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A Comparison Study Between Event Chain Methodology And Critical Path Method In The Construction Industry

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***Abstract*— In this paper, we look to describe a new perspective to consider and quantify uncertainty in construction schedules where a methodology was presented by modeling construction project scheduling using event chains, classification of the events and event chains, identification of critical events, analysis of effect of the events on project duration, and chance of project completion to find out the applicability of the proposed methodology. A residential apartment is considered as a pilot project and a project specific schedule risk analysis system and risk break down structure is also developed as an essential part. Earned Value Analysis is carried out to quantify the performance of the scheduling technique through Schedule Performance Index. The average Scheduling Performance Index value for the Event Chain Methodology schedule over the duration of the project is found to be 10.96% greater than that of Critical Path Method which can be used as one of the contributing factors to promote usage of Event Chain Methodology.**

***Keywords*—Event chain methodology, Critical Path Method, Earned Value Analysis, Project Scheduling, Scheduling Risk Analysis System.**

I. INTRODUCTION

Construction managers plan, coordinate, budget, and supervise construction projects from development to completion. In spite of so many efforts, man hours and resources, we still find it very difficult to finish construction projects on time within budget and available resources. Type of structure, complexity, location, type of resources and natural conditions make every project unique. There is no ideal condition for construction activity. Although the existing project management techniques like CPM, PERT, CCPM, LOB are facilitating better performance, effective utilization of these techniques is not done satisfactorily. Identification of the suitable construction management technique is very important for the successful completion of any construction project.

The construction industry has been using quantitative network modelling techniques to simulate the construction process since the late 1950s.

However, much has been written on the problems concerned with traditional scheduling processes. One of the issues with traditional scheduling processes is that the critical-path method (CPM) is deterministic in nature; the process thereby ignores the effects of uncertainty by using a single value for the time estimate of each activity and even the entire construction of the project.

Practically, in most cases, duration, start and finish time, and other task parameters are uncertain. To solve this issue, the PERT model (Program Evaluation and Review Technique) was developed in 1950s to address uncertainty in the estimation of project parameters. The expected task duration in PERT model is calculated as the weighted average of the most optimistic, the most pessimistic, and the most likely time estimates. However, the main problem with classic PERT is that it gives accurate results only if there is a single dominant path through a precedence network. When a single path is not dominant, classic PERT usually provides overly optimistic results.

Another approach to project scheduling with uncertainties is CCPM (Critical Chain Project Management) which was developed by Goldratt. Goldratt applied the theory of constraints (TOC) to project management known as critical chain project management (CCPM). The cornerstone of TOC is resource constrained critical path called a critical chain. Goldratt's approach is based on a deterministic critical path method. To deal with uncertainties, Goldratt suggested using project buffers and encouraged early task completion. Theory of constraints is well accepted in project management; however, this approach still does not pay enough attention to the specific stochastic risk events occurred in on-site construction environment. In addition, for its complex operation process, the range of use of this method is limited.

Event chain methodology (ECM) was developed as a risk and uncertainty modelling technique for project management based on existing mature quantitative method such as Monte Carlo simulation and Bayesian theorem.

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Event chain methodology focuses on identifying and managing the events and event chains that affect projects. Event chain methodology improves the accuracy of project planning while simplifying the modelling and analysis of uncertainties in the project schedules which the PERT and Critical Chain are not sufficiently equipped with. The highlight of this work is on the comparative study of two different scheduling techniques viz. Critical Path Method (CPM) and Event Chain Methodology (ECM) which aims to give a comparison of the scheduling techniques on their application through Earned Value Analysis.

II. Research Objective

1. To simplify and adopt a model for scheduling risk analysis system made according to project requirements.
2. To provide a methodology for modelling a construction project schedule using event chains, classification of the events and event chains, identification of critical events, analysis of effect of the events on project duration.
3. To check the applicability of the proposed Event Chain Methodology when compared to the application of Critical Path Method in terms of Schedule Performance Index.

III. Implementation Process

This study starts with the implementation of CPM and ECM for a pilot project on a trial basis for a residential apartment (G+4) framed structure with the scheduling done in CPM for the structural aspect of the building. The total duration for the handover of the structure was initially considered as 8 months, the project was on hold for several approvals and it had to resume from Ground Floor. The scheduling process involved the creation of an Enterprise Project Structure (EPS) with the pilot project being one among them, an Organizational Breakdown Structure (OBS) which indicates the roles of a particular individual in the pilot project, a detailed micro-level Work Breakdown Structure (WBS) where every small sub-division concerned to the project is indicated and every activity or the task concerned to the sub-divisions of the WBS are added.

