Delay Analysis for Slum Rehabilitation Construction Project

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Abstract : Delays are the main reason behind the project schedule overrun these days. The construction industry that is both the contractor and the client have to pay for delays in one or the other means. These delays can be effectively avoided if predictive approach is used from the beginning of the construction project. Indian government is providing support for construction investment, so the completion of project as planned schedule and budget is necessary. Thus, it is prime importance to tackle possible delay factors at the earliest stage to minimize collateral damage, to overcome time overrun during construction and its effects on budget. There are various delay analysis methods available in the construction management, which are considered for assessing the impact of project delays due to various factors. This study proposes one of the mathematical delay analysis methods to identify delays in each activity and focuses on classifying major causes of delays occurred in different phases of the project. This will also help in finding delay factors and responsible parties for delay in the project.

IndexTerms **- Causes of delays, delay analysis, delay factors, effects of delays, responsible parties, time overrun**

I. INTRODUCTION

In the construction sector, the term "delay" means the incident in which some part of the project has been extended beyond what was originally planned due to some unexpected circumstances. It will affect the performance of a particular activity of project, with or without affecting the project completion. These delays not only increase the time period to perform the work but may also increase the cost for many of the parties involved.

Delay may be caused by the one or more of the following parties:

- Owner and his team
- Contractor and his team
- Nature (i.e.; Acts of God)
- Society through some changes in political and economic systems.

Delay in construction could be defined as a time overrun beyond completion date of stated project timeline which can affect the owner and the contractor also especially in terms of budget. The delay in the project has a negative impact on the project's success in terms of time, cost and quality.

There are four basic ways to categorize the type of delays:

- Critical and noncritical
- Excusable and non-excusable
- Compensable and non-compensable
- Concurrent and non-concurrent

The entire construction phase is a critical phase of any project where many unexpected factors could occur. Failure to identify the delay factors in the construction project will result in the construction delays, time overrun and cost overruns. The implementation of the project in time is an indicator of efficiency, but the construction process is subjected to many variables and unpredictable factors, which come from many sources. These sources include the parties' performance, resource availability, environmental conditions, the participation of other parties and contractual feedback. However, it is rare for a project to be completed within the specified time period. So, the identification of delay factors in every phase of project is necessary.

Objectives of the study

- To identify major causes and sources of delay in the slum rehabilitation construction project.
- To classify factors for delay in various phases of the construction project.
- To apply mathematical method to calculate delays occurred in each activity.
- To identify responsible parties for delay in the project.

II. LITERATURE REVIEW

M. Z. Ramli at al. (2018) investigated the delay factor caused project delay in construction projects of rural areas in Malaysia. Authors used questionnaire survey to identify caused of delays and determined the top factors by using Relative Importance Index (RII). Meena V. (2015) studied on time delay analysis for construction project delay analysis. Questionnaire survey was used to find out the causes of delays in construction projects and effect of the delays on overall project. And also found the major causes of delay by ranking factors i.e.; shortage of labour, financial difficulties, improper planning, owner interference and insufficient labour

productivity. Nuhu Braimah (2013) suggested various delay analysis techniques for owners and contractors to investigate events or activities causing delay in project from detailed schedule analysis. And further explained various delay analysis methods that are used for finding delays in project. From the study of Jyh-Bin Yang (2011), it was examined that the computerized ICBF program rapidly and systematically analyses schedule delay, classifies delay liability and obtains analysis results. Author attempted in another study to propose six suggestions on developing an ideal delay analysis method. Jonathan Jingsheng Shi (2001) studied construction delay computation method and the results calculated from proposed method include various variations of activity scheduled and their contributions to the overall project. In the research work of Pablo Gonzalez (2013), the suggestion was given that the methodology of delay analysis can provide information for project managers to make better decisions about the delay causes and assisted in focusing management's actions toward mitigating delay impacts on a weekly basis.

III. METHODOLOGY

There are many existing methods for analysis of delays in project activities or project schedule, however different delay analysis methods tend to provide different results for resources available for the analysis and accessibility of project documentation.

The methodology for calculating schedule delay is based on the following steps:

- Collection of budgeted and actual schedule of the project activities.
- Identification of delay events associated with the project and factors causes delay in the project.
- Studying details of each activity with causes of delays and affected days due to delays.

This study proposed a delay analysis method which is explained by (Jonathan Jingsheng Shi, 2001) for computing delays and assessing their contribution to project delay. The proposed approach, known as the Shi's method, is elaborated below.

The proposed method consists of a set of equations which can be easily coded into a computer program. It contrasts as-planned and as-built schedules. The magnitude of the differences can be evaluated by calculating the variations between as-planned and as-built schedules.

VS = actual start time - planned start time
VF = actual finish time - planned finish time
VD = actual duration - planned duration
VF = VS + VD

Where, VS and VF measure the variation in the start and finish times, respectively; and VD denotes the variation in the activity duration comparing the as-built with the as-planned schedules.

