	VERY MUCH
SUB-STRUCTUTE				
1	0	0	0.6	0
2	0	0	0.6	0
3	0	0	0.8	0
PLINTH BEAM				
1	0	0	0.9	0
2	0	0	0.6	0
3	0	0	0.8	0
RCC WORK				
1	0	0.7	0	0
2	0	0.9	0	0
3	0	0.7	0	0
FINISHING ITEMS				
1	0	0	0.8	0
2	0	0	0.6	0
3	0	0	0.8	0
MECHANICAL,ELECTRICAL AND PLUMBING (MEP)				
1	0	0	0.8	0
2	0	0	0.8	0
3	0	0	0.8	0
OVERALL CIVIL CONSTRUCTION				
1	0	0	0.6	0
2	0	0	0.6	0
3	0	0	0.7	0

4 CONCLUSIONS

From the analysis of the results of the present study the following conclusions have been drawn:

i) Application of fuzzy approach for delay status in construction of building is found to be more appropriate compared to the current crisp approach.

ii) From the Fuzzy Rule–Based System (FRBS) results, it is possible to classify delay potential.

iii) It is also possible to classify Overall delay status for construction of building as Highly Tolerable, Tolerable, Just Tolerable and Non Tolerable.

FURTHER SCOPE OF THE RESEARCH WORK:

This study highlights the delay potential status of different construction activities of the construction of the building and this study can be linked with the scheduling of different construction activities of the building and on the basis of delay potential, scheduling can be changed as per the requirement.

For example, if delay status of preceding activity is less, then there is no need of changing the schedule of further activities. Similarly, if delay potential of preceding activity shows much or very much delay potential then there is a need of change of schedule for further activities.

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