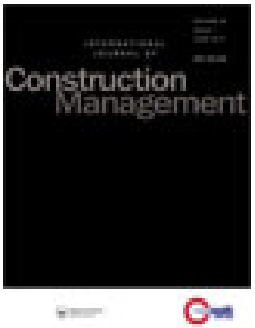

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Float loss impact on project cost

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ABSTRACT

This research contributes to a realistic schedule development that will benefit construction industry professionals to better analyse float loss impact on project cost. The research paper draws attention to the importance of float and how affects project cost, beside that the paper tries to solve the dilemma of float ownership by determining the cost impact of float loss due to project parties' delays. The paper proposes a new approach that classifies the cost impact of float loss into four cases including: interruption of resource usage which will be analysed considering the forgetting and learning theories; effect of Cash flow change; impact of the price change for construction materials during float consumption; finally, float loss impact on crews' cost (Labour and equipment), while activities' duration increase. After that the paper provides a case study to discuss the developed framework and developed simple application tool to calculate the total cost. The results indicated that the float loss has a tangible effect on the total project cost. For the dilemma of float ownership, the float should be available for all project parties with responsibility for float consumption cost damages.

KEYWORDS

Float loss; resource usage; cash flow

Introduction

There are many techniques that can be used to develop a project schedule and the most common used technique is the critical path method (**CPM**). In CPM technique, activities are classified into two types which are critical activities and non-critical activities. Many researchers gave attention to the critical activities, because if any delay occurred will affect the total project duration and cost. However, the non-critical activities have float range. The float can be considered as a time flexibility which activities may be delayed during the execution. So, any delay within these activities' float will not affect the overall project duration. Subsequently, if any one of the project parties caused delays, the float will be the refuge and approximately the only chance to decrease the impact of these delays on the total project duration. Then, the float will be consumed and the project party with later stage of delays will be compensated for the project delays. Accordingly, many disputes occurred between project parties to determine who has the right to own the float. From that, the activities' float gets its importance. The contractor requested to have the float ownership because the contractor has the overall responsibility to construct project works within the contractual milestone dates. However, the owner requested to own the float because the owner pays the project price to the contractor, in order to finishing the project scope, according to the approved schedule program which includes activities' float. This big debate between the two parties to determine which one has the right to own the float went through many phases of discussions and different solutions.

Several researches have been done to solve the float ownership dilemma between the owner and the contractor. Wickwire et al. (1991) assumed that the float is free for any project party that can use it first. Wickwire et al. (1999) mentioned that the float can be considered as an expiring resource which should be available for each party.

Some researchers solved this problem by distributing the float between the two parties. Garza et al. (2007) introduced a concept of pre-allocation of float by adding contract clauses, where the responsibility will be defined in case of any delays with 50%-50% for example, in this case the float pre-allocation should be defined on the project schedule. Also, they recommended that the float should be shared between the two parties. Al-Gahtani (2009) provided an approach to determine which party has the right to own the float according to the associated risks, where the project party with high risk responsibility should reserve the float ownership and should be compensated in case of another party consumed the activities' float. Su et al. (2018) discussed the float ownership using theory of voting among many participants. his approach was derived by applying scheduling and voting concepts then the float ownership has been quantified to protect the protect from delays.

Other researchers analysed the problem of float ownership using different ways, they started to deal with the float as a commodity instead of dividing the float between the owner and the contractor (De La Garza et al. 1991), where the float cost will be determined based on owner and consultant negotiation. Their method taking into consideration the impact of float consumption on flexibility amount, number of new critical paths resulted, liquidated damages if occurred, loss of bonus in case of early finish, etc. Lo and Kuo (2013) discussed cost impact quantification due to float loss using genetic algorithms model which have accurate results, the methodology combined the resource efficiency and the activities duration and concluded that the integration of effective resources can reduce the cost impact of float loss. Al Haj and El-Sayegh (2015) provided a model to calculate the optimum project duration with the least cost considering the effect of float loss. Their model used What's Best solver to

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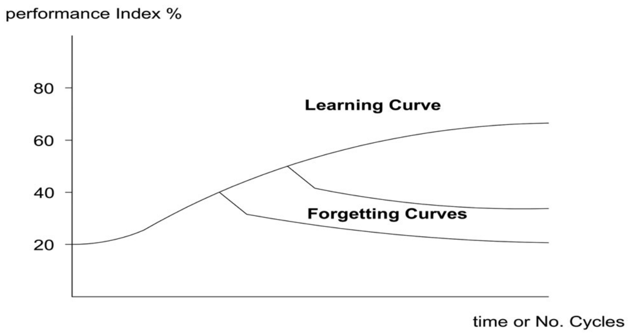

Figure 1. S - Shape forgetting curve (Globerson et al. 1989).

incorporate the impact of float loss on overall project cost, considering float as commodity. They applied project trade off considering cost, time and flexibility. El-Sayegh and Rabie (2016) developed a modified bidding model depending on three main parameters which are cost, time and cost of float loss. The modified model explained the effect of float loss cost on the selection of the project contractor during bidding stage considering the effect of activities' flexibility. El-Sayegh and Al-Haj (2017) proposed a framework incorporating the float loss effect with the time cost trade off analysis using Monte Carlo simulation to select the least total project cost. El-Sayegh (2018) developed non-linear integer model for solving the problem of resource levelling integrating the cost of float loss by using What's Best Solver and sensitivity analysis. their resulted schedule combined both resource optimization and time flexibility.

