Application of Fuzzy Logic in Delay Analysis in Construction

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Abstract

This paper describes an application of fuzzy logic in analysis of delays in construction projects using Fuzzy toolbox of MATLAB Program Software. Delays in construction projects are inevitable and may result in claims and disputes among different construction parties. Delays in construction projects can be due to a number of causes, which need to be classified and identified. For the success of a construction project, estimation of likelihood of delay resulting from different factors is a must. Fuzzy logic provides a simple way to arrive at a definite conclusion based upon vague, imprecise or missing input information. Fuzzy logic is a form of many-valued logic; it deals with reasoning that is approximate rather than fixed and exact.

Keywords- Construction projects; Fuzzy logic; Delays; Delay cause; MATLAB; Fuzzy Logic Toolbox

I. INTRODUCTION

The major problem occurring in any construction project is the delays occurring during the project, which cause the project to take longer time than planned. A construction project is commonly acknowledged as successful, when it is completed on time, within budget, in accordance with the specifications. A successful project means that the project has accomplished its technical performance, maintained its schedule, and remained within budgetary costs. Projects may differ in size, duration, objectives, uncertainty, complexity, pace, and some other dimensions. It does not matter how different or unique a project is; there is no doubt that every project contains some degree of uncertainty. It is required to be aware of these uncertainties and to develop necessary responses to get the desired level of the project success. Schedule delays are common in various construction projects and cause considerable losses to project parties. It is widely accepted that construction project schedule plays a key role in project management due to its influence on project success. The common results of schedule delays are: Late completion of project, increased cost, disruption of work, loss of productivity, third party claims, disputes and abandonment or termination of contracts. Therefore schedule delays in construction projects give rise to dissatisfaction to all the parties involved.

The aim of this paper is to propose a schedule delay assessment model using Fuzzy Logic Toolbox of MATLAB Program Software. An interview was conducted in which construction project team members were asked questions about the delays taking place in the project. The delay causes were grouped and categorized in different factors. The interview results were used in the assessment model and probability of schedule delay was evaluated. According to the results obtained from the model, the areas of most concern were discussed. The results obtained were accurate and acceptable.

II. CONSTRUCTION PROJECT DELAYS

Construction management focuses on best practices of managing resources such as materials, equipment, and labor. The challenge that the managers face in the construction industry is how to balance time, cost, and quality. Time delays are very clear measurements of project success as a simple comparison between actual and planned time could provide managers with project status.

Schedule delays in a construction project can be defined as the late completion of works as compared to the planned schedule or contract schedule. It could be possibly be interpreted as a loss of time. “Time” refers to the duration for completing the construction project. Time in a construction project is the construction period or in contract administration is the contract period. When the project period is delayed, it means the project cannot be completed within original schedule.

Usually there is no way of predicting how likely it is that a given project will meet its milestones and its predicted completion date. Uncertainty is an inherent aspect of project management. In the planning phase, an estimated project schedule is modeled and a critical path determined where all activities are future events. Uncertainty arises from different aspects such as task duration, resources encountered in execution and the dependency of tasks on the completion of other tasks. But in the execution phase, other non-controllable factors such as weather, resource limitations, and managerial actions can cause

alterations in the planned schedule and result in delays, especially if the task is part of the critical path. Delay in critical activities or near critical activities result in project delay. Some amount of delay on non-critical-path tasks can be tolerated, but any slippage on critical-path tasks directly results in delay of the project as a whole.

III.DELAY CLASSIFICATION

A Several factors can contribute to delays of a project. Analyzing the causes of delays is an essential task for resolving any conflicts or claims. Although many researchers emphasize the high cost and the associated risk related to litigating delay claims, few emphasize the responsibility for project delays. To avoid delays that might result in claims and disputes, the link between the actual tasks undertaken, the time required to complete them, and the ultimate cost estimate of the resources involved all need to be examined.

According to an earlier work by the author related to project schedule and project delay classification Al-Humaidi (2002) , classification of delay causes can follow different logic and can be classified according to their origin, timing, and compensability.

Classification of delays according to origin is when the delay is analyzed based on the party responsible for the delay. The party responsible for the delay can be the owner, the designer, or the contractor. The second classification of delay is based on compensability of delay. Compensable delays are classified further into excusable delays or non-excusable delays. The third classification of delay is based on timing of delay. If two or more delays occur simultaneously, then a concurrent delay takes place. If a single delay takes place at a time, then a non-concurrent delay occurs.

