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Time-cost tradeoff in fixed-price contracts based on activities float trading

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Abstract

One of the criticisms of float ownership in construction project is that it ignores the cost compensation of float consumption among project parties. In Fixed-Price contracts, on the basis of the ultimate risk associated with contractor, this party has the right to use float for resource leveling, and owner has the right for change orders. This paper integrates the concept of float in literature in order to introduce a time-cost tradeoff approach which responds to challenges resulted from owner change order consuming float in Fixed-Price contracts. The proposed approach focuses on quantifying the cost of float consumption due to change orders from owners. This new approach provides the opportunity of float control for contractors. It is also flexible to allow owners to consume float. The cost response to float consumption challenges of a sample project time network is presented to illustrate the application of the developed approach.

Keywords: Float, trade, time-cost, fixed-price contracts.

1. Introduction

Float is a time-contingency resource for both owners and contractors (Royer 1986; Householder and Rutland 1990). It is used to help project parties managing their plan. Float provides flexibility for contractor time and budget management (Arditi and Pattanakitchamroon 2006). It could be considered as an incentive for contractors to finish project on time/in time (De La Garza et al. 1991). Float could also serve as a safety guard against project risks (Al-Gahtani 2009). The consumption of float can create many subsequent challenges for contractors and may lead to project delays. Float concept in construction contract has received considerable attention in the literature, and two major float handling approaches have been proposed. First is float allocation approach. This approach addresses how float can be allocated among non-critical activities (Fondahl 1991; Gong et al. 1995; Gong 1997). The effectiveness of this approach was limited by the ambiguity of float ownerships among project parties.

Second is float ownership approach. The ownership approach addresses which party in projects should own float. This approach is a controversial issue in litigations of project delay (Al-Gahtani 2009). Many approaches related to the float ownership were introduced. Ponce de Leon (1986) proposed that both owner and contractor could decide who owns float and suggested that the owner of float have to be written in contract documents. Householder and Rutland 1990 assessed the float ownership based on contract language, and suggested that the contract party who has the ultimate risk should be the owner of the float. They concluded that contractors have the ultimate risk in Fixed-Price contract and owners have the ultimate risk in Cost-Plus contract. De La Garza et al. 1991 proposed a model evaluating the economic aspect of float. They suggested that contractors own the right of float and owners own the right of change orders. In developing the model, the process of pricing and negotiating change-orders is considered. Schedule Games introduced by Zack (1992) suggested that float ownership are owners, and contractors could reserve float by increasing activity durations in planning of project or changing project sequences. Prateapusanond 2004 proposed a 50/50 split approach between a project owner and a contractor. First, float is allocated to the owner and the contractor equally (50/50). Then, the owner and the contractor float consumption are tracked. If one part consumes float more than 50%, this part is the responsible for any delay caused by the consumption. On the basis of this approach, both the owner and the contractor must be cautious on consuming the float. An approach proposed by Al-Gahtani 2006 suggested that any party causing a change in float of a project should receive either credit or debit for the change. Al-Gahtani 2009 introduced Total Risk Approach, considers float ownership based on the total risk. This approach suggested that the party who has the most risk of project should own the most float: a party carries 80% of project risk should own 80% of the float. The approach gives full right to both parties to trade float. However, detailed approach on how to trade float was not provided.

Float consumption by one project party could have negative impacts on the other parties, in terms of increasing risk, duration, and/or cost of project. However, current existing approaches of float ownership did not clearly indicate how to quantitatively evaluate these impacts on other parties. Based on the existing research, this paper therefore proposes a time-cost tradeoff approach in order to consider time-cost challenges of float consumption among project parties in Fixed-Price contracts.

1.1 Float ownership in fixed-price contract

The literature has provided approaches determining float ownership in the language of different contracts, and it is found that type of contract is the key parameter to determine the float owners (Ponce de Leon 1986; Householder and Rutland 1990; De La Garza et al. 1991; Zack 1992; Pasiphol and Popescu 1995; Shumway et al. 2004; Prateapusanond 2004). Fixed-Price contract is a basic form of agreement between owner and contractor. In this contract, a fixed price is established for each unit of work. Fee adjustments and cost escalation are not allowed in Fixed-Price contract, and contractors could make no changes in the initial cost of activities. Therefore, contractor has the ultimate risk in such contracts. Contractor of the Fixed-Price contract, based on its ultimate risk, has the privilege for resource leveling and thus should be the float owner. This right is defined by Shumway et al. (2004) as "Means and Methods" which is a common term to entitle contractors to manage resources by float ownership. However, the owner has the right for change order (Pasiphol and Popescu 1995; Prateapusanond 2004), and therefore it might consume the float owned by the contractor.