The cost impact of the activity float loss depends on the extra costs associated with the float loss, then the party who uses the float will be responsible for the associated costs.

Initially, before calculating the float consumption impact, the float is one of the scheduling calculations results for the project activities. So, it is essential to prepare a good schedule planning to meet the project constraints. Good schedule planning depends on the benefits that can be obtained from the continuity of work. During the continuity of work, the labours gain more experience and the productivity increases resulting in less duration for the repeated activities. The activities' duration of the repeated cycles can be calculated using the Learning Theory developed by Wright (1936) based on in Equation 1.

$$\mathbf{Y} = \mathbf{AX^b} = \mathbf{AX}^{\log 2^{r}} \tag{1}$$

where: (**X**) is the number of times the activity done in a continuous way,

(**Y**) is the duration required to complete the activity repeated (**X**) times,

(**A**) the first activity duration and (**r**) is the learning coefficient.

While the duration of the repeated units is decreasing according to the Learning Theory, the direct cost of the repeated units (represented by labour and equipment cost) is decreasing, and in case of critical activities the project duration will be decreased. As a result, the indirect cost will be decreased as well.

During the schedule planning phase, some planners may neglect the importance of work continuity which affects the activities' duration and cost. Using the same productivity rates for all repetitive activities is not the optimum situation in the real construction projects. In practice, the labour productivity rates are affected by work experience gained from repeating the same work more than one time. As the labour experience increasing, better communication happens and adaptation to the site condition occurs. The Learning Theory technique, application and benefits, have been discussed by several researchers (e.g., Couto and Teixeira 2005; Feriyanto et al. 2015; Hinze and Olbina 2009; Jarkas and Horner 2011; Jordan Srour et al. 2016; Lam and Lee 2001; Mályusz and Varga 2016). They studied the learning Theory concept and discussed the corresponding changes on the productivity rate leading to decrease in the duration for the repeated activities.

However, after the planning phase and during the execution phase there will be many conditions that may lead to slippage and interruption to the work continuity. Accordingly, the duration of the repeated activities will be affected. In this case the Forgetting Theory can be used to calculate the new activities' duration. The interruption and work stop will lead to forgetting the experience gained as shown in Figure 1.

The impact of forgetting depends on the interruption duration, the experience gained from achieving the number of units before interruption, and the construction method for the activity.

So, both Learning Theory and the Forgetting Theory should be used during planning and updating the project schedule to calculate the new activities' duration (Huda Badri et al. 2016). The interruption increases the duration of the affected activities. In case of critical activities, the increase in duration due to work interruption can affect the overall project duration and will increase the total project cost. However, in case of non-critical activities the float will be consumption instead of duration increase and the interruption may not affect the total project duration. Although, there is no any effect on the total project duration, the float consumption will affect the activities' cost.

This research paper discusses to the determination of float loss impact on the overall project cost due to different cases of interruption against the plan. This research divided the associated extra costs into four categories including: the costs due to resource interruption, cash flow timing changes, changes of associated materials price, and the increase in labour and equipment costs due to duration slippage. The paper also developed a simple application tool to facilitate the calculation of the total project cost considering the float loss impact as well as a step toward the application in the practical field.

Research approach

The main research objective is to determine the impact of float loss for the non-critical activities on the total project cost which can be illustrated as shown in Figure 2.

The research methodology included four cases for the cost impact associated with float loss. The four cases will be discussed in details as follow:

(1) Resource interruption impact on the project cost

During planning phase, the scheduler should handle the resources with high priority by considering the resource limitations and availability to achieve the maximum possible productivity, which can be achieved through applying continuity of work using the learning Theory. So, the main project constraints including duration and budget can be achieved in an optimized way. While work continuity, the productivity rate increases for the repeated activities. The impact of work continuity on productivity increase is depending on the learning rate. The

