Time and Cost Optimization in Construction and Project Management

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Abstract- Nowadays, the project time-cost trade-off is very significant in construction management. Since all the activities of a project are related to each other and the completion of each paves the way for starting one or some other activities and the completion of each activity requires spending time and money, project activities should be started and completed according to a schedule. The necessity of this study is because the managers and owners of the projects tend to minimize the time and costs of the project as much as possible. The methods used to reduce the time should also reduce the cost as much as possible because the cost increases with the reduction of time. This study presents an approach that can provide better performance compared to time-cost trade-off methods. Thus, by using this approach, it is possible to start the project before the design phase is completed. Given what was stated, the present study presents a model to reduce direct and indirect costs as much as possible and minimize total project costs. The model was implemented with GAMS software. The results revealed that the implementation of the model reduces the costs and time of the project.

Keywords- Time-cost trade-off, Construction industry, Time and cost optimization.

Introduction

Nowadays, proper planning to estimate the time and cost of projects correctly and the level of needed resources, which have a direct impact on the implementation, management, and proper exploitation of construction projects, is considered a significant and crucial principle in the success of construction projects. The primary focus of managers in construction and implementation is not merely on reducing project costs, reducing the implementation time is also considered thanks to the rapid expansion of the application of various project delivery systems. Various methods have been presented to optimize the time, cost, and quality of construction in construction projects in the last decades. Each project includes a set of executive activities, some of which can be done simultaneously and some others are dependent on each other and are executed according to priority.

Different methods can be used to perform any activity, each of which can be different from the other in terms of duration and cost of implementation. Construction projects were implemented using the design-bid-build (DBB) method. This method had three phases. The first phase is related to the design; the second phase is related to the bid of a part of the activities, and finally the construction phase [1]. In this method, the activities start only if their prerequisite activities have been completed. It is possible to reduce the project completion time to a certain extent in this model. Thus, we should use newer methods to reduce the project completion time. The fast construction method is an efficient method for time management of construction projects [2]. The rework in the construction process is the hidden dimension of the rapid construction method. In this method, the information obtained from the upstream activities may change in a way that causes changes in the downstream activities since the activities are started based on incomplete information about their prerequisites. Thus, it is necessary to ensure that the volume of reworks in this method does not exceed a reasonable level [3]. Rework is defined as an unnecessary effort or modification of the implementation of a particular activity. Rework is at the core of the schedule and cost overruns of many construction projects. Fast-tracking of the primary source is a rework that may jeopardize the benefit of time savings [4]. These activities are not present in the planning and construction mode of construction projects. However, when we use the fast-tracking method, there are a series of activities called rework. It is like time optimization, a volume of which is acceptable that seems reasonable compared to the incurred costs [5].

Khorei et al. (2012) proposed a method of fast construction of construction projects. This method allows starting a downstream activity with incomplete information from upstream activities. To shorten the duration of the project, the project costs are increased. The objective function of the model of this article is to maximize the net benefits for the employers of construction obtained by the implementation of this method. This model was examined in a small-scale case study under different scenarios. This article presents a model for construction projects and finally concludes and provides recommendations [6]. Yamashita (2007) addressed project scheduling by considering the cost of resource availability in uncertain times. His primary goal was to minimize the available resources in a certain period, considering the uncertainty. He modeled this problem with a robust optimization framework. If we assume this problem is in a certain state, it will be the same as the above-mentioned RACP problem. This article is very similar to the mentioned study in terms of considering the uncertainty in some parameters and the type of the used approach, i.e. robust optimization. However, a significant difference between our study and the above-mentioned study is that uncertainty is discussed at the level of the resources required by the employer in our study, while uncertainty about the time parameter is considered in different intervals [7] in Yamashita's article. Cheung (2011) believes that the space of planning and scheduling is associated with uncertainty. To deal with this issue, he defined two scenarios as follows: A- The power of disturbance, B- The occurrence of time disturbance. He used a multi-objective model to model his problem [8].

