Schedule delay analysis of a multi-storied residential project using primavera

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Abstract: Procrastination in schedule is a major problem for any construction project. Completing the project on time is a very hard task as the delay in construction occurs due to various factors. Loss of time and money are the outcomes of the delay in the project. The delay may occur through various factors, which are mostly unpredictable. These delays cause losses to the contractor; sometimes this may also lead to discontinuation of the contract and affect the possession date of the project. It is necessary to determine the factors that are responsible for the delay. In this study, schedule delay analysis is conducted on the construction of a multi-storied residential project and the factors and parties responsible for the delays are found out. Many unforeseen factors and ignored issues that lead to the delay are identified. Using various features and tools of Primavera software, the schedule delay analysis is conducted, and an alternate schedule is created with increased resources and time so that it reduces the effect of delays, which would be worthwhile to the contractor and all other parties involved in the project.

1. Introduction
Planning is the most important factor which decides the quality of any project. A project which is well planned and executed will save a lot of time and money and minimizes the losses for the parties involved. An effective plan includes the proper usage of money, time and provided resources. If the plan is done without proper usage of resources, the quality of the project will be affected. Hence it is necessary that planning of a project is done with an objective of getting quality results. Before the start of a project, a schedule of activities is created by the project planner, which includes the list of all the activities involved in the construction, duration of each activity, parties involved in the activity. This schedule is included in the tender documents during the tendering process. After the tender is accepted, the construction process begins as per the schedule. If all the activities are done on time without any obstacles, the possession will be on time and all the parties will be in profits. But, due to many unpredicted factors by various parties result in the delay of construction. Schedule delays are common in the construction projects as the factors may not be unpredictable. Sometimes, various unexpected factors may lead to the delaying of the project. It is not sure that a project might be completed as per the schedule and many factors may lead to the postponement of completion. Even if a project is planned and is being executed as per schedule, some obstacles may interrupt the project resulting in the delay. In recent times, delays are most common in the construction projects. Even with advancements in technology and reduced manual work, delays occur in the projects. Even if the planning of the project is done in an organized manner, the project is being...
pushed beyond the deadline. There is no such method which can guarantee the completion of a project without any delays. Even some projects which are profitable to the contractors are turned into loss ventures due to the delays and time overrun. Equation). Various factors and obstacles affect the project in several ways. Some of these are excusable as they are uncontrollable, while some are non-excusable and cost the contractor and other parties involved. Below are listed some of the factors that are responsible for construction delays

- The conditions of the site are not always the same. They change from time to time and sometimes can be difficult to complete the work.
- The owner may sometimes change his tastes and hence it is needed to change some designs and therefore delay occurs.
- The weather conditions are not always the same. It is unpredictable in countries like India. Differing weather conditions result in delays.
- The labor, materials or equipment may not be available sometimes and this shortage may lead to delay in some activities.
- Failure in some plans may occur and some activities have to be rescheduled and delay occurs due to these activities.

2. Schedule Delay Analysis
Schedule delay analysis is conducted to identify the factors that are responsible for delays in the project. The impact of delays can be reduced if the remaining project is done at a faster pace. The activities which are delayed are first identified and then the cause of delay for these activities. The remaining schedule is modified based on the impact of delays. Primavera is used to conduct the delay analysis. Various tools available in the software help us to identify factors responsible for the delays, impact of delays and lag beyond the finish date. This helps to rectify and resolve the issue at an early stage and to think of an alternate situation to complete the project as soon as possible and reduce the impact of delays. This helps to reduce the lag and extra cost to be spent on the project.

Ali-Momani stated that “Construction technology has a great potential to improve productivity and decrease project duration. Delay happens in many construction projects, although the priority of delay causes is different in various countries due to environmental effects. Delays can lead to considerable negative effects such as lawsuits between owners and contractors, loss of productivity and revenue, and contract termination.

Megha desai and Rajeev Bhatt stated that “Delay could be defined as the time overrun either beyond completion date specified in a contract or beyond the date that the parties agreed upon for delivery of a project. It is a project slipping over its planned schedule and is considered as common problem in construction projects. To the owner, delay means loss of revenue through lack of production facilities and rentable space or a dependence on present facilities. In some cases, to the contractor, delay means higher overhead costs because of longer work period, higher material costs through inflation, and due to labor cost increases.

