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Developing a Decision Support System for Cost–Time Trade off in Project Management

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Abstract
Project managers are generally requested to finish their project in a scheduled time by reducing the total cost. They can reduce the project duration by assigning more resources to the project activities. The project managers generally face a trade-off between cost and time. Some of the project activities are sometimes subcontracted to suppliers. In such cases project managers needs to evaluate project activity times and their risks, project completion time, project total cost and quality of their supplier support. In this study, a multi-attribute decision support system is proposed where activity normal and crash times are evaluated along with the supplier ranking with respect to some of their attributes.
Keywords: Project management, Cost-Time trade off, Multi attribute decision-making

1. INTRODUCTION

Project managers are under the pressure of finishing their projects in a given time. In addition to finishing the project in a given time they are also requested to finish their project with a minimum cost. Keeping costs at acceptable levels is almost always as important as meeting schedules (Krajewski et al. 2013). Project activities could be finished earlier in some cases. Crashing is referred to the shortening of project completion time by speeding up one or more of the project activities (Chen and Tsai 2011). The time–cost trade-off problems have been extensively investigated (Chen and Tsai 2011). The project managers generally face a trade-off between cost and time. Some of the project activities are sometimes subcontracted to suppliers. In such cases project managers needs to evaluate the attributes of their suppliers in addition to project activity times and their risks, project completion time and project total cost. On one side of the project management there exist cost and time evaluations for the project managers. However on the other side of project management there exists supplier evaluation. In this study, a multi-attribute decision support system is proposed where activity normal and crash times are evaluated along with the supplier ranking with respect to some of their attributes. This paper is organized as follows: in Section 2, the methodology is presented. Section 3 introduces a case study of a construction company that uses the proposed decision support methodology. Section 4 summarizes the paper.

2. LITERATURE REVIEW

2.1 Project Management: Project Scheduling

The basic inputs for each activity such as time cost and resources are affected by uncertainty (V.Khodakarami,2007). Two network planning methods were developed in the 1950s. The program evaluation and review technique (PERT) and The critical path method (CPM) (Krajewski et al. 2013). Critical path method (CPM) is best known technique to support project scheduling. In this method critical path is calculated which takes maximum time to complete the project (B.Hooshyar, ARahmani and M.Shenasa. 2008). CPM is used for developing strategies to complete a project in less than what would normally be regarded as minimum time (S.M. Fahimifard and A.A. Kehkha, 2009). (PERT) is used for determining probabilities associated with completion times when activities duration are unknown. Many uncertain variables such as weather condition, productivity level etc. affect activity duration during project implementation and cost could also change (S.M. Fahimifard and A.A. Kehkha, 2009).

2.2 Project Management: Time-Cost Tradeoffs

Time and cost are two important aspects in any field of engineering. Generally there is non increasing relation between time and cost (B.K.Pathak and S.Srivastava. 2007). In TCTP the objective is to determine the duration of each activity in order to achieve the minimum total direct and indirect cost of project (A.Azaron, C.Perkgoz and M.Sakawa. 2005). Direct cost includes materials, human resource and equipment used. Indirect cost includes lease holds, machinery hiring, and management operations. Additional cost paid for reducing the normal time of an activity is defined by cost slope (B.Hooshyar, ARahmani and M.Shenasa. 2008). The heuristic approach select the activities to be shortened or expanded based on certain selection criteria which do not guarantee optimal solutions.(G.Mohammadi,2011) Generally methods consider linear times cost relationship with activities and also do not provide range of possible solutions. the standard way to reduce project duration is to expedite critical activities by assigning additional resources (e.g., more personnel, overtime, or faster or better tools), an approach known as crashing (Meredith, J.R. and S.J. Mantel. 2012). Crashing shortens an activity's duration at some added cost (PMI, 2013).

2.3 Application of the AHP in project management to choose the subcontractor

Subcontractors are specialist hired by the main contractor to perform specific tasks on a project as part of the overall contract (Chiang, Y.H., 2009). Subcontractor integration could also assist to reduce the time and cost, improved quality, enhanced performance in environmental issues, health and safety, and innovativeness (Eriksson & Westerberg, 2011). During the subcontractor selection for construction contract, Common in the selection of the contractor is offering the lowest price (Jarkas, 2013). Studies of (Doloi *et al*, 2011) to select subcontractors must not only on the bid price, but there are other criteria that play an important role in selecting the most suitable contractor to carry out construction work.