Azizoglu (2011) addressed the RIP problem with the time-resources trade-off approach. In his research, he considered a situation where the level of available resources is limited and if we need to use more resources in some stages of the project, we will have to increase the project completion time or increase the level of resources to reduce its completion time. He presented a mixed linear programming model for small problems and a meta-heuristic algorithm for large problems. In this study, he used the time-cost trade-off method. However, in the present study, we used a mathematical modeling method [9]. Kheireddin and Asghari (2013) acknowledged that one of the most significant issues in the management of construction projects is project time management. Nowadays, the issue of comprehensive and correct project time management, including resource planning, time estimation, scheduling, and time control, is one of the strategic issues in projects and one of the major concerns for officials and those involved in these projects. A reduction in the time of completion of projects is one of the most significant challenges in construction management and strategic management. In Iran, the problem of most construction projects is the failure to start the components and operate them timely based on the schedule. These lags are so large that they make the project uneconomic in addition to increasing the cost of construction and reducing their quality. This article identifies the factors involved in optimal time management by the employer, consultant, and contractor while defining time management. Finally, it presents the necessary solutions to solve them [10]. Jafaranjad et al. (2009) investigated the emergence of new contracts that consider the increase in the quality of the implementation simultaneously with the reduction in their time and cost. They argue the development of models that include the quality factor in addition to time and cost requires evaluating and optimizing project implementation methods.

Reducing the time and cost of implementation of a project and increasing its quality are different goals that are often not aligned with each other. Thus, such problems have been called time-cost-quality trade-off problems. In this article, a new search algorithm called the direct search algorithm of the time-cost-quality adaptive network of construction projects was used. The proposed algorithm was used to solve a practical problem and its results were compared with those of previous similar studies [11]. Rezaei Namdar et al. (2009) stated that housing construction in Iran is passing from the traditional to the industrial stage. Sufficing to the implementation of the building skeleton using industrial methods, implemented nowadays in Iran, and avoiding a comprehensive view of the industrial production process of the building, may lead to non-achieving the desired results in the industrialization after starting projects with industrial methods and not paying attention to other requirements of the industrial production of the building. In this regard, the factors reducing the project time, the primary stages of planning, and the control of construction projects using industrial methods were reviewed [12]. It was essential to conduct this study since managers and project owners tend to minimize time and cost as much as possible. In this regard, those methods should be used that reduce the cost as much as possible in addition to reducing the time since the cost increases as time decreases. The present study was conducted to design an optimization model to speed up and reduce the time of construction projects.

Methods

The scope of this study is the development of a new scheduling model based on the discrete TCTO model. The present study is related to Baran Commercial Office Complex. The six primary processes of this complex, including primary demolition and excavation, implementation of columns and shear walls and retaining walls, concreting, molding, implementation of beams and roofs, and joinery were selected for review. The order and relationships between the processes are as follows. Baran Commercial Office Complex is located on Shariati St., between Mirdamad St. and Hemmat Expressway, on the corner of Third Deshtestan St. in Tehran.

Table 1 presents the names of the activities, their time in months, and the cost in Rials. The processes of primary demolition and excavation, molding, implementation of beams and roofs, and joinery, which are done in two methods with different costs and times, are also included in the table.

Table 1: name of activities, their time, and cost

Type of the activity		Time (in months)	Cost (in millions of Rials)
Primary demolition and excavation (A)	A1	6 months	35000 million Rials
	A2	5 months	34000 million Rials
Concreting (B)	-	6 months	7500 million Rials
Molding (C)	C1	9 months	18000 million Rials
	C2	7 months	17500 million Rials
implementation of columns and shear walls and retaining walls (D)	-	8 months	9000 million Rials
implementation of beams and roofs	E1	11.5 months	12000 million Rials
	E2	10 months	11800 million Rials
Joinery (F)	F1	9 months	13000 million Rials
	F2	8 months	12700 million Rials

Table (2) shows the relationship between the activities and the lag time of each.

Table 2: The relationship between activities and the lag time of each activity

Activity	Alternative	relationship	Lag time
A	B	FS	0
	C	FS	1
	D	SS	2
B	E	FS	3
C	F	FS	3
D	E	SS	2
E	F	FS	0
F	-	-	-

Figure (1) shows the network diagram.

