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COST MANAGEMENT IN CONSTRUCTION PROJECTS WITH THE APPROACH OF COST-TIME BALANCING

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ABSTRACT

Project costs management is one of the main and undeniable components in the project management processes, which becomes more important in costly and long-term projects such as major construction projects. In this paper, the most important discussion of engineering is related to cost management, which is cost-time balancing. Cost-time balancing is one of the important issues in project control and planning. The purpose of this issue is the transactional analysis of a variety of project costs and project execution time. In computing the project scheduling, the earliest completion time of the last activity is usually considered as the project delivery date. On the other hand, the project completion time is met based on a series of internal or external restrictions or requirements. In most cases, the completion time is determined longer than the project delivery date by these restrictions. In such conditions, the project completion time can be reduced using some methods. Shortening the duration of the critical path method (CPM) is one of those cases by spending more cost or compressing them. However, the question that always involves the managers and planners' mind in various stages of projects is that how can achieve a proper balance between the estimated time and cost (which certainly are not certain) so that the project to be completed at the estimated time and proper quality while using the maximum available resources. A variety of algorithms and techniques have been developed in the last fifty years to help answering this question, which are divided into two classical and heuristic algorithms. In classical algorithms, some solutions have been presented for the time-cost balancing problem using mathematical techniques and research tools operations. Some of the most famous of these algorithms will be introduced. However, it has been tried in new algorithms to provide methods, which are more consistent with the actual space, or help the large-scale problems to find the optimal solution by using new algorithms such as fuzzy and genetic algorithms. Some of these heuristic algorithms have been proposed and studied in this research.

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KEY WORDS

project management, project cost management, cost-time balancing, Siemens algorithm, construction projects.

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INTRODUCTION

Today, the need for proper planning in order to estimate the project time and cost and the required resources in a project, which have a direct impact on implementation, handling, and operation such as the construction of equipment, construction of dams, highways, apartment complexes is not unsuspected for anyone. This problem is very important, especially in developing countries. Generally, management and planning activities, financial resources, human resources, and required equipment in a project need various analyzes that one of them is modeling and accurate estimation of project costs and time. This problem helps optimizing the project time and cost and decision-making in critical situations.

Programming problem and then, cost and schedule controlling in projects are becoming more important every day. In an environment where companies' competition gets closer every day and small differences in tender prices will lead to the success or failure of the tender, providing a plan that is consistent with the reality that can consider all economic realities in the model of a project has a great importance. This importance not only is for a project price before its implementation but also after beginning to work, a flexible schedule can help a company to face a variety of problems, which are often outside the scope of its discretion.

A flexible schedule is able to consider the necessary changes in the cost and time using the relationship between cost and time in a project. Thus, it can give proper solutions to decision-makers to have an appropriate estimation of time and cost in the project.

There are several steps for project control and planning, including project analysis, estimation of time, cost, and executive resources, and finally, project scheduling. In all these cases, especially during the initial evaluation of the project, it is assumed that all activities are calculated and executed in their real time. Sometimes, a project manager decides to reduce the project time for various reasons. This will have a direct impact on the project cost.
As mentioned earlier, time reduction is realized using special measures such as increased use of execution resources such as increasing human resources, raw materials, the number of machines and the use of advanced machinery, which increases the costs of the project. Sometimes, delay conditions are expected for the project regarding the relationships and dependencies between activities. This condition is associated with increased costs and an internal interactive with delay damages. Therefore, it can lead to increasing or decreasing the overall costs that should be monitored by project management.