Labour and Non-Labour resources, such as engineers and equipment are generally time bound, but this schedule has assigned these resources to the respective activities in terms of Cost/Unit and not in hours, the materials are also assigned in terms of Cost/Unit. The formula used for calculating the required manpower by using the productivity details maintained by the company is,

Manpower Requirement (numbers) = (Total Quantity for the Activity or Task) / (Average Productivity per day × Duration of the Activity in days)

Table I
The Pilot Project Information

Project Information - Vijay Kumar Residence		
Sl. No.	**Description**	
1	Super Built-up Area in sft	12,813.79
2	Number of floors	B+G+4
3	No. of Blocks	1
4	Total number of apartments	4 Nos. of 3BHK
5	Project duration	539 Days
6	Structure Duration	222 Days

A baseline schedule is created using the Critical Path Method (CPM) technique. The schedule so created is taken as a benchmark for the creation of a baseline schedule using the Event Chain Methodology (ECM) technique. The principles of ECM were the basis for the generation of the baseline schedule. A Scheduling Risk Analysis Model was developed for the pilot project according to the needs of the project and it is project specific. The flow chart shown in Figure 1 indicates the procedure through which the baseline schedule for ECM was created. Having taken the baseline schedule of CPM technique as benchmark, the risk register or the Risk Breakdown Structure (RBS) was created where the risk factors along with the probabilities and impact have been derived from the review technique with the help of members of the Planning Department of the organization, the past experience and the delay reports of five recently concluded projects of the organization with changes in the probabilities and impact through a continuous review technique involving the same members of the organization.

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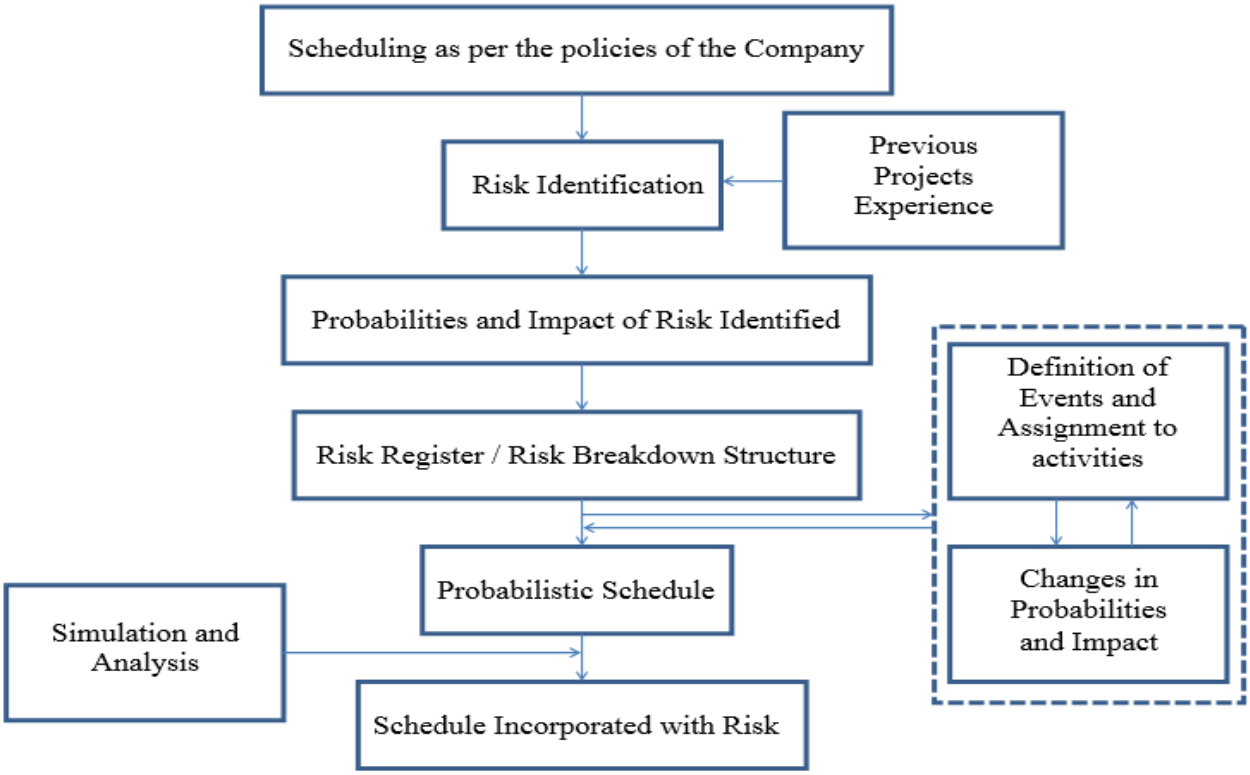

