A Practical Approach using CPM/PERT: 
for Certain Activity Times in Construction Parking Project

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Abstract: Project management technique varies and is applied based on the domain’s specifications. This research studies the applicability of a project management technique in the domain of construction project. The success of a construction project is measured based on three main factors; time, cost and project performance. The three factors must be delicately balanced and monitored in assuring the success of a project. This paper presents the parking project scheduling by using Critical Path Method/Project Evaluation and Review Techniques (CPM/PERT). CPM/PERT is used in providing the deterministic and probabilistic aspect that are used in the planning, scheduling and controlling the project’s duration and cost. By doing so, the scheduling the parking project with CPM/PERT method will be more adaptable to changes during the execution of the project by managing project delays and cost efficiently. Thus, the CPM/PERT is able to schedule the parking project and provide better schedule time.

Key words: Project Management • CPM/PERT • Schedule Parking Project

INTRODUCTION

Project management is the application of knowledge, skills and techniques to execute projects effectively and efficiently. It is a strategic competency for organizations in ensuring that a project meets its goals, time line and budget. However, there still exist some limits in accomplishing the project deadlines and actual outcomes. Sudden unexpected changes in construction technology, techniques, materials, or human resources can create stiff budgetary and scheduling pressures which may increase the possibility of project failure [1].

The problem of delays in the construction industry is a global phenomenon [2]. In Saudi Arabia, Assaf and Al-Hejji [3] found that only 30% of construction projects were completed within the scheduled completion dates. In Nigeria, Odeyinka and Yusif [4] have shown that seven out of ten projects suffered delays in their execution. In Malaysia, about 17.3% were considered sick (more than 3 months of delay or abandoned) [2]. Arditi et al. [5] showed that the major contribution on delaying in construction is the effect of organizational culture.
construction, IT, manufacturing and defence organizations [9]. They can be applied to solve many problems in project management and can be used in the programming of large-scale projects.

Thus, this paper focuses on the construction parking project which aims to identify the critical path using CPM/PERT. The rest of this paper is organized as follows: Next section discusses on the literature review of CPM/PERT. Then follows by the construction of CPM/PERT based on the real case of parking to demonstrate the feasibility and applicability of the proposed method. The last section concludes this paper.

Literature Review: This section is divided into two subsections. Subsection CPM/PERT focuses on the CPM/PERT method and the next subsection, reviews on the construction project using CPM/PERT.

CPM/PERT: Critical Path Method (CPM) was developed by Du Pont and Remington Rand in the late 1950s for industrial projects (chemical plant shutdown) [11]. Project Evaluation and Review Techniques (PERT) was developed by U.S. Navy for Polaris missile project in the year 1958 to handle uncertain activity times. Nowadays, CPM and PERT have been used to plan, schedule and control a wide variety of projects such as research and development of new products and processes, construction of buildings and highways, maintenance of large and complex equipment, design and installation of new systems and many more. In project scheduling, projects may have as many as several thousand activities. A complicating factor in carrying out the activities is that some activities depend on the completion of other activities before they can be started.

CPM/PERT assists the project managers in the following aspects: 1. The total time to complete a project. 2. The start and finish dates for each specific activity. 3. The critical activity that must be completed as scheduled. 4. The duration of noncritical activities that can be delayed to avoid exceeding time in project completion. Thus all these aspects can be depicted in the form of networks diagram to help a manager to have a better view in project implementation. Additionally, critical path can be determined on the network by identifying the activity with zero slacks.

The process in CPM/PERT can be described by the following phases:

Phase 1: Earliest Start and Finish Times: Make a forward pass through the network as follows: For each activity $i$ beginning at the Start node, compute:

Earliest Start (ES) Time = the maximum of the earliest finish times of all activities immediately preceding activity $i$. (This is 0 for an activity with no predecessors).

Earliest Finish (EF) Time = (ES Time) + (Time to complete activity $i$).

where the project completion time is the maximum of the EF Times and the Finish node.

Phase 2: Latest Start (LS) and Latest Finish [12] Times:

Make a backwards pass through the network as follows: Move sequentially backwards from the Finish node to the Start node. At a given node, $j$, consider all activities ending at node $j$. For each of these activities, $i$, compute:

Latest Finish [12] Time = the minimum of the latest start times beginning at node $j$. (For node $N$, this is the project completion time).

Latest Start (LS) Time = (LF Time) – (Time to complete activity $i$).

Phase 3: Determining the Critical Path: Calculate the slack time for each activity by:

Slack = (LS) – (ES), or

$\text{Slack} = [12] – (EF)$

where a critical path is a path of activities, from Start node to the Finish node, with 0 slack times.

The Uncertain Activity Times: Besides the three steps, the uncertain activity times are also a main keys in the CPM/PERT methodology. In the three-time estimate approach, the time to complete an activity is assumed to follow a Beta distribution.

An activity’s mean completion time is: $t = (a+4m+b)/6$

An activity’s completion time variance is: $\sigma^2 = ((b-a)/6)^2$

where $a$ is the optimistic completion time estimate, $b$ is the pessimistic completion time estimate and $m$ is the most likely completion time estimate

Phase 4: Determining the PERT/ Cost: PERT/ Cost is a technique for monitoring cost during a project. Work packages (groups of related activities) with estimated budgets and completion times are evaluated. A cost status report may be calculated by determining the cost overrun or underrun for each work package. Cost overrun

1181
or underrun is calculated by subtracting the budgeted cost from the actual cost of the work package. For work in progress, overrun or underrun may be determined by subtracting the prorated budget cost from the actual cost to date.

