International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 03 | Mar 2020 www.irjet.net p-ISSN: 2395-0072

FUZZY LOGIC APPROACH IN CONSTRUCTION DELAY ANALYSIS

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Abstract – *Delays are the biggest problem faced by the construction industry in India. Completing projects in time is the vital part of any construction project, but the construction process is subjected to many variables and unpredictable factors which make the time overrun. These factors result from many sources such as availability of resources, external factors, performance of parties, work specifications etc. When there is a delay in project not only it creates negative impact throughout the project but it also leads to loss of productivity, increased cost and contract termination. Delays in construction projects are inevitable and it may end in disputes among different construction parties. Delays in construction project needs to be identified and eliminated.*

This paper describes the application of fuzzy logic toolbox of Matlab Software for identifying the scheduled delays in construction projects. A case study of housing project at Kochi, Kerala is also included. Fuzzy logic provides a convenient deduction of result with vague input. The scheduled delay was obtained to be 32.9 percent from the actual schedule.

Keywords: **Delay Analysis; Fuzzy Logic; MATLAB; Construction project; Work specifications.**

1. INTRODUCTION

Planning and control of resources within the framework of a project is the main target of construction management. Various project management procedures guide on how the available resources can be best used during a construction work. Delay in schedule is widespread in most of the projects from around the world. Some of them may happen in the preconstruction phase, and some other in the construction phase. These delays create huge negative impacts on overall project performance. Schedule delay analysis is a method that is adopted in order to identify possible delay causing factors and measure the net impacts of these delays in a project. In schedule analysis, certain specific tools such as bar chart schedules and critical path method (CPM) schedules are used. Great amount of research works have been done in this field and presented common schedule analysis techniques. Some of them also have proposed new methodologies to the construction industry specifically. However, no single method is applicable in all kind of projects since each of these delay analysis technique has its own advantages and disadvantages. Main objective of this study is to propose a decision support tool for quantifying the probability of scheduled delay in construction projects.

2. LITERATURE REVIEW

Onur B. Tokdemir et *al* (2019) proposed a delay risk assessment method for project scheduled by Line of Balance (LOB). In this method the schedule is prepared considering the target rate of delivery. The risk scenarios are defined considering the sources of uncertainty and vulnerability of activities. Then probability distributions are determined for the required number of labor-hours for each activity. For quantifying the delay risk of the project, Monte Carlo simulation method is used. **Issaka Ndekugri et *al* (2016)** did an empirical study into the current practices of delay analysis methodologies used in the United Kingdom. The work was part of a wider project that aimed at developing a framework for improving delay claims analysis. The work was based on a questionnaire survey of key informants in the construction field. The research found out that delay claims require inputs from various personnel involved in a work such as, commercial managers, schedulers, site managers, external claim consultants and estimators. However, commercial managers have greatest involvement in it. The study also found that claims analyzed using the methods; as-built versus as-planned and the impacted as-planned, are both successful. **Nuhu Braimah (2015)** studied the various common construction delay analysis techniques (DATs) based on a case study, i.e.; a review of the key relevant issues often not addressed by the various delay analysis techniques, and the necessary improvements needed in them. From the study it was confirmed that different analysis techniques yield different results for the same delay claims scenario, and this was mainly due to their unique application procedures.

3. FUZZY ASSESSMENT MODEL TO ESTIMATE THE PROBABILITY OF SCHEDULE DELAY

3.1 INTERVIEW WITH EXPERTS AND CREATION OF FUZZY RULES

An interview with experts in construction field was conducted to obtain the fuzzy weight or rule weight for the rules in fuzzy logic toolbox. The interview was conducted with various personals such as Engineers, Quality controller, Planners, Supervisors, Builders etc. They were asked to give values to different delay causing factors ranging from 0 to 100, 0 being least causable and 100 highly causable. These results obtained were converted into percentage values

which are known as fuzzy weights or rule weights. The obtained results were summarized into a table as follows.

Table 6.1 Responses obtained from interview with experts.

Factors	Causes	Value
Labour Related Factors	a) Labour strike	0.276
	b) Conflicts among labour	0.206
	c) Inexperienced Labour	0.35
	d) Absent labors	0.311
	e) Labour shortage	0.35
	f) Less motivation for labour	0.255
	g) Poor communication between workers and supervisor	0.288
Project Related Factors	a) Short original contract duration	0.252
	b) Delay penalties	0.218
	c) Project complexity	0.355
	d) Disputes among project parties	0.334
Consultant related factors	a) Inexperienced consultants	0.261
	b) Inspecting and testing delays	0.313
	c) Conflicts between consultants and design engineer	0.266
	d) Poor communication and coordination with other parties	0.435
	e) Delay in approval of design documents	0.408
Contractor related factors	a) Poor site management and supervision	0.452
	b) Poor planning and scheduling of project	0.320
	c) Frequent change of subcontractors	0.257
	d) Poor communication and coordination with other parties	0.270
	e) Rework due to errors	0.326
	f) Inexperienced contractors	0.354
	g) Unreliable Subcontractors	0.438
External Related factors	a) Inclement weather conditions	0.282
	b) Variation in price	0.420
	c) Global financial crisis	0.397
	d) Changes in government regulations and laws	0.268
	e) Unexpected surface and subsurface conditions	0.355
	f) Delays in providing services from utilities	0.331
	g) Delay in transportation	0.272
	h) Accidents during construction	0.484
	i) Natural disaster	0.232

The proposed fuzzy assessment model was tested in a Project. An interview was developed to assess the perceptions of a leading Construction Company to test the proposed fuzzy assessment model considering the latest project conducted by the company. This company has a significant experience in construction projects as mass housing projects. Following tasks were performed by the company:

1. To fill in the evaluation form of schedule delay probability by assigning input values (schedule delay factors) from 0 (probability is very low: VL) to 100 (probability is very high: VH).
2. To estimate the probability of schedule delay of the project.