Figure I The Scheduling Risk Analysis Model

The schedules with different techniques were finalized and the baselines were worked out to be the following:

Table II
Baseline Durations Corresponding To Scheduling Techniques

Serial No.	Scheduling Technique	Baseline Duration (Days)
1	CPM	162
2	ECM	191

After the baseline schedule was fixed, the tracking and monitoring of the activities or tasks was started. The construction sequence of the pilot project was tracked with the two different schedules viz., CPM and ECM. The schedule was updated every fortnight in both the schedules. The actual start and actual finish of the activities were the same for both techniques and consequently Earned Value (EV) was carried to track the progress of work v/s planned work financially to quantify the project performance.

IV. Results

Earned Value Analysis was carried out to give a clear picture on the Schedule Performance Index (SPI) with respect to time for both the scheduling techniques. All the relevant cost details are according to the *Delhi Schedule of Rates (DSR) - 2013 released by the Central Public Works Department, New Delhi.*

A. Critical Path Method Results

Figure 2 shows the variation of the EV with time for CPM and the graph does not show much variation in the end, i.e. the deviation of the actual cost to the higher value than the planned value is not highly significant as the only important factor contributing to the higher value is the inflation of material cost for A-Class materials. The planned value is significantly higher than the earned value for the duration between September 2013 and Jan 2014 due to several delays that were anticipated but not accommodated in the schedule.

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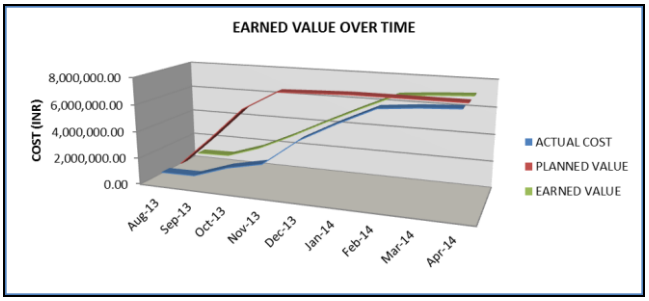

Figure II Earned Value Over Time For Cpm Technique

Table III
Values Used To Generate EV And SPI Graphs For CPM

Technique: CPM	ACTUAL COST	PLANNED VALUE	EARNED VALUE
Aug-13	833,987.34	756,537.86	877,925.44
Sep-13	865,456.09	3,053,840.36	940,862.94
Oct-13	1,737,833.30	5,493,106.84	1,799,039.30
Nov-13	2,294,631.25	6,929,982.93	2,995,238.14
Dec-13	4,238,263.39	7,020,799.76	4,294,928.95
Jan-14	5,621,573.10	7,097,261.76	5,540,274.09
Feb-14	6,864,914.34	7,097,261.76	6,718,041.41
Mar-14	7,101,618.14	7,097,261.76	6,921,877.67
Apr-14	7,246,650.17	7,097,261.76	7,060,828.77

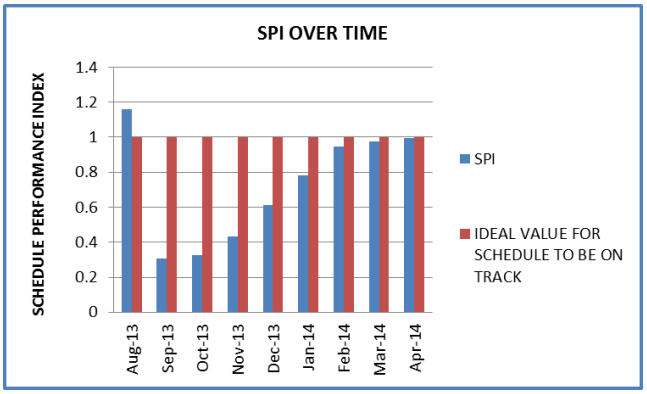

Figure III Schedule Performance Index Over Time For Cpm Technique

Figure 3 indicates the variation of SPI with time for CPM. The ideal value of the SPI for the project to be on track with the schedule is 1. The graph gives an indication that the project has never been on track with the schedule except for the month of August 2013 where the project was ahead of schedule.

The average SPI value for the CPM schedule over the duration of the project is found to be approximately 0.73 which is less than the ideal value of 1 indicating the project has been behind schedule.