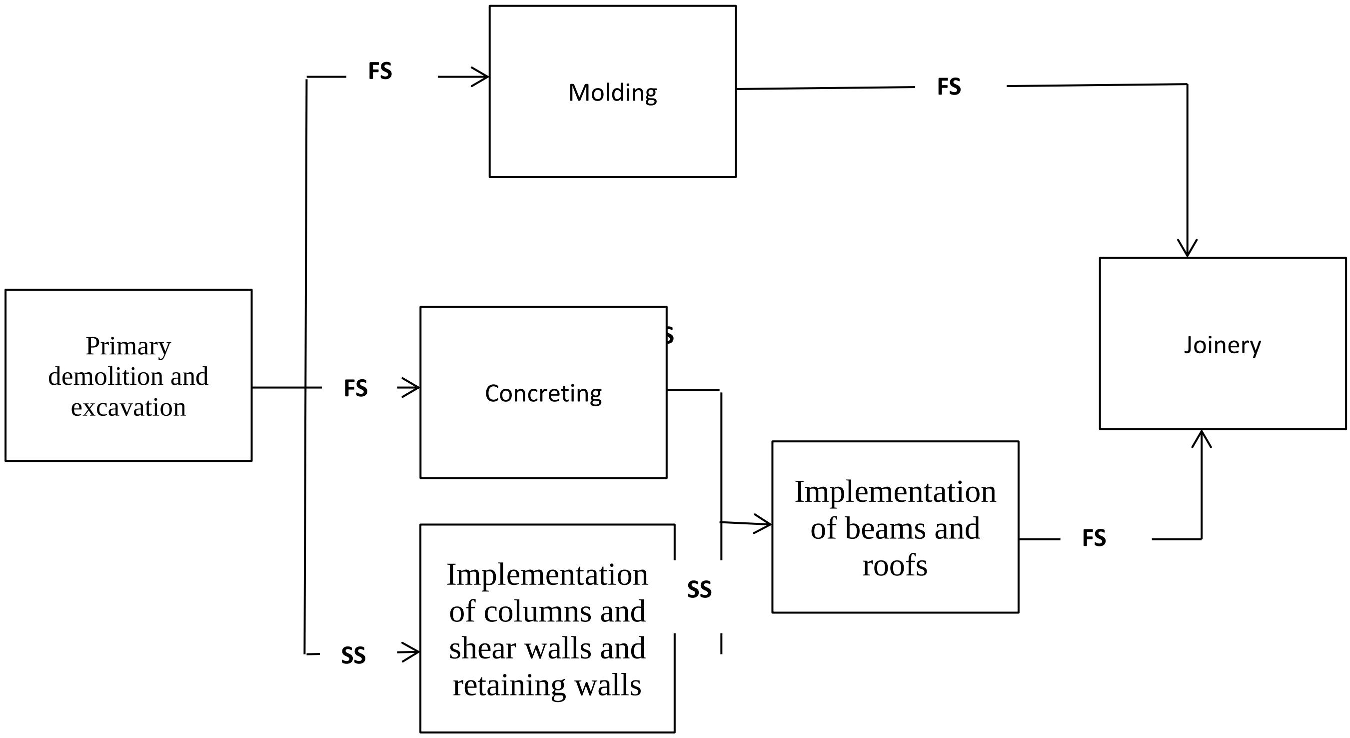

Figure 1: Network diagram of activities.

Proposed model

The model presented in this article is based on the model presented by Kang, Son, and Lee in 2015. They presented a TCTO model to reduce the time of construction projects and tried to meet the two goals of cost minimization and time minimization.

Model assumptions

A- Each project activity can have several states (priority)

B- Each priority has its time and cost

C- Each activity has a normal time and a random time.

D- Normal and random times have corresponding normal and random costs.

F- In this model, time and cost have a linear and continuous relationship with their normal and random time

Index

i: activity index = 1, 2 ...... n

k: state index = 1, 2 ...... m

Model parameters

PD: The duration of the entire project

IDC: Indirect cost rate

Lag A-B: The time lag between activities A and B

Si: Start time of activity i

mi: number of activity states i

Dik: time of activity i in state k

Model variables

X_{ik} : is 0 and 1 variable that:

X_{ik}-1 is used when the construction method of k state is used for activity i

X_{ik}-0 is used when the construction method of k state is not used for activity i

$Cost_{ik}$: Activity cost, when state k is selected for activity i.