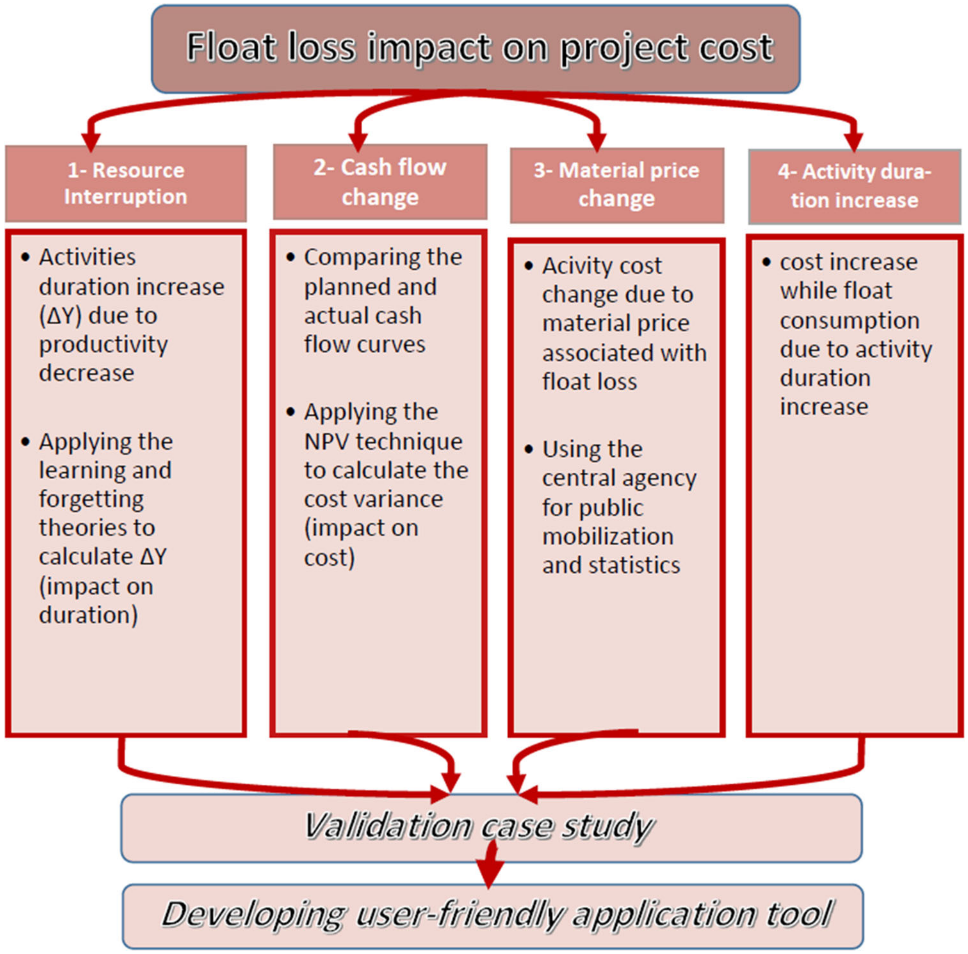

Figure 2. Research methodology.

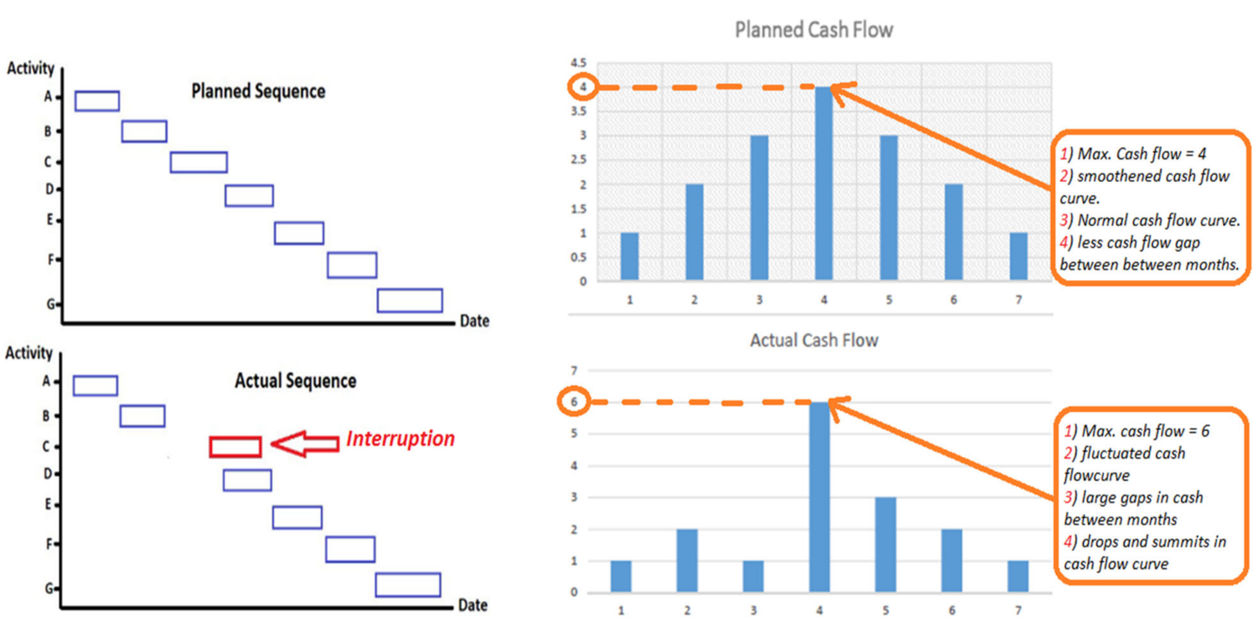

Figure 3. Planned versus actual cash flow.