Could start time = max {actual finish times of preceding activities}
VSP = could start time - planned start time
VSS = actual start time - could start time

Where, VSP is named to measure the variation in the start time caused by the preceding activities and VSS is named to measure variation in the start time due to causes associated with the activity itself.

VS = VSP + VSS
VF = VSP + VSS + VD
VA = VSS + VD

In the delayed activity, VA contributes the extra time needed to complete the activity.

To quantitatively evaluate the effect of activity variation on project delay, the following two factors are defined:

1. PDAC - Measuring the project delay due to accumulated activity variations contributed by activity itself and all its preceding activities; and
2. PDA - Measuring the project delay contributed only by the activity itself.

The PDAC and PDA values in this method provide the baseline information for delay analysis.

IV. CASE STUDY SELECTION

To achieve the objects and perform the delay analysis methods, the residential project is selected. Case study selected is a Slum Rehabilitation Project in Pune.

Details of the project

It consists construction of three towers -Tower C, D and E with Aluminium Shuttering and development works like underground (UG) tank, sewage treatment plant (STP), compound wall. Total area of project is 3,04,000 sqft and estimated total cost for RCC work is Rs. 21.79 crores. Estimated duration of contract is 19 months.

V. DATA COLLECTION

To identify factors and causes of delays, documents needed are as-planned schedule and as-built schedule. The data was collected from various sources. Data analysis will help to identify and categorize causes of delays in the pre-planning phase and construction phase.

A. Project schedules

- The schedule made as per actual progress of work i.e.; "As-built schedule".
- The schedule they have planned before starting of construction work i.e.; "As-planned schedule".

B. Hindrance register
- Hindrance register is a vital document. All the hindrances, delays with date of occurrence and removal are to be noted in the Hindrance register.
- Record of hindrance will help to take decisions while granting of Extension of Time (EOT) and remove hindrance by the site executive.

C. Factors for delay in the project were summarized by,
- Discussing with executive engineer, planning engineer, project head about starting phase of project.
- Observing activities, delays occurred on site.
- Reviewing past records of delays listed in hindrance register.

VI. DATA ANALYSIS

The collected data was analyzed and used for finding delay causes of the project. Major factors affecting delays in different phases of the project are found as below,

1. Pre-planning phase:
   - Slum transformation
   - Material shortage
2. Construction phase:
   - Labour payment
   - Heavy rainfall
   - Public strike
   - Shortage of labours
   - Drawings not received on time
   - Machine breakdown
   - Revision of drawings
   - Additional RCC work

The delay factors are computed in terms of days and represented in the pie-chart (shown in the Fig.1). The chart shows the contribution of major delay factors affecting project schedule.

Finding the responsible parties for delay, hinderance register is referred. Differentiating responsibilities of contractor and owner in days from the register,

In construction of Tower C and E,
Client's responsibility – 103 days
Contractors responsibility – 206 days
Natural calamities and other - 6 days

In construction of Tower D,
Client's responsibility - 167 days
Contractors responsibility - 23 days
Natural calamities and other – 5 days

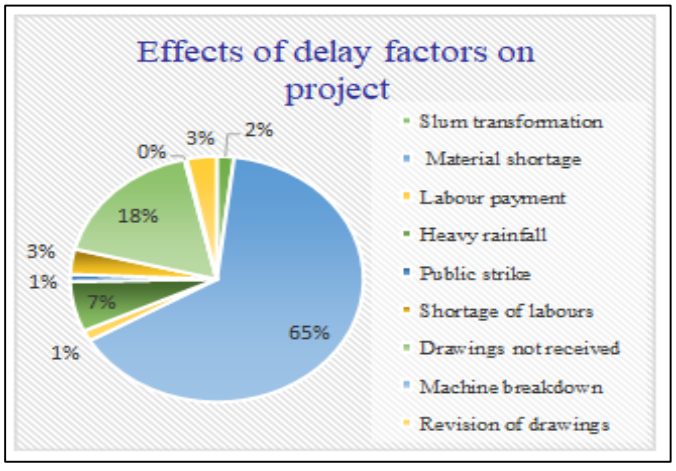

Figure 1. Effects of delays factors in project

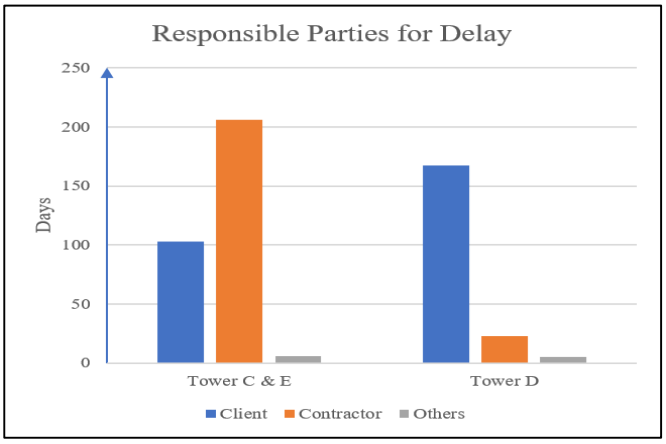

Figure 2. Chart showing the responsible parties

Delay calculation of particular activity is calculated by Shi's method for delay computation. This method requires as-planned and as-built schedule for calculation. Example of construction of Tower C is considered in this paper. The planned and actual dates are shown in the table 1.