Aziz and Remon Fayek stated that “Time is money; delay in a certain construction project affects time and thus money, which is the lifeblood of any economy. The timely completion of highway construction projects is considered one of the most important factors referring to the project success, as well as the quality and the safety. All around the world many construction projects face one of the biggest construction problems which is the delay, delays differ from a country to another, from a construction project to another and from construction type or cost to another due to every project circumstances Sullivan and Harris.

Tsegay Gebrehiwet and Hanbin Luo stated that “A construction project is commonly admitted as successful when it complete on time, with budget, according the specifications, and stakeholder satisfaction. However, most of the projects did not finish as the expected timetable. Instead, they completed before or after the schedule due to uncertainties of events and its uniqueness [1]. Construction projects experienced 70% of time overruns and 76% of contractors and 56% of consultants have indicated that they have been facing average time overrun of 10 to 30% from the original duration that causes 50% cost overrun.
Mohammed M. Marzouk and Tarek I. El Rasas stated that "Construction delay means a time overrun either beyond the contract date or beyond the date that the parties have agreed upon for the delivery of the project. In both cases, a delay is usually a costly situation [1]. Delay was also defined as an act or event which extends required time to perform or complete work of the contract manifests itself as additional days of work [2]. Poor site management can cause project delay and affect productivity.

Ogunlana et al. identified 26 delay causes affecting construction industry in a fast-growing economy in Thailand categorized them into 6 groups, and data were collected by visiting sites and mailing to 17 contractors, 18 consultants and design firms and one project owner. 8 contractors and 6 consultants gave approval of which only 12 projects were selected for visits. (a) problems of shortages or inadequacies in industry infrastructure (mainly supply of resources); (b) problems caused by clients and consultants and (c) problems caused by contractor incompetence/inadequacies.

Venu Malagavelli, Balakrishna Chetlapally, Prasad Bollini stated that "Delay analysis is a well-developed technique to find the delays in the project using Primavera. Delay analysis is used to find the delays and its effects on the project cost and factors affecting the project. The delays analysis also focuses on the precautionary measurement to complete the project within the time. Indian Building industry in the recent times is encountering a numerous issue resulting in the loss of a billion ringgit. The principle factor which produces the unsteadiness to the building profession is price and span."

Odeh and Battanieh identified 28 delay causes affecting construction projects with traditional type of contracts in Jordan; first, a survey questionnaire was developed to assess perceptions of contractors and consultants of the relative importance of construction delay causes. Second, the questionnaire was distributed to a random sample of contractors and consultants working on large projects in Jordan. The Spearman’s rank correlation coefficient was then used to test association between the contractors and consultants ranking.

Yang and Wei identified 35 delay causes, 15 causes in the planning phase and 20 causes in the design phase for construction projects in Taiwan by sending a structured questionnaire to engineers at the A/E companies for public construction projects resulting in 95 valid responses identifying the delay causes. This study used the Likert scale in questionnaire design to plot the importance frequency matrix and ranked the factors by the importance and frequency of delays using the relative importance index then calculated the severity index.

INVESTIGATION:
A detailed analysis of the sequence of activities (dependent or independent) executed from the commencement of the construction to its completion.

- Collection of ideas
- Literature review
- Site Visit
- Collection of raw information from site engineer and contractor
- Data Collection, which is the basis to prepare manual schedule
- Preparation of WBS and corresponding activities
- Preparation of the plan and schedule by using the different elements of primavera
- Comparing the updated schedule with original schedule to perform delay analysis

The multi storied residential project is located at Hyderabad. The residential project is a 6.5-acre gated community spread across 8 towers, of 12 floors each. The duration of the project was 623 days, when it was scheduled by the project planner. It took 705 days during execution phase. Delay analysis is conducted to identify the delay factors and the effect on the project completion. A schedule is prepared which helps to complete the project in planned duration.

3. Methodology
There are five major processes in the project planning management which include initiation, planning, execution, forecasting and controlling, close. Initiation is the process in which all the actions required at the start of a project take place. Proper planning is necessary to complete a project in a given time and limited budget. This process involves two stages namely scheduling and costing. Scheduling is
further divided into various groups: calendar creation, WBS (work breakdown structure) creation, activity creation, setting duration for each activity, assigning constraints and baseline creation. Execution process involves day to day updating of the project. The update can be done in two methods. If the project is being executed without any delays, spotlight updating is done. If there are any delays manual updating is done using duration and units. Monitoring is done to check the status of the project at any point of time and find out if any delays present or not. Controlling is the steps taken to reduce the further delays and reduce the impact. Monitoring is done by a tracking process where the project can be analyzed at any instant to find out any obstacles. After the completion of execution of the project, reports are generated to know the delays, their impact on the project and the loss occurring to various parties involved in the project. Then, these reports are exported to the contractor and owner and analysis is done on the delays and their impact on the project.