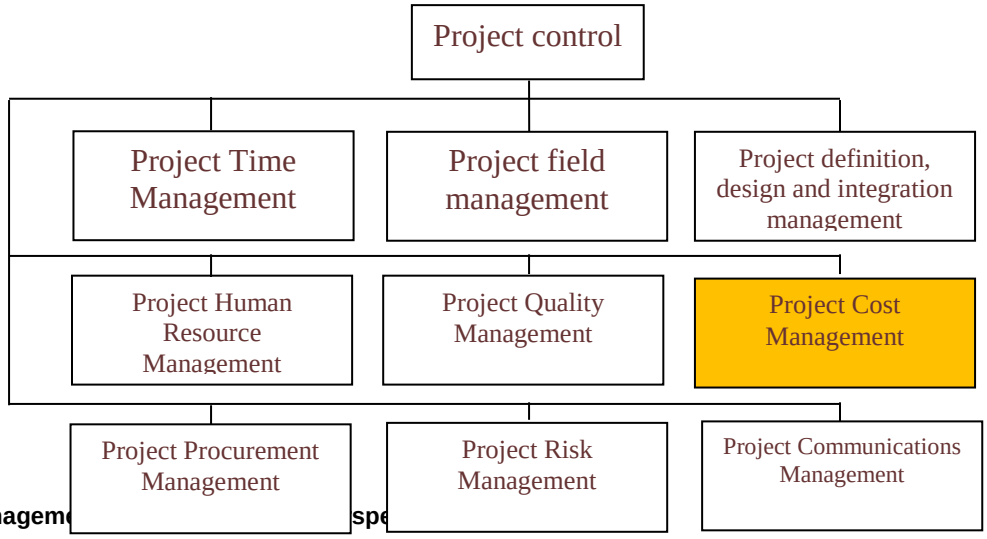

Fig: 1. Project managem sp

In the late 60's, seven principles of objectives, organization, planning, budgeting, coordination, control, and leadership were proposed to management. After a while, the project control issue was raised due to lack of efficiency in projects. Later, the ineffectiveness of control was also proved. Finally, project management topics were defined and explained in Article 9 for better efficiency to provide practical solutions to achieve project goals with less time and cost. It is for a while that the international community has accepted to choose project management instead of project control, but currently, the project control is unfortunately considered more in Iran. PMBOK[1] standard for cost management has identified nine sectors that are referred schematically in **Figure- 1**.

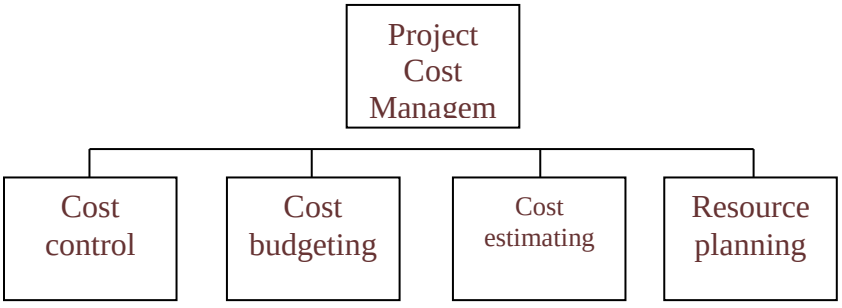

Fig: 2. Different parts of cost managementIn the first step, resource planning will be discussed.

Among these, cost management, which is related to this issue, will be considered. Cost management includes four topics, including resource planning, cost estimating, cost budgeting, and cost control, which is shown

schematically in **Figure- 2**. These four topics are linked together as a chain so that each topic contains 3 input, processing and output sections. Each output is the input of the next section.

MATERIALS AND METHODS

Resource Planning

Resource planning determines this point that what kinds of resources including human resources, materials, equipment, and how many of them should be used to complete each of the project activities. The following sections of this topic are shown in **[Figure-3].**