1.2 Need of quantitative approach for evaluating float consumption

In general, in Fixed-Price contract when owner consumes float, contractor is not compensated by owner. The float consumption has a potential to provide negative effects on contractor plan for a project, and therefore contractor should be compensated by owner if extra cost is incurred due to the float changes. As mentioned, Fixed-Price contract maintained that contractor is the float owner and therefore can trade the float as a commodity with the owner. To achieve this goal, a new method could be formulated based on current float trading approach. The approach served as the fundamental framework in time-cost tradeoff for float is the Commodity Approach introduced by De La Garza et al. 1991. In this approach, the party who owns and consumes float should pay for the cost to other parties due to consuming other parties' float. Day-by-Day Approach (Al-Gahtani 2006; Al-Gahtani and Mohan 2007) is another approach states each project party should pay cost of float changing. However, none of these two approaches effectively responds the float tradeoff in Fixed-Price contract. Introducing a formula (i.e. quantitative approach) can help project parties to trade float. Owner and contractor can make an agreement on the usage of the formula in contract documents. The formula is a good cost contingency for contractors, and it could reduce uncertainties caused by owner's change orders.

1.3 Formulation approach for float consumption in fixed-price contract

In this section, two main stages to determine a formula for trading float in the Fixed-Price contract are set. This formulation approach is based on the commodity approach introduced by De La Garza et al. 1991. In development of the formula, it is assumed that the owner's change orders only consume float of non-critical activities with happening of no splits; an activity which begins must come to its end.

1.4 Issues selection

The main point in the formulation is to estimate the value of activities and their float relating to each other. In this assessment, all relevant major aspects must be considered. For example, the earlier activity of a path is generally considered as more important activity due to the downstream impacts on other activities of the path (De La Garza et al. 1991). It can cause all activities in the path to start late, and thus this late start schedule is forced contractor to complete other activities within a very little time contingency. Furthermore, in developing the formula, no critical activity is considered. In fact, it is assumed that a project should be completed without changing on its completion date.

The author selects eight major issues which relate directly to project time, cost, and float.

- Number of all non-critical activities in a project time network.
- Float time of each non-critical activity.
- Number of all non-critical paths in a project time network.
- Number of non-critical paths that a given activity is on those.
- Time-critical degree of the paths that a given activity is on those. To determine the time-critical degree of a noncritical path in a project time network, all critical and non-critical paths should be considered. The path float time is the main factor to determine the path degree. The less float, the more critical. For example, a project time network has five paths, two critical and three non-critical. The float time of the non-critical path assumes to be 4, 6, 10 days. The non-critical path with 4 days of float assigns the third rank. The first and second ranks are assigned to two critical paths. Actually, the first and second ranks indicate the project time network has two critical paths. The much number of critical paths on a project time network addresses the importance of the time network for project parties.
- Time distribution of a given activity among its paths. If an activity takes more than half of a path, it may have more effect on the path than that of other path activities.

– Location of a given activity on its paths. This issue addresses the effects of a given activity on its successors. Any changes in time of the last activity on a non-critical path has no effect on the other activities and can only increase the possibility of delay in the project completion date.
– Cost of a given activity into the total cost of project.

The issues 1 to 7 were introduced/considered in previous studies (Love 1983; De La Garza et al. 1991; Callahan et al. 1992; Pasiphol and Popescu 1995; Gong et al. 1995; Gong 1997; Zhong and Zhang 2003; Al-Gahtani 2009). Issue 8 is considered in the literature (Love 1983; De La Garza et al. 1991; Prateapusanond 2004) and is used as the main issue to assess activities in MS Project software.

In order to assess the importance of the selected eight issues in managing real construction projects, a questionnaire survey was implemented on the issues. This survey was administrated by e-mail/fax to random sample of 71 construction project contractor companies in Middle East which years working experience are more than 10 years. General Managers in each company was asked to complete the questionnaire survey. The questionnaire was developed in two sections. In the first section, the contractors were asked to response to the importance of the eight issues (as the main issues relating directly to project time, float, and cost) by Yes or No. The second section asked that the contractors, based on their experience, add new important issues which were not mentioned among eight issues but the contractors thought that they are important. On the basis of general manger position and work experience, it was inferred that the respondents have adequate knowledge to assess the importance of issues. Table 1 presents the distribution of contractors. The response rate of the questionnaire survey was 80.28% (57 out of 71). In this survey, all the eight issues were responded by YES, and no new issues were added.