construction industry has learning rate within a range of 85%-95% (Mályusz and Varga, 2016) and by substituting in Equation 1 with average learning rate of 90%, the duration of each activity for the repetitive work can be obtained based on Equation 2.

$$Y = AX^{\ln(.9)} = AX^{-0.15} \tag{2}$$

During the execution phase, more effort is required to monitor and control the construction activities and to decrease the

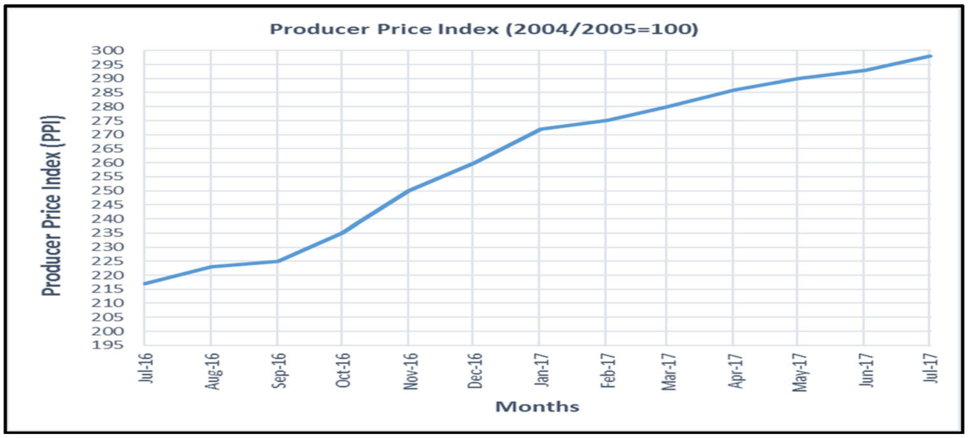

Figure 4. Producer Price Index (PPI) 2016/2017.

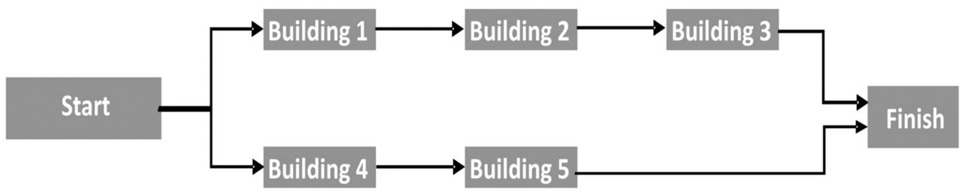

Figure 5. The sequence of work between buildings.

Table 1. The activities included according to the project scope.

Activity Name	Original Duration (A) days	Crew	No. Crews /day	Crew Component	Crew Cost / day	Material Cost
Excavation Works	4	Excavation Crew	1	4 Labor + Loader + 4 Truck	3400	———
Form Work PC	10	Carpenter Crew	2	4 carpenters + 2 helpers	800	15,000
Pouring PC	1	Pouring Crew	1	8 Workers + Pump	2700	80,000
Form Work RC	20	Carpenter Crew	2	4 carpenters + 2 helpers	800	50,000
Steel RC	18	Steel Crew	2	4 steel fixer + 2 helpers	800	380,000
Pouring RC	1	Pouring Crew	1	8 Workers + Pump	2700	180,000
Form Work Col.	6	Carpenter Crew	2	4 carpenters + 2 helpers	800	30,000
Steel Col.	4	Steel Crew	2	4 steel fixer + 2 helpers	800	70,000
Pouring Col.	1	Pouring Crew	1	8 Workers + Pump	2700	30,000
Form Slab	10	Carpenter Crew	2	4 carpenters + 2 helpers	800	50,000
Steel Slab	8	Steel Crew	2	4 steel fixer + 2 helpers	800	270,000
Pouring Slab	1	Pouring Crew	1	8 Workers + Pump	2700	100,000

PPI according to I.S.I.C. — 2004/2005=100
For Jul. 2017 — Cont. Table (4) Manufacturing

Economic Activity	% change from		Index Number		
	Jul-16	Jun-17	Jul-16	Jul-17	Jun-17
Manufacture of basic iron and steel	96.6	3.5	222.4	434.5	420
Manufacture of Bars and rods, hot rolled	92.1	4.8	227.8	437.7	417.7
Manufacture of wood and products of wood	46.7	2.7	244.8	359.2	349.8
Manufacture of wire of aliminum and copper	30	0	184	239.3	239.3

Figure 6. Producer Price Index (July-2017) for some construction materials.

effect of any interruption may happen to the project plan. But in case of if interruption occurs in project resources, the impact of resource interruption should be analysed and the effect on the affected activities' duration and its effect on the affected activities' duration and cost should be calculated.

