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Float Loss Impact Assessment

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Abstract
Construction projects are challenging and one of the main challenges facing project managers is quantifying the risks associated with delays in the construction industry. In delay analysis, the focus is on delays that occur on the critical path and thus delaying the project. The loss of float is as important and may result in delaying project completion and increasing the project cost. It is difficult to assess the impact of float loss deterministically. This is due to the fact that the deterministic critical path method cannot cope with such delays unless they exceed the total float values.
This paper presents a method that was developed recently to quantify the risks associated with float loss in construction projects. The method uses Multiple Simulation Analysis Technique. Least-squares nonlinear regression is used to convert the stochastic results into a polynomial function that quantifies the float loss impact. The model relates directly the float loss value to project duration and cost at a specified confidence level. This makes easier for project participants to manage the risks associated with delays. It is found that after a range of safe float consumption, any extra delay in non-critical activities leads to significant increases in project time and cost.

Keywords
Risk management, Scheduling, Monte Carlo Simulation, Cost control, Construction Management.

1. Introduction

Managing risk and uncertainty in construction projects is of paramount importance and can lead to the success or failure of projects. The objectives of project management in construction are mainly to complete the scope of work on time, within budget and deliver a quality product safely. In order to achieve these objectives, the project manager must manage construction risks properly. Construction projects are risky due to several factors such as weather conditions, labor skills and productivity, differing site conditions, materials, equipment, and management capabilities. These factors have different degrees of impact on construction activities and project duration. The risk of project delay is high in construction projects. Delays have adverse impacts on construction projects such as increase in project completion time, extra direct and indirect costs, loss of morale, loss of productivity, etc.

Although construction projects participants are aware of the high costs and risks associated with delays and their litigation impact, they have a hard time identifying the scope or magnitude of risks at the activity level accurately. The lack of appropriate tools to assess the impact of delays in construction projects increases the chances of disputes between owners and contractors and makes it harder for the contractor to foresee and mitigate the disruptive effects of delays.

The Critical Path Method (CPM) is the most widely used method in planning, scheduling and controlling construction projects. CPM is a deterministic method in that it is based on the assumption that the duration and cost of activities in a project network are known with certainty. Accordingly, the project duration and cost with calculated using CPM would naturally also be deterministic. However, in most projects, activities' durations and costs are not deterministic due to the uncertainty inherent with the involvement of labor, materials, equipment, weather, and management. Construction delay can be defined as any delay to the start or finish of the activity compared to the baseline schedule calculated by CPM. Construction participants focus on delays on the critical activities as they result directly in project delays. Critical activities are those with a total float equal to zero. Total float is a by-product of the CPM calculations and is defined as the amount of time that an activity can be delayed without delaying the whole project. A major draw-back of the deterministic CPM is that it can not quantify the influence of delays of non-critical activities on the project duration and cost. Delays in non-critical activities do not result in increasing project duration. However, they reduce the available float for the activity and thus reduce the project flexibility. Also, they result in reducing the probability of completing the project on time and/ or within budget.

The use of float is a new subject of interest to many researchers. Gong and James (1995) presented a safe float use range concept. Zhong and Zhang (2003) presented a new method to calculate the path float in PERT. Sakka (2005) and Sakka and El-Sayegh (2007) proposed a new method to quantify the float loss impact on construction project's time and cost. Some researchers recommended the use of the float as a commodity with trade-in value (Garza and Vorster, 1991). Householder and Rutland (1990) raised the issue of float ownership. Other researchers developed new scheduling techniques that can deal with the uncertainties in construction projects. Isidore and Back (2001) expanded the optimum-cost schedule concept to be used with probabilistic scheduling techniques. They used Activity Based Costing Simulation (ABC-Sim) in their research. Isidore and Back (2002) presented an integrated cost and schedule technique based on simulation to obtain reliable project costs and durations. The authors used multiple simulation analysis technique (MSAT) to quantify the relationship that exists between probabilistic scheduling and cost range estimating.. Gong and Hugsted (1993) developed a merge-event time-estimation technique to combine the uncertainties of both critical and non-critical path activities into the time-risk analysis of a project network. They used Back-Forward uncertainty-Estimation (BFUE) technique in their analysis.

This paper presents a method that enables schedulers to quantify the impact of delays in non-critical activities. The MSAT technique, Isidore and Back (2002), is used and expanded to generate reliable project costs and durations at different values of float loss values in concerned activities. Monte Carlo simulation is used to generate these sets of durations and costs.