In the following, we will analyze the objective function and constraints.

Objective function

$$Min\sum_{i=1}^{n}\sum_{k=1}^{m_i} Cost_{ik}\times X_{ik} + IDC\times PD \qquad (1)$$

$$\sum_{K=1}^{m_i} X_{ik} = 1, X_{ik} = \{0,1\} \qquad (2)$$

Constraints

A- Constraints related to activities A and B with a finish-to-start sequence:

$$S_B \geq S_A + \sum_{k=1}^{m_A}(D_{AK}\times X_{AK}) + \text{Lag A-B} \qquad (3)$$

$$\sum_{k=1}^{m_A} X_{AK} = 1 \quad (4)$$

B- Constraint related to activities A and B with a start-to-start sequence:

$$S_B \geq S_A + \text{Lag A-B} \quad (5)$$

C- Constraints related to activities A and B with a finish-to-finish sequence:

$$S\_B + \sum_{k=1}^{m_B} (D_{Bk} \times X_{BK}) \geq S\_A + \sum_{k=1}^{m_A} (D_{Ak} \times X_{AK}) + LagA - B \quad (6)$$

$$\sum_{k=1}^{m_A} X_{AK} = 1 \quad (7)$$

$$\sum_{k=1}^{m_B} X_{BK} = 1 \quad (8)$$

D- Constraints related to activities A and B with a start-to-finish sequence:

$$S\_B + \sum_{k=1}^{m_B} (D_{Bk} \times X_{BK}) \geq S\_A + LagA - B \quad (9)$$

$$\sum_{k=1}^{m_B} X_{BK} = 1 \quad (10)$$

$$Cost_{ik} \geq 0 \quad X_{ik} = \{0,1\} \quad (11)$$

The mentioned model is a linear programming model and will be solved by GAMS software. To examine the accuracy and validity of the proposed model, data related to a construction project were collected and will be used to solve the model.

Results

The research model is a linear programming model and will be solved by GAMS software. The data of this study were obtained from Baran Commercial Office Complex. The problem was implemented once without considering alternative activities. The results showed that the project completion time is 36 months with a cost of 94500 million Rials. Also, the indirect cost of the project is 9000 million Rials, and the total cost of the project is estimated at 103500 million Rials.

In this study, a relationship between activities was established by presenting a conceptual model. For example, the relationship of SS was considered between the activities of implementing columns, shear walls and retaining walls, and the implementation of beams and roofs. It means that the implementation of the beams and roofs can be started 2 months after the implementation of the columns. Also, alternative activities with lower costs were considered to the activities of primary demolition and excavation, molding, implementation of beams and roofs, and joinery to save the costs. After applying the constraints, we concluded:

A- The duration of the project is 32 months and the cost of the project is 92500 Rials

B- Since the duration of the project was reduced, the indirect costs were calculated at 8000 million Rials

C- The total cost of the project was estimated at 10050 million Rials in this state

D- Between activities A1 and A2, activity A2 is selected with a time of 5 months

E- Between activities C1 and C2, activity C2 is selected

F- Between activities E1 and E2, activity E2 is selected

G- Between activities E1 and E2, activity E2 is selected

Conclusion

The results revealed that the minimum cost of the project is 100050 million Rials and the duration of the project is 32 months. We also concluded that reducing project time increases project costs. Also, based on the relationships between the activities, there is a possibility of overlap between the activities. For example, there is a relationship between the excavation activity and the implementation of columns (SS), indicating that it is possible to perform some activities related to the implementation of columns since the excavation activity starts. Also, there is a relationship between the implementation of columns and the implementation of beams (SS). For example, the molding of beams and roofs can be implemented simultaneously with the implementation of columns. However, overlapping may cause rework in some activities. It is recommended for future studies to consider a non-linear relationship between cost and time.

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