When the resource interruption occurs, the planner should determine the loss in labour productivity and calculate the corresponding increase in duration and cost. The updated duration for the affected activities can be calculated using the Forgetting Theory as shown in Equation 3. Then, the associated cost can be calculated according to the change in duration between planned and updated duration.

$$Y' = A' \mathbf{X}'^{-0.15} \quad (3)$$

$$A' = A - (A - Yx)(\alpha \mathbf{H} + 1)\mathbf{e}^{-\alpha \mathbf{H}}$$

where: (**A'**) is the first activity duration after interruption, (**A**) is the first activity duration before interruption. ($\mathbf{Y_X}$) is the last unit duration before interruption, (**α**) is the Coefficient of forgetting, (**H**) is the duration of interruption, (**Y'**) is the duration required to complete the activity repeated (**X'**) times after interruption, (**X'**) is the number of repeated times after interruption and (**e**) is the exponential factor.

The activity duration increase will be the difference between the duration calculated from Equation 2 (Planned Duration) and Equation 3 (updated duration after interruption). Accordingly, the increase in the cost for the affected activities can be calculated based on Equation 4.

$$\Delta \ \text{Cost}_{(\text{resource interruption})} = \sum_{\mathbf{i}=1}^{\mathbf{n}} \mathbf{W_i} \ \mathbf{x} \ \mathbf{\Delta d} \tag{4}$$

where: (**Δd**) is the increase in activity duration, (**W**) is the total crews' cost/day for activity, including the equipment and labour costs and (**n**) is the number of affected activities.

(1) Float loss impact on cash flow change

The project work sequence should be carefully planned to efficiently manage the project resources. So, the resulted cash flow will be smoothened and the maximum cash required will be minimized. However, during the Execution phase, work interruption may occur to some activities and affect the cash flow in terms of the timing change for the cash amount as shown in Figure 3. The left part of Figure 3 shows the planned activities sequence versus actual sequence due to delaying an activity. While the right part of Figure 3 represents the effect of the delayed activities on cash flow diagram. Then, the effect of work interruption on the project cost can be calculated using the net present value (NPV). The difference between the NPV of the planned cash flow and the actual cash flow can be calculated based on Equation 5.

$$\Delta\text{Cost}_{(\textbf{CashFlowchange})} = \mathbf{NPV}_{(\mathbf{PL})} - \mathbf{NPV}_{(\mathbf{AC})} \tag{5}$$

where: ($\mathbf{NPV_{(PL)}}$) is the Planned net present value and ($\mathbf{NPV_{(AC)}}$) is the Actual Net Present Value.

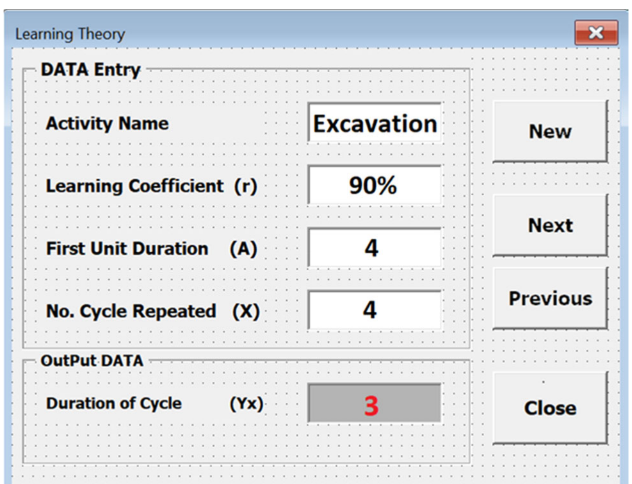

Figure 7. Duration estimate input form.

(2) Material price change during float loss

The baseline schedule which is prepared during planning phase is the reference for the priority and the sequence of work to be applied during the execution phase. During project Execution, the contractor is obligated to achieve the baseline constraints mainly project time and cost. But some deviations may occur to some critical activities which will affect the project duration and increase the total project cost (specially the indirect cost). On the other hand, the deviation for the non-critical activities causes float consumption and the affected activities may become critical or near critical. In case of non-critical activities delayed within their float range, the project total duration will not be affected, although the activities dates have been changed. In this case the price of material for the delayed activities may change due to shifting the activities construction dates. As a consequence, the final project cost will be changed. The change in the material price may have a big effect on the activities' cost, when there is instability in the market price. The change reports in the material price in this research have been analysed based on the reports published by the Egyptian Central Agency for Public Mobilization and Statistics, which revises the monthly price index for each material and for example, Figure 4 shows the material price change during the period from Jul-2016 to July-2017, as the producer price index (PPI) for different materials increased from a value of 215 to a value of 295. Which means that the price has been increased about 80% (using the PPI of 2004/2005 to be equal to 100%) through only one year with an average of 6.67% per month for material prices. Hence, if some activities encountered float consumption for one month between Jul-2016 to July-2017. Then, the related activities material will be increased by about 6.67%. So, while the activities float is being consumed, there will be a cost impact for the associated material

Table 2. Activities duration and associated cost information.