Thus, the whole phases of PERT/CPM method can be summarized as follows:

- Break project into operations necessary for completion
- Determining sequential relationship of operations
  - Event to mark commencement
  - Overlapping possibility
- Creating time estimates for each operation
  - Determining earliest possible start date and earliest possible finish date
    - Determining free float and total float
- Determining free float and total float
- Determining the slack time for each activity
- Establish time-cost relationship
  - Establish scheduling variations
    - Determine most favourable balance between time-cost
      - Normal Start – normal time, least cost
      - All-Crash Start – least time, higher cost

Figure 1 summarizes the four main phases involved in CPM/PERT. Each phase produces output that can be used in project planning. As illustrated, this technique compiles the work done towards the completion of a project. The start and finish dates and the activities involve represented as grid visual information. The duration of activity in deterministic method such as CPM is assumed to be constant [13]. This paper will only focuses on Phase 1, Phase 2 and certain activity times in Phase 3 to manage the scheduling of the parking project. The previous studies on the methodology of CPM/PERT are been discussed in the next subsection.

Overview on Construction Project using CPM/PERT: CPM/PERT has been actively used in many area such of construction, IT, manufacturing and defence organizations [9]. For example, Lee et al. [14] constructed a Program Evaluation and Review Technique (PERT) to find the critical activities when constructing the plant and to calculate the total project cost and total duration time for the project under normal condition. Gladysz et al. [15] modified the PERT method with mixed linear programming to illustrate the construction project. Dolabi and Abbasnia [12] proposed a methodology of Heuristic Line of Balance (HLOB) from CPM/Line of Balance (LOB) for scheduling projects with serial activities. This proposed method was successfully tested on large-scale highway project. Boushaala [16] proposed a PERT/CPM and Petri Net (PNs) Tools for project scheduling. Aziz [10] developed Repetitive-Project Evaluation and Review Technique (RPERT), which is a simplified software and generated the expected project completion probability of a specified/ certain duration (contract duration). Thus this paper proposed a CPM/PERT method for a real case of parking project.

Calculation for Certain Activity Times in Construction Parking Project: In this research, we have chosen randomly a contractor among the small and medium enterprise (SME) contractors who involved in the construction of parking lots at University Sultan Zainal Abidin (UniSZA), Besut Campus. Specifically, this parking project is developed at students' hostel. Once the contractor has been awarded a tender to develop the project, he has to fulfil the predefined requirements. The contractor needs to submit a project scheduling and planning to the committee. It is important that the project must be completed on time otherwise the contractor will face penalty. Therefore, the contractor needs to comply with the scheduling activities. For that reason, CPM/PERT
is highly recommended to assist the contractor and the stakeholders to have a clear picture of a timeline on each activities.

CPM/PERT analysis have the capability to be adopted in a scheduling system which involves the activities of the project, times and critical paths. For example, in certain circumstances, contractors may face conflict decisions such as which parallel activities that need to be prioritized. Besides, another issue is the earliest time to start the prioritized activities. Generally, many SME contractors used their intuitions or discretion to plan and schedule the construction activities. However, one of the drawbacks of this traditional method is the susceptibility to errors. Therefore, we propose a practical approach to develop an application to assist SME contractor in scheduling their construction project activities. In this paper we test the feasibility of the CPM/PERT approach in scheduling the activities for parking lot construction.

There are four (4) variables were used in this system, activities, start times, end times and the duration. The developed scheduling system provides a decision output based on the input criteria from the contractor. Each of the four parameters was assigned as shown in Table 1.

**Table 1: Time Estimation for Project A by ABC Enterprise**

<table>
<thead>
<tr>
<th>Activity</th>
<th>ES time</th>
<th>EF time</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Formwork</td>
<td>0</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>B Reinforcing</td>
<td>0</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>C Cast in place</td>
<td>5</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>D Brick Masonry</td>
<td>5</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>E Waterproofing</td>
<td>5</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>F Glazing</td>
<td>6</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>G Plastering and Pointing</td>
<td>10</td>
<td>24</td>
<td>14</td>
</tr>
<tr>
<td>H Cement Mortar Coating</td>
<td>9</td>
<td>21</td>
<td>12</td>
</tr>
</tbody>
</table>

**Table 2: Activity Schedule for Project A**

<table>
<thead>
<tr>
<th>Activity</th>
<th>ES</th>
<th>EF</th>
<th>LS</th>
<th>LF</th>
<th>Slack Time (LS – ES)</th>
<th>Critical Path</th>
</tr>
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<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>0</td>
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<tr>
<td>B</td>
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</tbody>
</table>

Based on the information provided in Table 1, the network activities will be constructed which will include the activity, event and network itself. In order to determine the critical path, the values of LS and LF must be determine prior to calculating the backward pass. The following Figure 2 presents the complete network diagram.

The Slack Time and Critical Path will be calculated in order to find the best schedule time. Activity with zero (0) slack time is considered as the Critical Path. The following Table 2 indicates the resulted activities identified with critical path.

Based on the Table 2, a complete network diagram is derived as in Figure 3. In Figure 3 the shaded box indicates critical path of the project where A–E-F-G-I = 26 weeks. Based on the calculated critical path, the project completion time equals to the maximum of the activities’ earliest finish times.
CONCLUSIONS

In this paper, we have presented a method that combines CPM/PERT. CPM/PERT is an efficient method to be used in scheduling the construction project planning as it helps in answering main questions such as total time to complete the project, scheduled start and completion time for each activity, the activities are critical and the time taken for non-critical activities that can be delayed during the project execution. In this project, an expert was interviewed and nine activities starting from Formwork activity until Cement Mortar Coating had been identified. In addition, this project calculated the Slack Time and Critical Path. In future, a software tool can be developed to assist SME contractors in scheduling their construction project activities.

REFERENCES