B. Event Chain Methodology Results

Figure 4 shows the variation of the EV with time for ECM technique and the graph indicates a small deviation of the actual cost to the higher value than the planned value is not highly significant as the only important factor contributing to the higher value is the inflation of material cost for A-Class materials. The planned value is significantly higher than the earned value for the duration between September 2013 and December 2013, but lesser than that compared to the CPM schedule because of the incorporation of the scheduling risk analysis model.

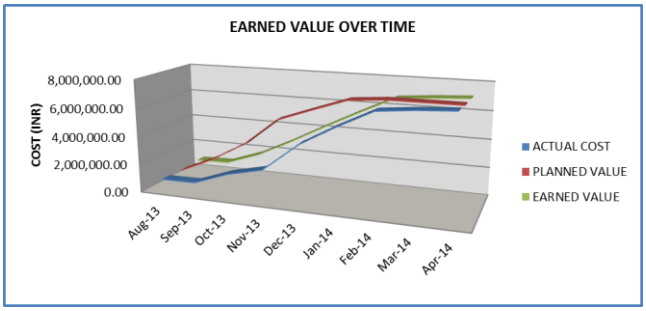

Figure IV Earned Value Over Time For Ecm Technique

(GENERATED FROM THE VALUES IN TABLE 4)

TABLE IV
VALUES USED TO GENERATE EV AND SPI GRAPHS FOR ECM

Technique: ECM	ACTUAL COST	PLANNED VALUE	EARNED VALUE
Aug-13	833,987.34	756,537.86	877,925.44
Sep-13	865,456.09	1,830,614.17	940,862.94
Oct-13	1,737,833.30	3,185,645.14	1,799,039.30
Nov-13	2,294,631.25	5,157,438.99	2,995,238.14
Dec-13	4,238,263.39	6,040,321.11	4,294,928.95
Jan-14	5,621,573.10	6,899,343.09	5,540,274.09
Feb-14	6,864,914.34	7,097,261.76	6,718,041.41
Mar-14	7,101,618.14	7,097,261.76	6,921,877.67
Apr-14	7,246,650.17	7,097,261.76	7,060,828.77

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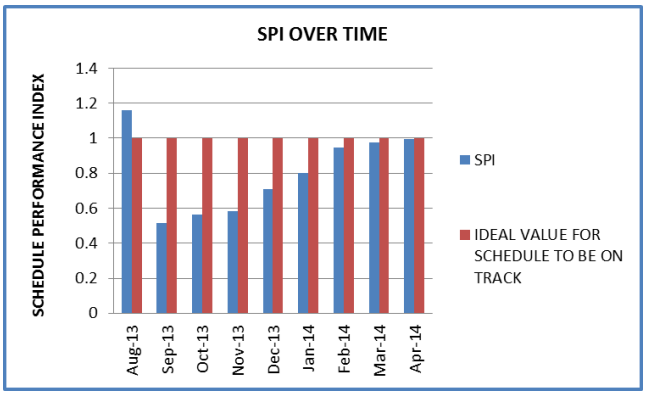

Figure V Schedule Performance Index Over Time For Ecm Technique

Figure 5 indicates the variation of SPI with time for the ECM technique. The ideal value of the SPI for the project to be on track with the schedule is 1. The graph gives an indication that the project has never been on track with the schedule except for the month of August 2013 where the project was ahead of schedule. The average SPI value for the schedule ECM over the duration of the project is found to be 0.81 which is greater than that of CPM but lesser than the ideal value of 1 indicating the project has been behind schedule.

V. Conclusion

As discussed in the results, the implementation of ECM gave better results than CPM. The preferred choice of a scheduling technique for a similar project would be ECM among CPM and ECM for the following reasons:

1. The average SPI for ECM schedule was found to be 10.95% better than that of CPM.
2. ECM gives some importance to resource allocation and resource calendar constraints unlike CPM where there is no emphasis on resource allocation.
3. ECM is seen to be very effective in construction project management where a structured approach is provided to identify the sources of risk and based on these risks, to determine the range of schedule outcomes. The incorporation of risk analysis is ground zero for ECM unlike CPM.
4. ECM gives equal importance to non-critical activities which is indicated by a Critical Event Chain which is a sequence of linked activities which affect the project's completion date due to risk assignments. Critical Event Chains can lie outside of the calculated critical path.

"The study can be concluded by saying ECM approach is a better approach to this kind of a project."

VI. Scope For Future Research

Research has shown that Event Chain Methodology gave good results to an airport terminal project and also is applicable to different time related development projects. We can also try to implement the same for different types of construction like bridge construction, commercial buildings and infrastructure projects and so on as a part of extending the research. The contractor's perception towards the acceptance of ECM can also be a part of the extended research where the contractor's direct cost and indirect cost shoots up with prolonged delays and reduces his profit margin.

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