Duration (d) Activity	BL. (1)	BL. (2)	BL. (3)	BL. (4)	BL. (5)	Total Duration	Crews Cost	Material Cost
Excavation	*4*	*4*	*4*	*3*	*3*	*18*	*61,200*	————
Formwork PC	*10*	*9*	*9*	*10*	*9*	*47*	*75,200*	*75,000*
Formwork RC	*20*	*19*	*18*	*20*	*19*	*96*	*153,600*	*250,000*
Steel work RC	*18*	*17*	*16*	*18*	*17*	*86*	*137,600*	*1,900,000*

Superstructure Works Duration (d) Activity	BL. (1)			BL. (2)			BL. (3)			BL. (4)			BL. (5)					
	G	F	R	G	F	R	G	F	R	G	F	R	G	F	R	Total Duration	Crews Cost	Material Cos
Formwork Col.	*6*	*5*	*5*	*5*	*5*	*5*	*5*	*5*	*4*	*6*	*5*	*5*	*5*	*5*	*5*	*76*	*121,600*	*450,000*
Formwork SL.	*10*	*9*	*8*	*8*	*8*	*8*	*8*	*7*	*7*	*10*	*9*	*8*	*8*	*8*	*8*	*122*	*195,200*	*750,000*
Steel work Col.	*4*	*4*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*4*	*4*	*3*	*3*	*3*	*3*	*49*	*78,400*	*1,050,000*
Steel work SL.	*8*	*7*	*7*	*6*	*6*	*6*	*6*	*6*	*6*	*8*	*7*	*7*	*6*	*6*	*6*	*96*	*153,600*	*4,050,000*
Pouring																	*108,000*	*3,250,000*
Total direct cost																	***12,859,400***	

BL: Building; G: Ground; F: First;
R: Roof; Col.: Column; Sl.: Slab.

Table 3. Interruption information and the associated impact.

No.	Activity name	Time interruption	Reason	Affected activities	Planned float	New Float	Planned duration	New duration	Cost impact
1	***Excavation of building** (4)*	*Work Stop for (5) days*	*Delay due to Owner's new Instructions*	*Excavation of BL. (4)*	*30*	*25*	*3*	*4*	*-3400*
				Excavation of BL. (5)	*30*	*25*	*3*	*4*	*-3400*
2	***Roof floor slab for building** (4)*	*Work Stop for (7) days*	*Delay in activity Inspection by the Consultant*	*Formwork Col. Bl. (5)-G*	*30*	*23*	*5*	*6*	*-1600*
				Formwork Sl. Bl. (5)-G	*30*	*23*	*8*	*9*	*-1600*
				Formwork Col. Bl. (5)-F	*30*	*23*	*5*	*5*	——
				Formwork Sl. Bl. (5)-F	*30*	*23*	*8*	*9*	*-1600*
				Formwork Col. Bl. (5)-R	*30*	*23*	*5*	*5*	———
				Formwork Sl. Bl. (5)-R	*30*	*23*	*8*	*8*	———
				Steel work Sl. Bl. (4)-R	*30*	*23*	*7*	*8*	*-1600*
				Steel work Col. Bl. (5)-G	*30*	*24*	*3*	*4*	*-1600*
				Steel work Sl. Bl. (5)-G	*30*	*23*	*6*	*7*	*-1600*
				Steel work Col. Bl. (5)-F	*30*	*24*	*3*	*3*	———
				Steel work Sl. Bl. (5)-F	*30*	*23*	*6*	*7*	*-1600*
				Steel work Col. Bl. (5)-R	*30*	*24*	*3*	*3*	————
				Steel work Sl. Bl. (5)-R	*30*	*23*	*6*	*6*	————
The total cost impact							***-18,000 pounds***		

price that will affect the total project cost. The cost increase can be calculated according to Equation 6:

$$\Delta\ \text{Cost}_{(\text{Material price change})} = \sum\nolimits_{i=1}^{n} \mathbf{Q_i\ xP\ x\Delta PPI} \quad (6)$$

where: (**ΔPPI**) is the change in the producer price index during the period of float consumption, (**Q**) is the total material quantity for activity, (**P**) is the material unit price before float consumption and (**n**) is the number of the affected activities.