There are many ways to choose a contractor in the construction industry, and a statement that the main factor in choosing a contractor depends on the lowest tender (El-Mashaleh 2013). And some studies referring to previous relevant project performance, financial efficiency, implementing projects within the specified duration, quality of work, working level, quality of materials used, prompt payment to labour, compliance with site safety requirements, compliance with contract and collaboration with other subcontractors are also paramount factors to be considered in the selection of subcontractors (Arslan et al., 2008). Mbachu (2008) opined that the optimal selection of subcontractors based on overall ability to perform, rather than on the tender price alone, is crucial to a sustainable project. Subcontractors are evaluated using Analytic Hierarchy Process

3. THE METHODOLOGY OF THE RESEARCH

The proposed decision support system uses project crashing to get the minimum cost and Analytic Hierarchy Process (AHP) techniques to rank the suppliers with respect to their attributes. AHP helps to bring consistency in selection problems whose decision criteria are expressed in subjective measures based on managerial experience (Bryson, 1996). AHP is a technique for considering data or information about a decision in a systematic manner (Golden et al., 1989; Saaty, 1980; Saaty, 1988). Details about the proposed method are explained as follows;

Step 1: Project scheduling and network representation of a project:

The target of project scheduling is to construct a time table for a given list of activities. The scheduling process is based on the traditional critical path method. The two most common techniques of basic project scheduling are the Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT). Project and activities are represented by a network. Network is a graph showing each activity to be performed its predecessor, successor and duration. In this step of the method the project network is constructed.

Step 2: Identify activities that will be implemented by subcontractor

As the proposed decision support system is for project managers, the decision makers are considered as the project manager of the main contractor. The decision maker (main contractor) will identify some of the activities on the project network to be implemented by subcontractors (secondary contractor) for several reasons, including activity specialization, skilled labor, experience etc.

Step 3: Method of selecting subcontractor:

A subcontractor is selected by the decision maker to implement some of the activities of the project, so the subcontractor must be suitable in terms of the technical offer (benefits) for example experience, quality performance, financial stability, etc. as well as commercial offer (cost, time) for the implementation of identified activities.

Step 4: The technical offer (benefits):

Step 4-a: Define criteria

The decision maker defines the criteria that will be used to judge the alternatives (subcontractors), (experience, quality performance, financial stability, manpower resources, equipment resources, current workload etc.)

Step 4-b: Evaluate subcontractors with each criterion:

Calculation of the pair wise comparison matrix for each level is required. For the pair wise comparison, a ranking scale is used for the criteria evaluation. The scale is a crisp scale ranging from 1 to 9, this scale values are assigned to the criteria based on the experts' opinions (Saaty, 1980).

Step 4-c: Calculate benefit of subcontractor:

The benefits of the subcontractors are calculated in this step by using the AHP technique.

Step 5: The commercial offer (costs):

Step 5-a: The assessment of the commercial offer (normal cost and normal time)

In this step the activities which will be subcontracted are determined. Normal time, crash time, normal cost and crash cost of the activities are collected from the subcontractor.

Step 5-b: Calculate the minimum cost with subcontractor activities (crashing)

Total project cost can be reduced by using method of crashing for time and cost because the crashing time lead to reduction of the project duration and thus to avoid delay penalties. By doing so, the minimum cost is obtained for each subcontractor.

Step 6: Final evaluation of subcontractors:

The final evaluation is done in this step after getting the highest criteria evaluation (benefits) and the commercial offer. For each supplier alternative, benefit-cost ratios are calculated in order to get final rating of the alternative subcontractors.

Step 7: Select the best subcontractor:
Use benefit to cost ratios to select the best subcontractor.
Figure 1 summarizes the proposed methodology.

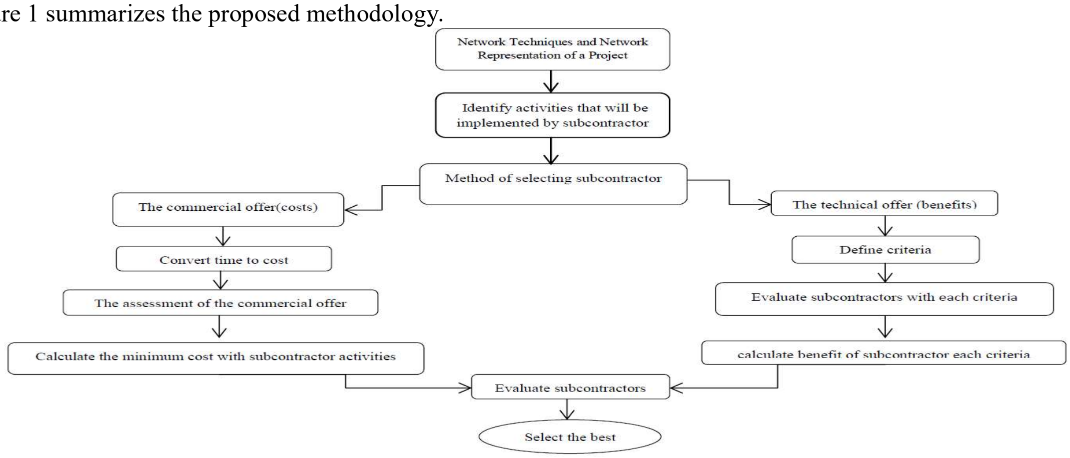

Figure 1. Flow diagram for the proposed decision support system

4. CASE STUDY

In this section a simple case study which uses the proposed decision support system is presented. A project management process of a construction company in Iraq is considered. The project network is represented in Figure 2. The activities are represented with letters (A- Excavate, B- Foundation, C- Building with bricks, D- Exterior plumbing, E- Electrical works, F- Roof, G- Install the interior, H- Paint the grandpa I run cement, I- Interior painting, J- Flooring, K- External wall , L- Exterior painting, M- Interior fixtures, N- Exterior fixtures)