2. Method

In this paper, the authors present a method that is based on Isidore's and Back's MSAT technique (2002) to quantify the impact of within-float delays in non-critical activities in construction projects. The proposed method enables contractors and owners to quantify the impact of float loss on project duration and cost. The suggested analysis method consists of six main stages. These stages are: (1) Preliminary deterministic analysis, (2) Stochastic analysis of the baseline schedule, (3) Development of scenarios, (4) Stochastic analysis of scenarios, (5) Project duration impact model, and (6) Cost impact model.

In this approach, the results of the stochastically complicated analysis are converted into a simple polynomial equation that directly relates the float loss value in any activity to the new expected project duration and cost at any pre-selected confidence level.

For the purpose of demonstration of this approach, an example used by Gong and Hugsted (1993) and, later, by Zafer (2005) and Zafer and Sameh (2007) is implemented here. The project data is listed in Table 1. In this example, variability is assumed in both cost and schedule to be normally distributed. The total project cost is made of two primary cost items; the direct cost and the indirect cost. The direct cost represents the cost of all labor, equipment, and materials required to complete the entire project. The indirect cost is estimated to be $600/day.

Stage 1: Preliminary Analysis

The CPM showed that path 1-4-12 is the only critical path in the project with a total duration of 66 days and a total cost of $219,100. The total float for all the activities in the project is listed in Table 1.

Table 1: Activities, durations, and costs of example project.

Activity	Predecessor	Mean Duration (Days)	Duration Standard Deviation (Days)	Cost	Cost Standard Deviation
1	-	14	4	$12,000	$2,000
2	-	11.33	2	$8,000	$3,000
3	A	15	5.657	$10,000	$3,000
4	A	21.17	6.1644	$18,000	$3,500
5	B	15.33	1.3342	$12,500	$3,500
6	B	15.83	2.5	$10,000	$2,000
7	D, E	13.17	3.1686	$17,000	$5,000
8	D, E, F	14	2.8583	$7,000	$1,000
9	C	11.17	2.1679	$22,000	$5,000
10	C	1	0	$9,000	$1,000
11	G, H, I	9.17	0.83667	$22,000	$5,000
12	D, E, F	30.83	2.5	$23,000	$6,000
13	J	8.83	0.83667	$9,000	$500

Stage 2: Stochastic Analysis of Baseline Schedule

A stochastic analysis with Monte Carlo simulation, using @Risk, was run on the baseline schedule with no delays in any activity. The simulation was run with 10,000 iterations. The stochastic analysis showed that the mean project duration is 66.9 days with a standard deviation of 6.75 days. The project total cost is $219,644 with a standard deviation of $13,358.
The simulation run for the baseline project resulted in a set of different durations and their associated total costs. Directly relating these durations (after rounding them up) with their corresponding costs produced Figure 1.

The Critical Index (CI) for each activity is calculated and listed in Table 2. The Critical Index is defined as the probability of an activity to be on the critical path. The CI's indicate that the path 1-4-12 (CI_1 = 82.5%, CI_4 = 81.2%, and CI_{12} = 94.7%) has the highest probability of being the critical path.

Stage 3: Development of Scenarios

To reduce risks in construction projects, it is essential to consider the different scenarios of delay that the project might experience. The stochastic analysis showed that although the most probable critical path is 1-4-12, however, activity 2 has a CI value of 17.5% which means that it has a 17.5% probability of being on the critical path. Therefore, the delay in activity 2 needs to be investigated to develop a model to quantify the impact of its within-float delay on project duration and cost.

Stage 4: Stochastic Analysis of Scenarios

The CPM showed that activity 2 has a total float of 8.01 days. Different scenarios of 1, 2, 3, 4, 5, 6, 7, and 8 days delays in activity 2 are considered and analyzed. Monte Carlo simulation with 1000 iterations for each assumed delay value was run for each value of delay. Table 3 summarizes the results of the eight simulations. It can be seen that increasing the delay in activity 2 increases the expected mean project duration and decreases the probability of finishing the project within 66.9 days. Table 3 shows that if the delay in activity 2 is less than 4 days, the reduction in the probability of finishing the project within 66.9 days is insignificant. However, when the float loss exceeds 4 days, considerable reduction in the probability of finishing the project within the baseline schedule is observed. This suggests that activity 2 has a safe float loss level of 50% (4 days) of its total float.