(3) Crews' cost increase due to float loss

The activity duration during planning stage is calculated based on the resources productivity rate and the activity quantity. During Project Execution, some interruption may prevent the planned productivity to be achieved and the activity duration will increase accordingly. In case of duration increase was within the affected activities' float, the float consumption will not increase the total project duration. However, while the duration is being increased and the float is being consumed, the direct cost of activities increases (Labour and equipment) but the indirect cost will not be affected. Then, the total activities' cost may be increase. The cost impact due to the float consumption can be calculated according to Equation 7.

$$\Delta\ \text{Cost}_{(\text{Activity duration increase})} = \sum\nolimits_{i=1}^{n} \mathbf{W_i\ x\ \Delta d}\ (7)$$

where: ($\boldsymbol{\Delta d}$) is the amount of duration increase, ($\mathbf{W_i}$) is the total crews' cost/day for the affected activity including the equipment and labor costs and (**n**) is the number of affected activities.

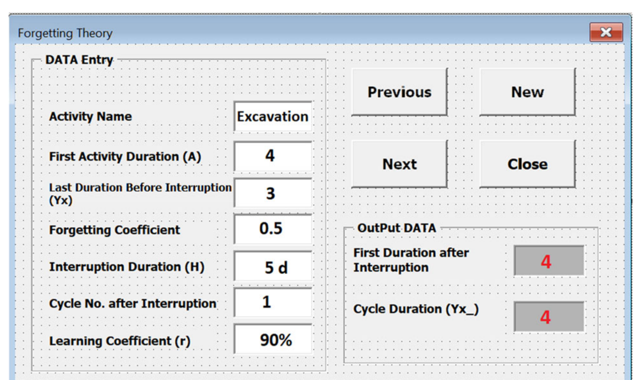

Figure 8. Application tool for forgetting theory.

Validation case study

To discuss the impact of float loss on the total project cost, a theoretical case study will be analyzed in detail to proof the concept and to validate the four points of the research methodology. A simplified application tool has been developed using Visual Basic for Application (**VBA**). The developed tool is user-friendly and can be used to easily analyze the impact of float loss and identify parties responsible and their associated cost.

The case study is a project consists of five buildings, each building has three floors (Ground, First and Roof floors). The considered scope of work contains excavation and concrete skeleton works only. The sequence of work has been assumed as shown in Figure 5. Table 1 shows the project activities, their resource requirements and labors and materials cost.

Assumptions

- The excavation crew moves from Building (1) to Building (5) consecutively.
- Buildings (1) and (4) will start at the same time, and Buildings (2) and (5) are starting at the same time as well.
- The sequence between activities for each building starts with ground floor then first floor and finally the Roof floor.
- The indirect cost is about 10% from the total direct cost which is 214,000 per month.
- The PPI has been assumed according to I.S.I.C for July 2017 as shown in Figure 6.
- The mark-up has been assumed as 15% from the total cost.
- The invoice is scheduled to be monthly.
- The annual interest rate is 15%.

A- Planning stage

To develop the planned project schedule considering continuity of work. Learning Theory shown in Equation 2 has been applied to find activity duration for each building. Figure 7 represents the input form to calculate activities' duration for the five buildings. The output from this process as shown in Table 2 shows all activities duration considering learning rate effect. Table 2 also, shows the total crew cost and the materials cost for each activity

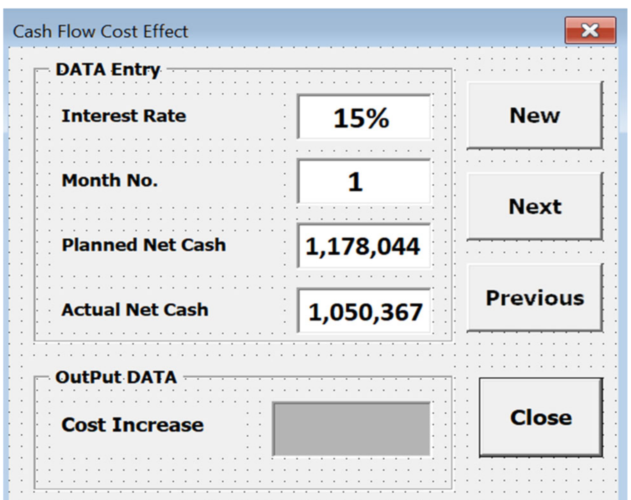

Figure 9. Cash flow cost impact input form.

B- Execution stage

During the construction stage, the project encountered some obstacles and external conditions prevented the continuity of work for some non-critical activities and delayed these activities which shorten their float. Table 3 shows the work stop, delay reasons, old and new durations and cost impact. According to the work interruption, the productivity rates have been decreased and accordingly, the cost increase due to the float consumption which will be discussed according to the following four cases:

(1) Cost impact due to resource interruption

For the resource interruption case, some activities encountered resource interruptions due to work stop which cause delays for some activities (Excavation and roof slab for building **4**) as shown in table 3. The input form shown in Figure 8 has been used to calculate the cost impact by applying the Forgetting Theory shown in Equation 3 to consider work interruption. Output data for resource interruption impact as shown in table 3 including: The impact on time and cost, reasons, the planned and new float for affected activities as well as the new activities' duration calculated based on resource interruption impact. Last column of Table 3 represents the impact on activities' cost which