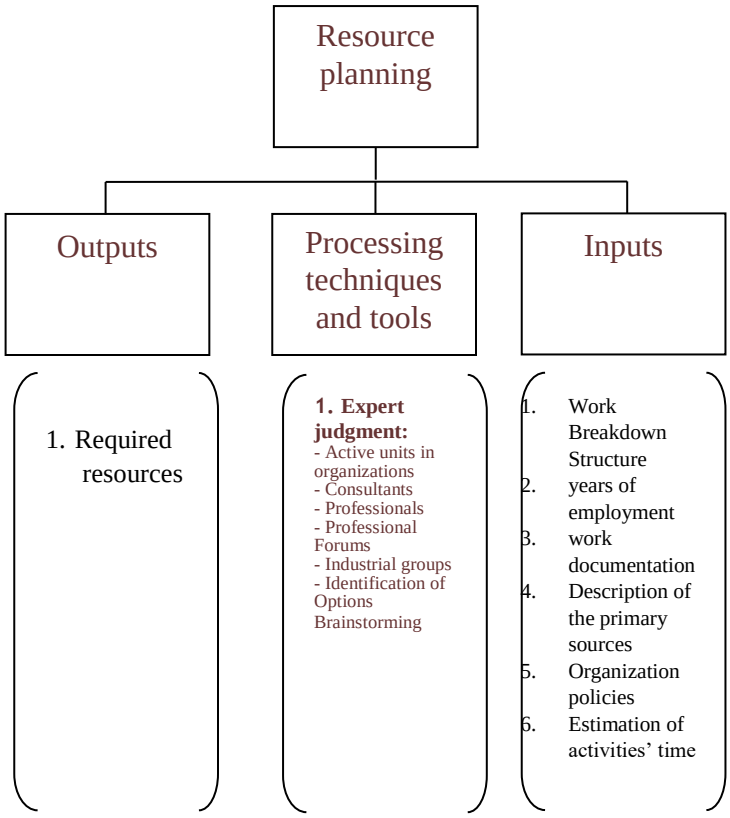

Fig: 3. Resource planning sub-sections in cost management

Cost Estimation

This section provides an estimation form of costs related to the required resources to complete the project's activities. Every project needs a level of estimation of costs regardless of its implementation duration. The economic success of the project or the possibility of a series of measures depends on assumptions about future events. Estimation begins with an understanding of the current situation, and experience is its main base. The most important data for estimation is the recorded cases in the company. The most common estimation methods are trend and regression analysis, which are both mathematical methods for estimating based on previous historical data. Computer modeling is also another method, which has been considered so much in the recent years [1].

The purpose of estimation is our knowledge about the project and the time and cost that we are willing to pay. The accuracy and reliability of an estimation depend on the accuracy of the limited definition of the project and the time and effort that have been paid. Some of the factors that affect the estimations include:

- Technology advancements
- Inflation Forecasts
- Potential cost controls
- Safety and environmental regulations

- Social issues
- Money value fluctuations
- Export-Import considerations (sanctions)
- Commercial and tax prohibitions
- Inflationary pressures, etc.

Due to the limitations of this study, the cost estimation techniques in construction projects were just introduced. The cost estimation sub-sections that are the same in all techniques are shown in **[Figure- 4]**.

The most common techniques to estimate the project cost include:

- Similar estimation
- Bottom-up estimation
- Parametric estimation
- ABC-based activities estimation
- Resource cost rates estimation