Table 1
First Questionnaire: Distribution of Contractors

Contractors	Respondents			
	Assumed to Respond		Respond	
	Number	Percent	Number	Percent
Building	39	54.93	33	57.89
Road & Highway	14	19.72	9	15.79
Tunnel	3	4.23	2	3.51
Dam	7	9.86	5	8.77
Refinery & Power Plant	8	11.27	8	14.04
Total	71	100	57	100

2. Formula development

The cost of float time tradeoff between owners and contractors in Fixed-Price contract implements according to the formula (1):

$$\text{Trade off cost of float} = \text{Project penalty cost} \times \text{Activity factor (AF)} \tag{1}$$

In development the formula, the penalty cost for delay in project completion date is considered as the basis for tradeoff cost of float. The delay in project completion date usually happens when for example the completion date of a critical activity is exceed and thus the project completion date is delayed. The calculation method of the project penalty cost always has to be written in contract documents. Since consuming float may lead to raising the possibility of delay happening in project completion date, the tradeoff cost is determined on the basis of project penalty cost.

The activity factor (AF) for a given activity is determined on the basis of the eight selected issues. In order to achieve AF in the quantitative mood, first, the eight issues are written into six major factors as follow (the sequence of factors is not as same as the sequence of issues):

- F_1 = (Activity duration) ÷ (Activity duration + Path* float time)
- F_2 = (Activity duration) ÷ (Path* duration)
- F_3** = (Activity digits) ÷ (Sum of activities digits on path*)
- F_4 = (The number of paths on which the given activity is) ÷ (The number of critical and non-critical paths of project time network)
- F_5*** = (Path* digits) ÷ (Sum of digits of critical and non-critical paths of project time network)
- F_6 = (Activity cost) ÷ (Total cost of project)

$0 \leq Fi \leq 1$
* The path that the activity is on. If a given activity is on more than one non-critical path, the most critical path of non-critical paths (the path with the least float) must be considered.

** This factor is on the basis of Sum-of-the-Years' Digits (SOYD) method of engineering economics. Accordingly, the downstream impacts of earlier activities on the other activities of a path could effectively respond. If the numbers of activities on a path is n, the digits for activity j are: (n-j+1). e.g. a path has three activities, thus the digits of the first activity is 3 (3-1+1), the second activity is 2 (3-2+1), and the last activity is 1 (3-3+1) respectively. Conclusively: F_3 (first activity) = 3÷6 = 0.500; F_3 (second activity) = 2÷6 = 0.333; F_3 (third activity) = 1÷6 = 0.167

*** This factor, like F3, is on the basis of SOYD method. F6 addresses the time-critical degree of a path in a project time network. The path float time shows the time-critical degree of the path. The critical path should also be considered to show the numbers of all project paths. e.g. a project has three critical paths and six non-critical paths, the digits of the most critical path of non-critical paths is: 4, and its F5 is: 6÷45 = 0.133

F1 is a linkage among issues 1, 2, and 5. F2, F3, and F4 address issue 6, 7, and 4, respectively. F5 is a linkage between issue 3 and 5. Issue 8 is addressed in F6.

The next stage is to achieve to an initial factor (IF) for each activity. To achieve this goal, a weight ($0 \leq Wi \leq 1$, i=1,2,3, …, 6) is assigned to each factor (W1, W2, …, and W6 for F1, F2, …, and F6, respectively). The weight for each factor must be selected by project management teams according to the factor importance in construction project. The initial factor is (2):

$$\text{IF (initial factor)} = \sum_{i=0}^{6}\left(W_i \times F_i\right) \qquad \left[\sum_{i=0}^{6} W_i = 1\right] \tag{2}$$

$0 \leq IF \leq 1$

In order to verify and understand the importance of the introduced factors (Fi), another questionnaire survey was implemented. This new questionnaire asked the 57 general managers to assign weight (Wi) to each factor in order to assess the six factors. The responses of contractors were statically analyzed. Table 2 shows the final results. In Table 2, the Total row shows the weighted mean for each Wi. On the basis of given weights, all contractors mentioned that the cost (F6) is the most important factor.