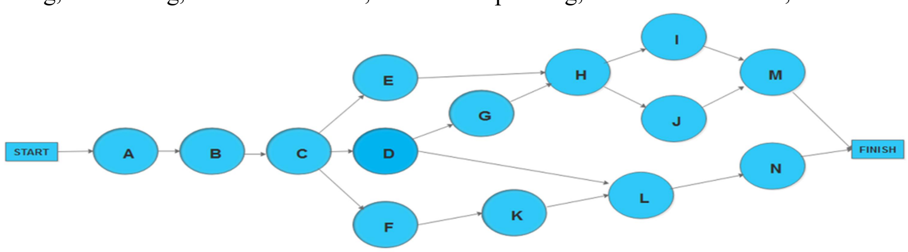

Figure 2. Project network

In this case study main contractor is willing to subcontract activities B, C and F. These activities are colored in Figure 2. Penalty cost of $25, 000 is determined for each week after the 66th week. For the given activities 5 subcontractor alternatives are determined.

The benefits of the alternative subcontractors are determined by AHP. Table 1 is showing the criteria and alternative subcontractors. Data about each alternative subcontractors are obtained and presented in Table1.

Table 1. Alternative subcontractors and evaluation criteria

	Subcontractor (A)	Subcontractor (B)	Subcontractor (C)	Subcontractor (D)	Subcontractor (E)
Experience (Similar work)	6 years experience Two similar	8 years experience One similar	5 years experience Two similar	12 years experience Two similar	4 years experience
Financial stability	$5,000,000 assets	$7,000,000 assets	$10,000,000 assets	$9,000,000 assets	$2,000,000 assets
Quality of work	Good	Average	Good	Good	Bad
Staff	20 Engineers 60 Employees	15 Engineers 40 Employees	20 Engineers 50 Employees	12 Engineers 40 Employees	8 Engineers 25 Employees
Equipment	4 mixer machines 1 excavator 1 bulldozer	5 mixer machines 1 excavator 1 bulldozer	6 mixer machines 1 excavator 1 bulldozer	1 batching plant 2 concrete transferring 2 mixer machines	2 mixer machines
Current works load	1 big project ending 2 projects in mid (1 medium +1 small)	2 projects ending (1 big + 1 medium)	1 medium project started, 2 projects ending (1 big + 1 medium)	2 big projects ending, 1 medium project in mid	2 small projects started, 3 projects ending (2 small + 1 medium)

After applying the AHP method overall ranking for the subcontractors are presented in Table 2.

Table 2. Priority matrix for subcontractors

	Experience (0.3714)	Financial stability (0.2935)	Quality (0.1571)	Staff (0.0551)	Equipment (0.0381)	Current works load (0.0848)	Overall Eigen vector
Company (A)	0.0862	0.4248	0.2693	0.1512	0.0845	0.1437	0.2227
Company (B)	0.2492	0.0885	0.0739	0.2732	0.2641	0.5369	0.2008
Company (C)	0.1521	0.1781	0.4615	0.4489	0.5561	0.1729	0.2418
Company (D)	0.4574	0.2682	0.1636	0.0813	0.0571	0.0843	0.2889
Company (E)	0.0551	0.0396	0.0317	0.0406	0.0336	0.062	0.0458

After crashing the activities B, C and F project completion costs are calculated and presented in Table 3. The costs are also normalized and presented in Table 3.

Table 3. Normalized total costs

Subcontractors	Completion time for project(weeks)	Total cost $	Normalized costs
A	27	1,510,000	0.1979
B	26	1,570,000	0.2058
C	28	1,420,000	0.1861
D	27	1,690,000	0.2215
E	30	1,440,000	0.1887
		7,630,000	1

In order to obtain the best subcontractor a benefit/cost ration is done. Table 4 is showing the benefit/cost ratio for the given 5 subcontractors. Subcontractor C is the best subcontractor after calculating the ratio.

Table 4. Benefit to cost ratios

Subcontractors	Normalized costs	(benefit)	Benefit/ Costs
Subcontractor (A)	0.1979	0.2227	1.1253
Subcontractor (B)	0.2058	0.2008	0.9757
Subcontractor (C)	0.1861	0.2418	1.2993
Subcontractor (D)	0.2256	0.2889	1.2805
Subcontractor (E)	0.1887	0.0458	0.2427

5. CONCLUSION

In this paper a multi-attribute decision support system is proposed where activity normal and crash times/costs are evaluated along with the supplier ranking. AHP and project crashing techniques are combined in the proposed decision support system. Project managers are generally requested to finish their project in a scheduled time by reducing the total cost. However, in such cases only considering the total cost may result in some biased decisions. Therefore, both total cost of the projects and attributes of the subcontractors need to be assessed simultaneously before deciding about a supplier. As the case study illustrates Subcontractor D seems best with respect to total benefit, and subcontractor C best with respect to total cost, however, at the end of the analysis Subcontractor C is found as the best subcontractor.

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