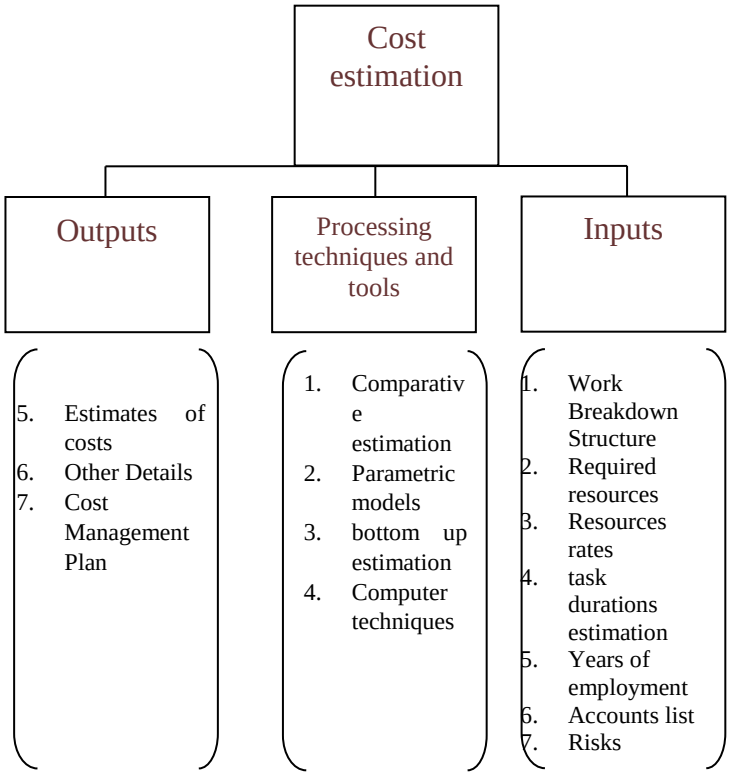

Fig: 4. Cost estimation sub-sections in cost management

Cost Budgeting

This process allocated the total estimated cost of the project to the amount of work for each project activities or its work packages. Cost budgeting provides the possibility that the amount of project performance to be assessed and measured in the future by creating a cost base line. Executive realities may obligate the mentioned estimations after the project approved funding. However, the implementation of such estimations should be done before the project budgeting request and it should be done any time [2]. Budgeting in a simple word is estimating the required resources in organizations, their required amount and time and costs. Budget ties the project to the objectives of organizations and the organizational policy prospects [3]. In this section, the cost budgeting techniques in construction projects were just introduced. The sub-sections that are the same in all techniques are shown in [**Figure- 5]**.

The most common budgeting techniques in project cost budgeting include:

- Cost aggregation
- Bottom-up budgeting

THE IIOAB JOURNAL
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- Reserve analysis

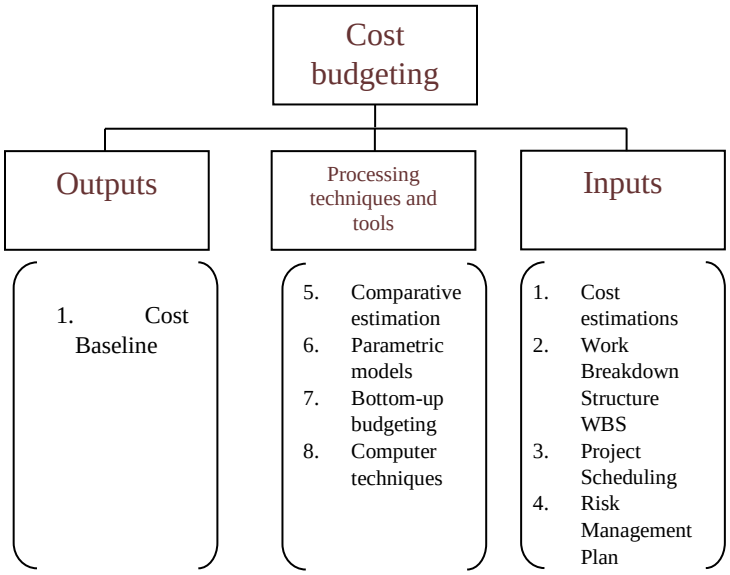

Fig: 5. Cost budgeting sub-sections in cost management

Cost Control

Cost Engineering Association of America defines the cost control as following:
".Process application to observe the cost and performance against the project progress or production operations for measuring the difference between the authorized budgets and allowing effective actions to achieve the lowest cost." [1]

Earned Value Management System is used as the most important cost control technique in projects. Cost control sub-sections are shown in **[Figure- 6]**.