A. Critical Path Method
Calculating the free float and total float using the relationships between two or more activities and some of the float calculating formulae is done in this process. By this method, whether the project gets completed on time or gets delayed can be determined. For calculating the float of an activity, the float of its predecessor or successor activity is also necessary.

B. Constraints
In the as-planned schedule, various constraints are assigned to activities and most of the activities are given flexibility which was an error, and this led to some delays in the construction stage. In the proposed schedule, the critical activities are assigned with mandatory start and mandatory finish constraints. The non-critical activities are assigned with start on and finish on constraints. This reduces the flexibility and the resources involved will have to complete the activities on time. This minimizes the delays to zero. As the delays are identified, we can conclude that there was no perfection in the planning phase and the constraints were not set properly by the planner. This plays a major role in delaying of certain activities. In the updated schedule, constraints were set to critical as well as non-critical activities. The assigned constraints include start on or before, finish on or before, mandatory start and mandatory finish.

C. Adjusting Baselines
A baseline is a copy of the project data, which is used to determine the delay of activities. It can be used to measure the project progress. An as-planned schedule is used to create a baseline for the project. Using this baseline, the performance of as-built schedule is measured, whether it is following the as-planned schedule is identified. For a project, many baselines can be created upon the request of the management. The activity bars that cross the baseline not only get delayed, but also may delay the other activities related to them and even the finish date of the project. Hence, monitoring the baselines and controlling is necessary to minimize the effect of delayed activities on the entire project. Hence, baselines should be adjusted by setting constraints, increasing work hours and resources to reduce the impact of delays on the successive activities.

D. Time Impact Analysis
The process of finding out the activities that are being delayed, the causes are found out in the time impact analysis. This analysis is helpful to find out the impact of delays and the parties responsible for the delays. Depending upon the impact of delays on the project, some modifications are done to Necessary steps are taken after the analysis to minimize the effect of the delays.

E. Duration of Project
The duration of the project was 705 days with a delay of 82 days constituted by 15 parameters. The proposed schedule is created with utmost care and resolving the errors of the as-built schedule and hence the duration of this schedule is less than the as-built one. The duration of the proposed schedule from the start to finish of the project is 657 days. When this schedule is compared with the as-built schedule, it is 45 days ahead and hence if the proposed schedule is used, the project can be completed earlier. The resources assigned for as-planned schedule is 100% but in case of the proposed schedule, 120% resources are assigned. There would be no extra cost as the activities will be completed the earliest. The working hours for both as planned and proposed schedules are 48 hours per week. The proposed schedule is created referring to the errors that happened in the as-built schedule and the factors that caused delays are taken into consideration. The proposed schedule takes more time to
build compared to the as planned schedule considering the weather factors that may disturb the pace of the project progress. In this case, the overall cost of the project increases, but it is less compared to the extra cost incurred due to contractor

4. Results and Discussions
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A. Calculation of float
To find out the impact of delayed activities on the remaining activities, float for the delayed activities is found out. For calculating the float, early start, early finish, late start, late finish of an activity are required. Table I shows the calculation of total float and free float for delayed activities. It is necessary that the activities that caused delays are identified to minimize delays. The activities that caused delays and their causes are shown in Table II.

Table I: Calculation of total flow and free flow for critical activities

| Activity | Duration | Start (planned) | Finish (planned) | Start (as-built) | Finish (as-built) | Total float | Free float |
|----------|----------|-----------------|------------------|------------------|------------------|-------------|------------|
| 1-2      | 20       | 0               | 20               | 0                | 20               | 0           | 0          |
| 1-3      | 25       | 0               | 25               | 5                | 30               | 5           | 5          |
| 2-3      | 10       | 20              | 20               | 20               | 30               | 0           | 0          |
| 2-4      | 12       | 20              | 32               | 23               | 35               | 3           | 3          |
| 3-4      | 5        | 30              | 35               | 30               | 35               | 0           | 0          |