Company has formed commission, whose members were composed of five (5) experienced civil engineers including site managers, site engineers, technical office engineers, technical consultants. It was assumed that:

1. The commission members had significant information about schedule delay factors in construction projects.
2. The commission members allocated necessary time to perform the required tasks.
3. The commission members were experts of construction projects.

Based on their professional judgment, the commission members checked and filled in the form including eighty three well organized schedule delay factors. The consultant, contractor, design, equipment, external, labour, materials, owner and project related delay factor groups were considered. The filled the questionnaire form is as shown in the table 6.2.

Table 2 Questionnaire filled by commission members

Factors	Causes	Values
Labour Related Factors	a) Labour strike	21.25
	b) Conflicts among labour	1125
	c) Inexperienced labour	18.75
	d) Absent labors	32.5
	e) Labour shortage	37.5
	f) Less motivation for labour	18.75
	g) Poor communication between workers and supervisor	10
Project Related Factors	a) Short original contract duration	20
	b) Delay penalties	5.75
	c) Project complexity	28.75
	d) Disputes among project parties	33.75
Consultant	a) Inexperienced consultants	175
	b) Inspecting and testing delays	28.75
	c) Conflicts between consultants and design engineer	33.75

related factors	d) Poor communication and coordination with other parties	25
	e) Delay in approval of design documents	31.25
Contractor related factors	a) Poor site management and supervision	27.5
	b) Poor planning and scheduling of project	31.667
	c) Frequent change of subcontractors	5
	d) Poor communication and coordination with other parties	17.5
	e) Rework due to errors	27.5
	f) Inexperienced contractors	23.75
	g) Unreliable Subcontractors	20
External Related factors	a) Inclement weather conditions	47.5
	b) Variation in price	26.66
	c) Global financial crisis	20
	d) Changes in government regulations and laws	47.5
	e) Unexpected surface and subsurface conditions	32.5
	f) Delays in providing services from utilities	18.75
	g) Delay in transportation	12.5
	h) Accidents during construction	22
	i) Natural disaster	55

Since fuzzy model calculations were so much time consuming, Fuzzy Logic Toolbox of the MATLAB Program Software was utilized to save time. The interface of fuzzy toolbox of MATLAB is shown in figure 1.

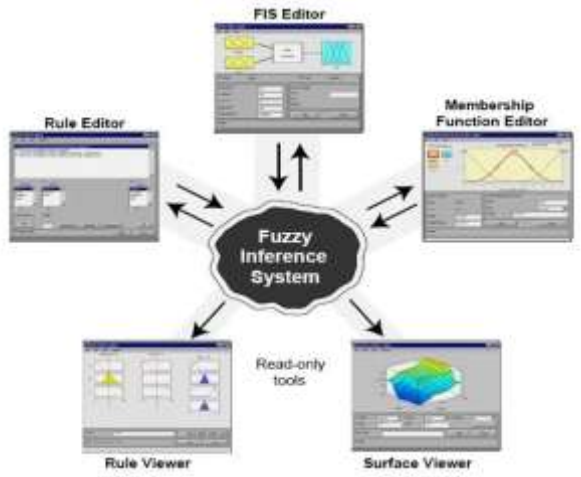

Fig.1 Graphical user interface tools in the fuzzy logic toolbox

Delay probability outputs of this case study were obtained using Fuzzy Logic Toolbox of the MATLAB Software and are shown in the Table 3.

Table 3 Probability outputs of the case study

Group of factor	**Probability output**
Labour Related Factors	21.42
Project Related Factor	22.68
Consultant Related Factor	29
Contractor Related Factor	21.975
External Related Factor	34.67
Owner Related Factor	12.17
Material Related Factor	13.30
Design Related Factor	32.96
Equipment Related Factor	41.245
SCHEDULED DELAY	**32.9**

CONCLUSIONS

In construction projects the management of time is highly important. Therefore, predicting the likelihood of schedule delay play a key role towards a project's success. This research aimed to propose a decision support tool for contractors to quantify the probability of schedule delay before the bidding stage. For this purpose, fuzzy logic from fuzzy logic toolbox of Matlab software is used.

The ***main*** objective was to address the most contributing factors and groups to cause schedule delays (i.e., to discuss the probability of the factors and groups that need attention).This objective was achieved through discussion of the case study results. The highest probability output for the groups was found as "Equipment related delay factors" by ***41.24*** showing a range of ***medium causable*** probability level for the case study project. For each groups, the most and least contributing factors to cause schedule delay were presented. Future studies can be designed by utilizing different model parameters such as: different number and group of schedule delay factors, linguistic variables and membership functions, fuzzy rules, weights of rules, aggregation and de-fuzzification methods. This thesis opens up a realm of possibilities where future researchers can produce more powerful, user friendly softwares that can analyze all the possible schedule delay factors, producing fast and reliable results.

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