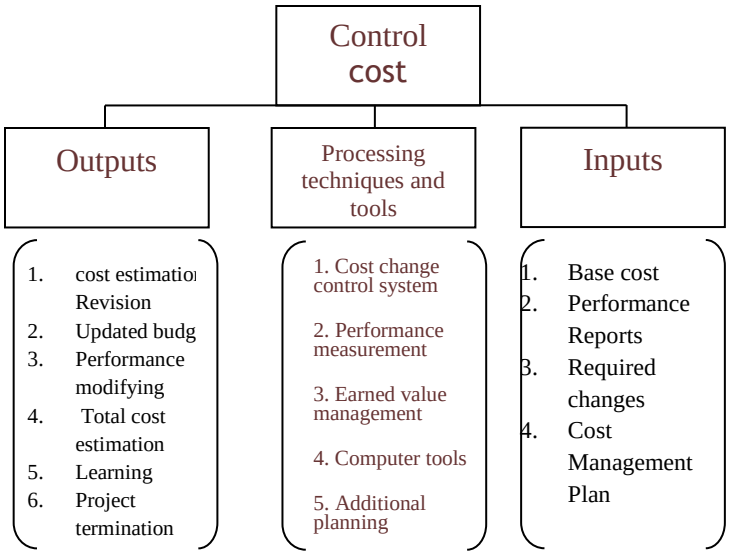

Fig: 6. Cost control sub-sections in cost management

RESULTS AND DISCUSSION

With the development of technology and various methods of construction and creating changes in project implementation systems, contractor companies have been faced with such a complexity and rapid changes, that management cannot lonely have a sufficient knowledge of the environment in the project. For these and other reasons, managers cannot perform their duties. By relying their personal experience and even reflected information in financial statements. Hence, a system is required to help the management to identify the problem and possible solutions, to assess these solutions, to select an optimal solution, to implement the solutions, and their control and evaluation.

Cost-time balancing problem

Cost-time balancing is one of the important issues in project control and planning. The purpose of this problem is the transactional analysis of a variety of project costs and project execution time. In computing the project scheduling, the earliest completion time of the last activity is usually considered as the project delivery date. On the other hand, the project completion time is met based on a series of internal or external restrictions or requirements. In such cases, the completion time can be reduced by following ways:

- Shortening the project completion time through revising the network logic (implementation of some critical activities in parallel)
- Shortening the implementation duration of critical activities to spend more cost or compression [4]

As we know, the costs of implementing an activity (and therefore the cost of full implementation of the project) show different behavior against increasing or decreasing the time. In the overall analysis of project costs, initially, the cost-benefit analysis can be considered in relation to the direct costs of the project. Although the project time reduction leads to high direct costs because of increasing the resources related to project activities, but it has many advantages such as avoiding late penalties, faster operation and more than project product, and reduction of project risks. In addition, the time value of money is also an effective factor in projects. Thus, by reducing the project time, it will be possible to begin flowing the involved capital and increasing the profitability for project investors. On the other hand, the limitation for project time reduction should be considered. This means that by increasing resources and spending more costs in some activities, we reach an extent point, in which the possibility of further time reducing is not possible, or the cost of this time reduction is not reasonable due to project dimensions.

Since 1950, CPM method has widely been used for project control and planning. The main objective of the CPM method is to determine the amount of possible time to carry out a specific project. However, in a real project, project activities should be planned given the resources (such as labor force, materials, equipment, etc.). However, the duration of an activity can be defined as a function of the available resources. Furthermore, combination of various sources has certain costs. Finally, the project planner should create a balance between project costs and its time. Finding the most economical method of carrying out the project in a specified time (as well as finding the shortest time to implement the project with specific budget) is a problem that many heuristic and mathematical algorithms have been created to answer it. These models are usually focused on certain solutions. However, many uncertain factors dynamically affect activities in projects, which may change the time and cost of the project implementation. Some of these factors include: the level of productivity, weather conditions, etc. Various methods such as PERT and Monte Carlo simulation have been developed to solve this problem. These methods rarely provide an answer in providing cost-time balancing [5].

Recently, a number of researchers have used some of the computational methods such as Genetic Algorithm and Simulated Annealing for solving the cost-time balancing problem in construction projects.
Siemens algorithm or cost-effective slope model is explained as one of the most widely used methods in cost-time balancing problem.