Table 2
Second Questionnaire

Contractors	Percent of Respondents	Average weight					
		W1	W2	W3	W4	W5	W6
Building	57.89	0.025	0.061	0.013	0.031	0.039	0.831
Road & Highway	15.79	0.016	0.149	0.050	0.083	0.009	0.693
Tunnel	3.51	0.056	0.214	0.129	0.025	0.094	0.482
Dam	8.77	0.079	0.120	0.198	0.077	0.021	0.505
Refinery & Power Plant	14.04	0.038	0.185	0.115	0.043	0.072	0.547
Total	100	0.031	0.103	0.053	0.045	0.039	0.728

It must be considered that the possibility of potential delays in project completion date is decreased by the physical progress of project. Therefore, at the time of happening a change order, the physical progress of project can be considered in achieving more realistic results, and therefore it can be used in activity factor calculation.

Finally, the AF for a given activity affected by the owner change order implements according to formula (3):

$$AF = IF \times (1 - \text{Physical progress \% of project}) \quad (3)$$

2.1 Formula usage rule

When a change order consuming float of an activity happens, it clearly consumes the float of successors, and therefore consumes float of project paths. For example, a path has a couple of non-critical activities, and a change order consuming a day of float of first activity on this path happens. This change order assumed consumes one day of float of all successors and thus a day float of path. Indeed, this change order practically increases the possibility of one day delay happening in project completion date. On the basis of this concept, when a change order happens for an activity, the influence of the change order on project paths must be assessed, and the concept of trading float should be generalized to project paths. To achieve this goal, when a change order happens, first, the main activity is chosen. This choice is on the basis of biggest AF among activities that the change order directly affects those and their successors. Then, the tradeoff cost of the change order is determined based on the main activity AF and project penalty cost (Formula 1). Finally, this cost should be considered for the change order affecting the path. In other word, when a change order happens, only the main activity of the path is assumed for calculation of tradeoff cost.

3. Discussion

Generally, cost escalation happens during implementing of construction projects. In a case, costs of main highway materials have risen significantly during 2006 to 2008 (Federal Highway Administration). Project Schedule changes which are controllable by owner could contribute to cost escalation (Shane et al. 2009). Such changes might shift a risk to contractors and therefore have negative impacts on contractors' plan. Changes in project scheduling normally uses the float of non-critical activities which is a source for contractors to manage their planning. This paper proposed a time-cost tradeoff approach to quantify the cost of float consumption due to owners' change orders. The approach is flexible enough to let owner full authority to consume float. It can also control owner change orders consuming float and reduce conventional conflicts usually happens between owners and contractors as a result of float consumption. The usage of the formula could limit owner change orders consuming float of main activities. Accordingly, the optimum use of float can be resulted. The approach also allows calculating the cost of everyday float consumption, and so it can be considered as a kind of day-by-day approach. The commodity approach (De La Garza et al. 1991) is the basic concept and framework of the introduced tradeoff approach. However, the commodity approach does not clearly address the influence of activities on each other. It only depends on the early finish cost, late finish cost, and total float of activities. However, the introduced approach solves the deficiency of the commodity approach in assessing the multilateral relationship of activities on a project time network. This solution is based on the introduced factors (F_i). The author defines the factor based on the activities multilateral relationship. Another challenge in using commodity approach (De La Garza et al. 1991) is that whereas the late finish cost is only resulted after completing an activity, owners can only estimate cost of change orders after activity completion. However, the formulation approach helps owner to estimate the cost of every change order before happening of change order. The main use of the proposed approach is that considering the tradeoff cost can be delayed until completion of project. Then, if any delay has happened, the owner and contractor can discuss the reasons of delay. The introduced trade-off cost can be implemented if it is determined that the owner change orders consuming float have influence on delay happening. Indeed, this cost can be considered as a discount of project penalty cost for contractors. Although the introduced approach of this paper can respond every change order consuming float in all project paths and regulate float management in a project time network, it has some limitations. It only answers challenges in Fixed-Price contract. Indeed, the proposed formula only has to use when each unit of work is fix. In two other main types of contract, Lump-Sum and Cost-Plus, contractors can manage cost of change order by using fee adjustments. Furthermore, it must be considered that after every change order consuming float, overall project time network must be updated. Float time consuming of an activity can make a new time network, and therefore the evaluating process of activities must be implemented from beginning to end of the new network. After any float consumption, the using of formulation approach and defining activity weight would be time-consuming. A computer-based model on the basis of formulation approach can help owners and contractors implementing formulation approach when time network is updated.