Table 2: Total float for all the activities according to CPM.

Activity	Total float (Days)	Critical Index
A	0	82.5%
B	8.01	17.5%
C	16.66	1.3%
D	0	81.2%
E	8.51	5.9%
F	8.01	11.6%
G	8.49	1.5%
H	7.66	2.5%
I	16.66	1.3%
J	27.17	0.0%
K	7.66	5.3%
L	0	94.7%
M	27.17	0.0%

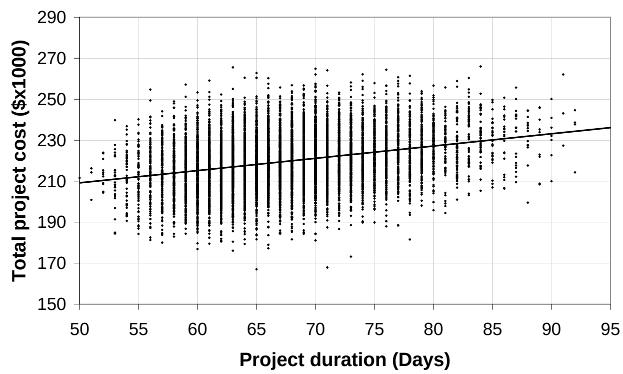

Figure 1 : Project duration versus total cost generated by Monte Carlo Simulation using @Risk.

Stage 5: Project Duration Impact Model

The float loss value and the corresponding mean project duration data generated in Stage 4 is plotted in Figure 2 and fitted in Equation 1. The R^2 value of 0.9995 shown in the figure indicates that using the float loss (FL) in activity 2 helps to explain almost 100% of the variability in the mean project duration.

$$PD_{(Mean\,Value)} = 0.023FL_2^2 + 0.158FL_2 + 66.904 \quad \textbf{(1)}$$

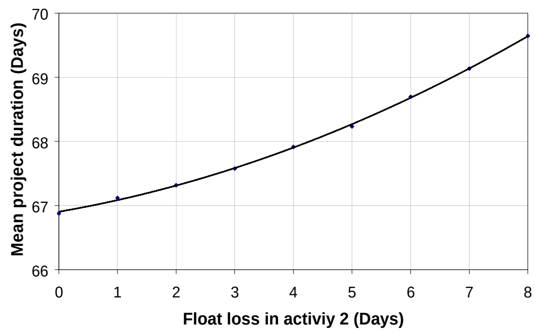

Figure 2: Float loss in activity 2 versus mean project duration

Table 3: Simulation results for different values of float loss in activity 2.

Delay in 2 (Days)	Mean Project Duration (Days)	Rounded up Mean Project Duration (Days)	Probability @ 66.9 days (%)
0	66.9	67	54.1
1	67.1	68	52.6
2	67.3	68	52.9
3	67.6	68	53.2
4	67.9	68	49.9
5	68.2	69	46.0
6	68.7	69	39.3
7	69.1	70	38.1
8	69.6	70	30.2

Stage 6: Cost Impact Model

The stochastic analysis of activity 2 at different values of float loss has shown that the rounded up mean project durations were 67 days @ 0 days float loss, 68 days @ 1, 2, 3, and 4 days float loss, 79 days @ 5 and 6 days float loss, and 70 days @ 7 and 8 days float loss.

The important consideration now is to choose a cost that is directly related to the delay in activity 2 and a sufficient high confidence level, such that, there is a very small chance of exceeding that value.

To estimate the new cost associated with any float loss in activity 2, the "Multiple Simulation Analysis Technique MSAT" (Isidore and Back 2001 and 2002) is applied. In this paper, the application of this technique is extended to quantify the impact of within-float delay in non-critical activities. This is achieved by:

1. Picking the datasets of costs, generated in Stage 2 that correspond to 67, 68, 69, and 70 days of project duration.
2. Sorting the simulation dataset for each project's duration and determining the percentile level of each cost value.
3. Fitting the costs and their associated percentile level at all project durations. Figure 3 shows the graph for the 67 days project durations. Same type of figures can be generated for the 68, 69, and 70 days of project duration. The fitting results are expressed in Equations 2-5. These equations give a total cost at any required percentile level (PL).