1. **Siemens algorithm for cost-time balancing problem**
   Siemens algorithm provides a way to find a proper combination to reduce the activity time so that the project can be done on the specified date and at the same time, the amount of additional costs for the time compression to be at least possible [6].

The definition of Siemens symbols that are used in the algorithm is as follows:

1. Cost factor:

$$c_{ij} = \left|\frac{C_f - C_n}{D_n - D_f}\right| \quad (1)$$

2. Path length

$$D_p = \sum D_{ij} \quad (2)$$

3. Reductionable time of activities:

$$TA_{ij} = D'_n - D_f \quad (3)$$

In which, Cf and Df are compressed time and cost and Cn and Dn, respectively, are the normal cost and time of activity. (In this relationship, D'_n is equal to the current time of activity ij.)
(It should be noted the purpose of the path in this paper is the critical path or CPM, which is usually the longest path of project activities.)

4. It is said the path is short enough when the project can be completed at Tp date and therefore there is no need to further reduction of the time.

5. **Effective Cost factor:**

$$EC_{ij} = \frac{C_{ij}}{N_{ij}} \quad (4)$$

In which, Nij is the number of paths that ij activity is done on it and they were not shortened enough.

6. **Path reduction**
7.

$$TR = \begin{cases} \text{the current path length} - T_p & \text{if (current path length} > T_p) \\ \text{zero} & \text{if } (\text{current path length}) \leq T_p \end{cases}$$

The stages to optimize and shorten the duration of the project (to expedite working or lag compensation)
Step 1: preparation of CPM based on regular times.
Step 2: specifying the paths, which are not short enough and determining the necessary time reduction (TR) for each path.
Step 3: separating all activities, which are in at least one of the specified paths and noting cost and time reduction coefficients.
Step 4: calculating the effective cost coefficient for identified activities in Step 3.
Step 5: Choose an activity that has the minimum cost-effective coefficient for the paths that have the maximum time reduction. If two or more activities have equal conditions, follow these priorities:

A) Choose an activity that is on a larger number of not short enough paths.
B) Choose an activity that has the maximum time reduction.
C) Choose one of the activities randomly.

Step 6: shorten the activity ij that was selected in Step 5 up to the maximum amount. This maximum reduction is equal to the least following values:

A) Reductionable time of activity ij
B) the minimum amount of the necessary reduction for the paths that are not shortened enough and include activity ij:

$$Min\left(TA_{ij}[\min(TR)]\right) \quad (6)$$

Step 7: increase the time for activities that have been shortened more than the necessary amount to the amount that does not create new not short enough paths.
Step 8: If all paths were short enough, stop; otherwise, recalculate the effective cost coefficient for activities that are on not short enough paths.
Step 9: Go back to step 5 [6].

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There are other algorithms for cost-time balancing, which will a near-optimal answer by removing a part of the possible space. Generally, linear programming can be considered as that the best method in terms of accuracy, but problem formulation in this way is time consuming and the answer cannot be achieved quickly. Compared with other classical algorithms, Siemens algorithm can achieve the final answer with a better speed and the answers will have a better accuracy.

CONCLUSION

In this paper, a different series of concepts related to cost and cost management were introduced and studied. The mentioned concepts are general, which will be discussed in the cost management process in various projects. At the end of this section and among the engineering concepts that are discussed in Project Cost Management, time-cost balancing in construction projects has been evaluated as one of the most important cases. This discussion can help project managers to accelerate the work or lag compensation. Then, it has been tried to introduce the most important efforts, which have been done until today in providing cost-time algorithms in the form of classic and new (heuristic) algorithms. Obviously, the detailed review of all these algorithms in the limited volume of this paper is impossible. Thus, it has been tried to explain the main concepts related to these algorithms and a summary of assumptions and their application in the form of one of its kinds in the name of Siemens algorithm or the effective cost slope model. This algorithm makes it possible to compress the project time in an applied mode that imposes the least cost to the project.

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