4. Illustrative example

To show how the proposed formula can be implemented, a small project is expanded. The project is the example of a previous research work; De La Garza et al. 1991.

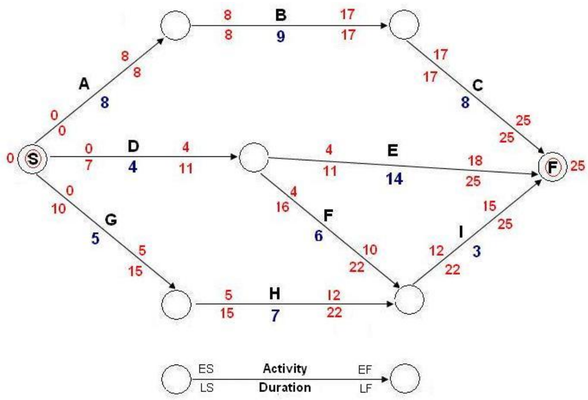

Fig. 1. Project time network

Figure 1 presents the time network of the project, and Table 3 shows total cost and float of the activities.

Table 3
Activities Specifications

Activity	Total Cost ($)	Duration	Total Float
A	10	8	0
B	15	9	0
C	8	8	0
D	5	4	7
E	4	14	7
F	3	6	12
G	8	5	10
H	6	7	10
I	7	3	10

Total cost of project is 66 $, and the project time network has the following four paths:

- First Path: A – B – C = 8 + 9 + 8 = 25 days (total float = 0)
- Second Path: D – E = 4 + 14 = 18 days (total float = 7 days)
- Third Path: D – F – I = 4 + 6 + 3 = 13 days (total float = 12 days)
- Forth Path: G – H – I = 5 + 7 + 3 = 15 days (total float = 10 days)

Table 4
Fi and IF of all Non-Critical Activities

Activity	F_1	F_2	F_3	F_4	F_5	F_6	IF
D	0.364	0.222	0.667	0.500	0.300	0.076	0.159
E	0.667	0.778	0.333	0.250	0.300	0.061	0.186
F	0.429	0.462	0.333	0.250	0.100	0.045	0.126
G	0.333	0.333	0.500	0.250	0.200	0.121	0.178
H	0.412	0.467	0.333	0.250	0.200	0.091	0.164
I	0.231	0.200	0.167	0.500	0.200	0.106	0.144

The owner assumed makes a change order at the start day of activity F consuming 3 days of float. The results of this change are shown in Table 5. It is noteworthy that when change order happens, the physical progress of project is 16%.

Table 5
Activities Specifications

Activity	Duration	Total Float
D	4	7
E	14	7
F	6	9
G	5	10
H	7	10
I	3	9

The second path is the most critical path among all non-critical paths. Based on project time network and cost, the IF of all the activities are assigned (Table 4). For activity D, for example, the IF is as following:

IF = 0.364 × 0.031 + 0.222 × 0.103 + 0.667 × 0.053 + 0.500 × 0.045 + 0.300 × 0.039 + 0.076 × 0.728 → IF = 0.159

As mentioned, activities A, B, and C are on the critical path and therefore those are not considered for this example. The result shows this change order influences on both activities F and I, and therefore influences on the third and fourth paths. This change order consumes three days of activity F, however, one day of activity I, the third, and forth path is actually consumed.

Therefore, this change order only increases the possibility of one day delay on project completion date.

The AF of activity F and I are:

- Activity F: AF = 0.126 × (1 – 16%) = 0.106
- Activity I: AF = 0.144 × (1 – 16%) = 0.124

Since activity I have the bigger AF, it is chosen as the main activity and the tradeoff cost for this change order is:

- Tradeoff cost = Project penalty cost × 0.124

If the owner change order makes one day delay on the project completion date, 12.4% of daily project penalty cost could be considered as a discount for project penalty cost.

5. Conclusion

This paper presents a quantitative float trading approach in Fixed-Price contract. In this approach, contractor owns float which is treated as a commodity between owner and contractor. Based on a quantitative activity factor and the penalty cost for delay in project completion date, the cost of float trading is determined. In order to define the activity factor, eight major qualitative factors of literature were converted to six quantitative factors. A questionnaire survey on 57 general managers of construction contractor companies checked and verified the factors. If owner change orders cause delay in project completion date, the float tradeoff cost can be considered as a discount for project penalty cost.

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