Delays can be classified as:

1. ORIGIN
   - Those over which neither party has control
   - Those over which the owner has control
   - Those over which the designer has control
   - Those over which the contractor has control

2. COMPENSABILITY
   - Excusable delays
   - Non-excusable delays
3. TIMING
   - Concurrent delays
   - Non-concurrent

IV.DELAY FACTORS

The project team members from different construction projects were interviewed about the delays occurring in their projects. They were asked to fill in the questionnaire and give values to the delay causes ranging from 0 to 100. These values were converted into percentage values and used as fuzzy weights to be used in the Fuzzy Logic Toolbox of Matlab as rule weights to be given to the delay causes. They were also asked to give scores to the factors as ‘Least causable’; ‘Medium Causable’ and ‘Highly Causable’. The delay factors are shown below in the form of table:

Factors	Causes	Values
Labor Related Factors	a)Labor strike	0.34
	b)Conflicts among labor	0.37
	c)Inexperienced Labor	0.70
	d)Labor shortage	0.79
	e)Absent labors	0.49
Project Related Factors	a)Short original contract duration	0.69
	b)Delay penalties	0.54
	c)Project complexity	0.36
	d)Disputes among project parties	0.60

Consultant Related Factors	a)Improper project management assistance	0.56
	b)Inexperienced consultants	0.72
	c)Inspecting and testing delays	0.80
	d)Conflicts between consultants and design engineer	0.47
	e)Poor communication and coordination with other parties	0.74
	f)Delay in approval of design documents	0.61
Contractor Related Factors	a)Poor site management and supervision	0.79
	b)Poor planning and scheduling of project	0.83
	c)Shuffling of subcontractors	0.34
	d)Poor communication and coordination with other parties	0.74
	e)Rework due to errors	0.50
	f)Inexperienced contractors	0.81
External Related Factors	a)Inclement weather conditions	0.81
	b)Variations in price	0.61
	c)Global financial crisis	0.87
	d)Changes in government regulations and laws	0.42
	e)Unexpected surface and subsurface conditions	0.79

	f)Delay in providing services from utilities	0.52
	g)Delay in transportation	0.35
Owner Related Factors	a)Slow decision making	0.76
	b)Delay in approving design documents	0.46
	c)Late site delivery	0.71
	d)Change in orders by owners	0.89
	e)Improper study of designs	0.55
	f)Progress payments delays	0.62
	g)Poor communication and coordination with other parties	0.81
	h)Inexperienced owners	0.72
Material Related Factors	a)Material manufacturing delay	0.35
	b)Damage of material	0.42
	c)Material shortage	0.77
	d)Delay in delivery	0.73
	e)Rising prices of materials	0.43
Design Related Factors	a)Inadequate experience of design team	0.64
	b)Complexity in project design	0.38
	c)Errors made by designers	0.62
	d)Delays in making design documents	0.65
	e)Unclear details in drawing	0.56
	f)Insufficient data collection	0.50
Equipment Related Factors	a)Damaged equipment	0.46
	b)Equipment shortage	0.45
	c)Breakdown of equipment	0.54
	d)Low efficiency	0.71
	e)Problem in allocation	0.65

V. CASE STUDY

A real case study was undertaken and an interview was conducted in a housing project in Gwalior, to assess the causes of scheduled delays in the project, thereby causing delay in the planned duration of the project. The project manager was requested to form a group of decision makers to perform the following tasks:

1. To check the delay factors cited in the questionnaire.
2. To cite additional factors if necessary.
3. To assign values to the factors ranging from 1 to 100 as probability of schedule delay (1 being probability very low and 100 being probability very high).Following results were obtained after the interview.

Factors	**Causes**	**Probability**
Labor Related Factors	a)Labor strike	20
	b)Conflicts among labor	60
	c)Inexperienced Labor	65
	d)Labor shortage	60
	e)Absent labors	30
	a)Short original contract	65

	duration	
Project Related Factors	b)Delay penalties	20
	c)Project complexity	50
	d)Disputes among project parties	40
Consultant Related Factors	a)Improper project management assistance	50
	b)Inexperienced consultants	60
	c)Inspecting and testing delays	30
	d)Conflicts between consultants and design engineer	75
	e)Poor communication and coordination with other parties	40
	f)Delay in approval of design documents	60
Contractor Related Factors	a)Poor site management and supervision	60
	b)Poor planning and scheduling of project	55
	c)Shuffling of subcontractors	35
	d)Poor communication and coordination with other parties	60
	e)Rework due to errors	65
	f)Inexperienced contractors	25
External Related Factors	a)Inclement weather conditions	25
	b)Variations in price	70
	c)Global financial crisis	95
	d)Changes in government regulations and laws	85
	e)Unexpected surface and subsurface conditions	20