The delay computation method of Shi's consists series of different equations and observations from the project schedules. In this study, schedules in MS Project are used for reference and the calculation is done in Microsoft Excel. The method is modified by linking the terms and by putting equations for every possible term in the excel sheet. Variations between the project schedules and contribution to project delay for each activity are calculated. The values of the same are given in the table 2.

Table 1. Schedule of construction of Tower C

Slab Casting	Planned dates		Actual dates	
	Start	Finish	Start	Finish
1st Slab	10-Oct-17	15-Nov-17	11-Nov-17	04-Dec-17
2nd Slab	15-Nov-17	30-Dec-17	17-Apr-18	27-Apr-18
3rd Slab	03-Jan-18	18-Jan-18	05-May-18	17-May-18
4th Slab	20-Jan-18	30-Jan-18	15-May-18	01-Jun-18
5th Slab	03-Feb-18	13-Feb-18	30-May-18	13-Jun-18
6th Slab	16-Feb-18	26-Feb-18	09-Jun-18	23-Jun-18
7th Slab	27-Feb-18	09-Mar-18	18-Jun-18	30-Jun-18
8th Slab	12-Mar-18	22-Mar-18	29-Jun-18	15-Jul-18
9th Slab	26-Mar-18	05-Apr-18	07-Jul-18	24-Jul-18
10th Slab	07-Apr-18	17-Apr-18	18-Jul-18	31-Jul-18
11th Slab	19-Apr-18	29-Apr-18	26-Jul-18	08-Aug-18
12th Slab	01-May-18	11-May-18	04-Aug-18	17-Aug-18
13th Slab	13-May-18	23-May-18	11-Aug-18	27-Aug-18
14th Slab	26-May-18	05-Jun-18	23-Aug-18	04-Sep-18
15th Slab	07-May-18	17-Jun-18	01-Sep-18	12-Sep-18
16th Slab	19-Jun-18	29-Jun-18	11-Sep-18	22-Sep-18

Table 2. Summary results of delay computation for Tower C

Activity (1)	Variations between As-planned and As-built schedule			Variation due to various reasons			Contribution to project delay	
	VS (2)	VF (3)	VD (4)	VSP (5)	VSS (6)	VA (7)	PDAC (8)	PDA (9)
1st Slab	32	19	-13	0	0	-13	20	-13
2nd Slab	153	118	-35	20	133	98	20	20
3rd Slab	122	119	-3	115	7	4	75	4
4th Slab	115	122	7	118	-3	4	75	4
5th Slab	116	120	4	119	-3	1	75	1
6th Slab	113	117	4	118	-5	-1	75	-1
7th Slab	111	113	2	117	-6	-4	75	-4
8th Slab	109	115	6	111	-2	4	75	4
9th Slab	103	110	7	112	-9	-2	75	-2
10th Slab	102	105	3	109	-7	-4	75	-4
11th Slab	98	101	3	104	-6	-3	75	-3
12th Slab	95	98	3	100	-5	-2	75	-2
13th Slab	90	96	6	97	-7	-1	75	-1
14th Slab	89	91	2	94	-5	-3	75	-3
15th Slab	117	87	-30	121	-4	-34	75	-34
16th Slab	84	85	1	86	-2	-1	85	-1

VII. RESULTS AND DISCUSSION

The result shows the delays contributed by the activity itself i.e. PDA, and the delays contributed by - previous activities and activity itself i.e. PDAC. The activities contributing delays in the project are:

Table 3. Cause analysis of delays

Activity	Contribution to project delays	Reasons of delay
2nd Slab	20 days	Aluminium material shortage
3rd Slab	4 days	Aluminium material shortage
4th Slab	4 days	Delay in shuttering
5th Slab	1 day	Public strike
8th Slab	4 days	Shortage of steel

The contribution of each activity in project delay is calculated so it helps to find the reason and responsible parties for the same. However, the delay has occurred due to some activities, but other activities with negative delays had minimized the total delay of the project.

The pie-chart (Figure 1) also represents that in the construction phase, more delay was occurred due to material shortage. Being the MIVAN structure, Aluminium shuttering material was not reached on site within the time limit. So, the work was delayed and affected on staff payment, labour idle time, machinery cost.

The project completion period was also affected by additional construction work given by builder i.e.; construction of sewage treatment plant (STP), compound wall and UG tank. The project was delayed by 4 months. By managing the construction activities and proper planning, the delays can be reduced.

Identification of delayed activities is important to quantify affected budget after completion of the project. This study proposes Shi's method for delay computation which can be used in practice to find the contribution of activities in the complete project delay.

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