Table II: Causes and factors for the delays

| Activity                      | Delay (days) | Causes for delay | Parties responsible |
|-------------------------------|--------------|------------------|---------------------|
| Backfilling & consolidation   | 4            | Labor shortage   | Contractor          |
| Plinth beam concrete          | 4            | Shuttering delay | Contractor          |
| Supply of steel at site       | 2            | Late delivery    | Supplier            |
| Slab shuttering               | 10           | Labor shortage   | Contractor          |
| Reinforcement                 | 8            | Less equipment   | Contractor          |
| Conduit laying                | 2            | Plumber          | Contractor          |
| Slab concreting               | 2            | Equipment fail   | Equipment           |
| Conduits &plumbing            | 3            | Plumber          | Contractor          |
| Terrace waterproofing         | 4            | Less equipment   | Contractor          |
| External plastering           | 10           | Scaffold delay   | Labor               |
| External painting             | 8            | Shortage         | Contractor          |

B. Comparison of Durations
After the creation of updated schedule, both the planned and proposed schedules are compared. This is done to know the number of days that are saved and that can be reduced by using the proposed schedule. After comparison, it is found out that the proposed schedule reduces 45 days of duration. Figure 1 shows the pictorial results of comparing both the schedules.

C. Resource usage

The usage of resources in the proposed schedule is increased so that the delay can be reduced. The resources used is increased by 20% for the proposed schedule. This might increase the cost of the project, but it is less than the extra loss incurred on the contractor. The comparison of resource usage for planned and proposed schedule is shown in pictorial representation

Fig. 1 Comparison of durations (planned and proposed schedule)
5. Conclusions
Delay analysis is done on the planned schedule of the multi-storied residential project and the following were the observations:

- The updated duration after completion of the project is 705 days.
- Constraints are not properly assigned to the critical activities, which led to delay of several activities.
- The contractor was observed to be the cause of delay for various factors.
- Out of the 15 parameters, 4 were observed to be excusable and the other parameters lead to the delay in critical activities.
- After the proposed schedule, the duration of the project is reduced by 45 days.
- The actual duration of the project is 705 days but the duration of the proposed schedule is 660 days.

6. References
[1] Ar. Meena. V, Ar. K. Suresh Babu; “Study on Time Delay Analysis for Construction Project Delay Analysis”; International Journal of Engineering Research & Technology Vol. 4, March-2015.
[2] Megha Desai and Rajeev Bhatt; “Critical Causes of Delay in Residential Construction Projects”; International Journal of Engineering Trends and Technology; V4 (4):762-768 Apr 2013.
[3] Aziz, Remon Fayek (2013); “A Critical Literature Review on Main Cause of Delay in Construction Projects”; International Journal of Engineering Research & Technology, Volume: 05.
[4] Tsegay Gebrehiwet and Hanbin Luo; “Analysis of Delay Impact on Construction Project Based on RII and Correlation Coefficient”; Creative Construction Conference 2017.
[5] Mohamed M. Marzouk, Tarek I. ElRasas; “Analyzing delay causes in Egyptian construction projects”; Journal of advanced research (2014) 5, 49-55.
[6] Al-Momani; “The importance of new technology for delay mitigation in construction projects” American Journal of Civil Engineering and Architecture. 2015, Vol. 3, No. 1, 15-20.
[7] El-Razek et al.; “Studying the suitability of different data mining methods for delay analysis in construction projects”; Journal of Applied Research on Industrial Engineering Vol. 2, No. 1 (2015) 15-33.
[8] L Muhwezi, J. Acai, and G. Otim; “An Assessment of the Factors Causing Delays on Building Construction Projects in Uganda” International Journal of Construction Engineering and Management 2014; 3(1): 13-23.
[9] Mr. I. Michael Raj, Ms. M. Panimalar; “Schedule delay analysis in construction projects using Primavera” International Journal of Engineering Research & Technology e-ISSN: 2395-0056 Volume: 06 Issue: 05.
[10] G. Sweis, R. Sweis, A. Abu Hammad, A. Shboul; “Delays in construction projects: the case of Jordan”; International Journal of Project Management 26 (2008) 665-674.
[11] Venu Malagavelli, Bala Krishna Chetlapally, Prasad Bollini; “Delay analysis of raw water reservoir and pumping station”, International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249-8958, Volume-9, February, 2020.
[12] S.O. Ogunlana, K. Promkuntong, V. Jearkjirm, “Construction delays in a fast-growing economy: comparing Thailand with other economies”, Int. J. Project Manage. 14 (1) (1996) 37-45.
[13] Odeh, H.T. Battaine, “Causes of construction delay traditional contracts”, Int. J. Project Manage. 20 (1) (2002), 67-73