	f)Delay in providing services from utilities	65
	g)Delay in transportation	35
Owner Related Factors	a)Slow decision making	55
	b)Delay in approving design documents	55
	c)Late site delivery	40
	d)Change in orders by owners	85
	e)Improper study of designs	45
	f)Progress payments delays	60
	g)Poor communication and coordination with other parties	50
	h)Inexperienced owners	20
	a)Material manufacturing	30

	delay	
Material Related Factors	b)Damage of material	30
	c)Material shortage	60
	d)Delay in delivery	85
	e)Rising prices of materials	65
Design Related Factors	a)Inadequate experience of design team	60
	b)Complexity in project design	75
	c)Errors made by designers	60
	d)Delays in making design documents	70
	e)Unclear details in drawing	50
	f)Insufficient data collection	40
Equipment Related Factors	a)Damaged equipment	50
	b)Equipment shortage	20
	c)Breakdown of equipment	30
	d)Low efficiency	40
	e)Problem in allocation	50

The project members also estimated a range from 40-60 showing a medium probablity schedule delay of the project.

The results obtained from Table1 in the form of 'Rule viewer' of Matlab Program Software, were then used to obtain graphs for probability schedule delay factors obtained from the interview, using Matlab Program Software. Fuzzy Logic Toolbox of Matlab Program Software did the calculations easily and saved time, thereby giving suitable results. Following schedule delay probability outputs of the case study was obtained using Fuzzy Logic Toolbox of Matlab Program Software:

Group of Factors	Probability output
Labor Related Factors	44.8
Project Related Factors	41
Consultant Related Factors	49.1
Contractor Related Factors	40.1
External Related Factors	42.2
Owner Related Factors	49.6
Material Related Factors	57.5
Design Related Factors	61.9
Equipment Related Factors	36.8
Schedule Delay	47.7

VI. DISCUSSION OF RESULTS

1. **Labor Related Factors**

Probability output was calculated as 44.8 showing low-medium probability delay level. The most contributing factors for this delay are:

Very high probability	Very low probability
Inexperienced labor (65)	Labor strike (20)

2. **Project Related Factors**

Probability output was calculated as 41 showing low-medium probability delay level. The most contributing factors for this delay are:

Very high probability	Very low probability
Short original contractor duration (65)	Delay penalties (20)

3. **Consultant Related Factors**

Probability output was calculated as 49.1 showing low-medium probability delay level. The most contributing factors for this delay are:

Very high probability	**Very low probability**
Conflicts between consultant and design engineer(75)	Inspecting and testing delays(30)

4. Contractor Related Factors

Probability output was calculated as 40.1 showing very low-medium probability delay level. The most contributing factors for this delay are:

Very high probability	**Very low probability**
Rework due to error(65)	Inexperienced contractors(25)

5. External Related Factors

Probability output was calculated as 42.2 showing very low-medium probability delay level. The most contributing factors for this delay are:

Very high probability	**Very low probability**
Global financial crisis(95)	Inclement weather condition(25)

6. Owner Related Factors

Probability output was calculated as 49.6 showing very low-medium probability delay level. The most contributing factors for this delay are:

Very high probability	**Very low probability**
Change in orders by owner(85)	Inexperienced owner(20)

7. Material Related Factors

Probability output was calculated as 57.5 showing high-medium probability delay level. The most contributing factors for this delay are:

Very high probability	**Very low probability**
Delay in delivery(85)	Material manufacturing; and damage of materials(30)

8. Design Related Factors

Probability output was calculated as 61.9 showing very high-medium probability delay level. The most contributing factors for this delay are:

Very high probability	**Very low probability**
Complexity in project design(75)	Insufficient data collection(40)

9. Equipment Related Factors

Probability output was calculated as 36.8 showing very low-medium probability delay level. The most contributing factors for this delay are:

Very high probability	**Very low probability**
Damaged equipment, and problem in allocation(50)	Equipment shortage(20)

Schedule Delay

Schedule delay probability output was calculated as 47.7, showing a range of medium-low probability level for this project.

VII. REFRENCES

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