At 0 days float loss in 2 (mean project duration = 67 days)

$$\text{Cost} = 126999\,\text{PL}^3 - 188199\,\text{PL}^2 + 115380\,\text{PL} + 192561 \qquad \textbf{(2)}$$

At 1, 2, 3, and 4 days float loss in 2 (mean project duration = 68 days)

$$\text{Cost} = 139724\text{PL}^3 - 215118\text{PL}^2 + 132210\text{PL} + 190929 \qquad \textbf{(3)}$$

At 5 and 6 days float loss in 2 (mean project duration = 69 days)

$$\text{Cost} = 120650\text{PL}^3 - 177798\text{PL}^2 + 112601\text{PL} + 193360 \qquad \textbf{(4)}$$

At 7 and 8 days float loss in 2 (mean project duration = 70 days)

$$\text{Cost} = 134776\,\text{PL}^3 \quad 199871\,\text{PL}^2 + 123990\,\text{PL} + 193479 \qquad \textbf{(5)}$$

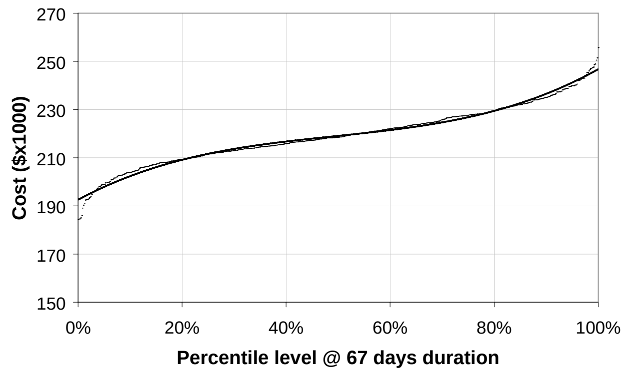

Figure 3: Cost at 67 days duration.

4. Deciding on percentile level to be the confidence level to use in cost prediction. The 95% confidence level is used in this example.
5. Calculating the cost at the chosen confidence level for all values of float loss in activity 2. Figure 4 shows the float loss in activity 2 versus cost at 95% confidence level.
6. Fitting the costs and float loss values in a linear or nonlinear model. Equation 6 presents the fitting results. Interestingly, the same conclusion made earlier from Table 3 about the safe float consumption level can be seen and verified in Figure 4.

$$Cost_{\ (@95\%\,Confidence\ Level)} = 15.624FL_2^3 - 86.191FL_2^2 + 373.46FL_2 + 241480 \qquad \textbf{(6)}$$

Figure 4 shows that if activity’s 2 float is totally consumed (i.e. delayed by 8 days) an increase in cost of 2.2% ($241,208 at 0 days delay to $246,439 at 8 days delay) is expected. This increase might jeopardize most of the profit margin in many construction projects.

The same procedure can be followed for any other activity that is of concern to the contractor and/or the owner.

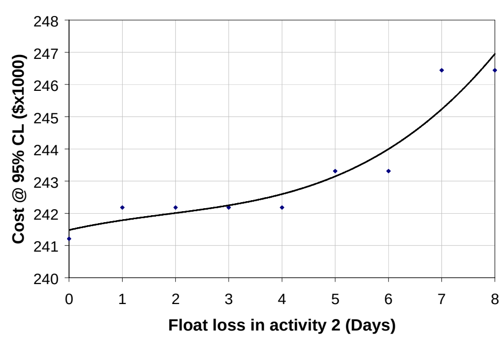

Figure 4: Float loss in activity 2 versus (a) mean project duration, (b) cost.

3. Conclusion

Float loss is one of the risks that needs to be considered by all construction projects stakeholders. Delaying non-critical activities to finish beyond their early finish date make construction projects schedule less flexible and can lead to an increase in project's duration and/or cost. The proposed method managed to quantify the impact of within-float delays in non critical activities on both project's duration and cost.

The method provides contractors and owners with a planning tool to assess and quantify the impact of any change orders or delays on the project duration and cost. This can reduce the conflicts, disputes, and litigations between all construction stakeholders. This is mainly because subjective evaluation will be replaced with objective identification and quantification of opportunity values that are generated by float loss. The method also can predict the safe float consumption level for any activity.

Finally, the proposed method managed to convert the complicated stochastic analysis into a simple polynomial equation that can be used easily by owners and site personnel to quantify the impact of within-float delays.

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