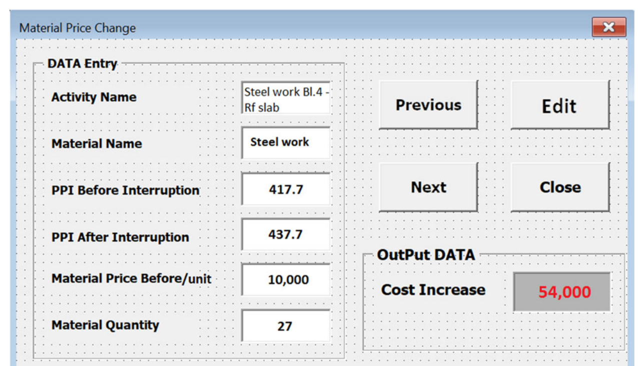

Figure 11. Material price change input form.

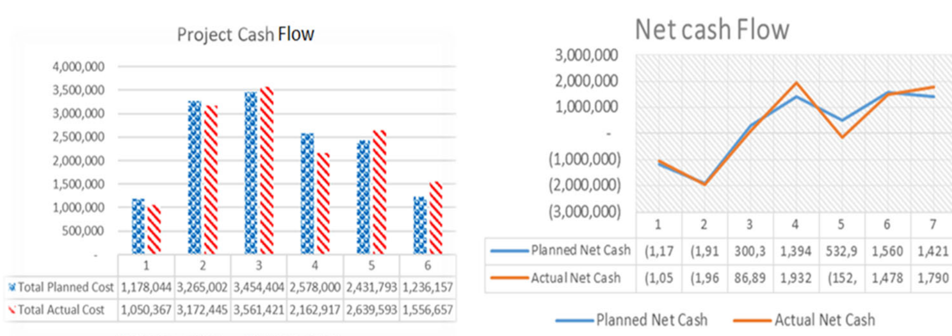

Figure 10. Planned versus actual project cash flow.

Table 4. NPV calculations for planned and actual values (annual interest rate 14%).

Month	1	2	3	4	5	6	7	Total NPV
Planned Net cash	−1,164,459	−1,866,447	290,077	1,331,340	502,880	1,455,502	1,310,718	**1,859,611**
Actual Net cash	−1,038,254	−1,919,474	83,919	1,845,094	−143,660	1,379,453	1,650,550	**1,857,628**

Table 5. Increase in activities duration.

Activity	Reason	Duration increase	Float Before	Float After	Total Crews cost/day	Cost increase
Formwork slab Bl.5 -G	*Contractor material delivery delay (causing less productivity with no effect on the learning curve)*	*2 days*	*23*	*18*	*2*800*	*3,200*
Steel work slab Bl.5-G		*4 days*	*23*	*18*	*2*800*	*6,400*
Total cost increase					*9,600*	

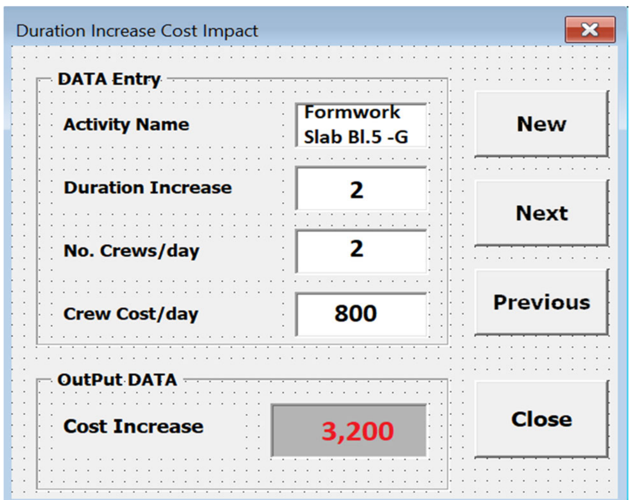

Figure 12. Crew cost increase input form.

all have negative value which means extra cost of total 18,000 pounds for the all affected activities.

In Case of Steel work activity for Roof floor slab of building (4) for example, there was work stop for 7 days. By substituting in Equation 3, H = 7 Days, A = 8 Days for the first activity duration, α is the forgetting coefficient, α> 0 and α< 1. So, α has been assumed to be 0.5. Y_X is the last activity duration before work stop (Y_X = duration of steel work for first floor slab of building (4) = 7 days) using Equation 3, A' = 8 days and the interrupted duration of Steel work for roof floor slab of building (4) = 8 days, and the planned duration is 7 days, which mean that there will be an increase in the activity duration of 1 day. The impact on cost due to the resource interruption has been calculated as 1600 Egyptian Pound. The cost increase represents 1.66% from the total crew cost and 0.14% from the total project direct cost.

(2) Cost impact due to cash flow change

During execution some activities also have been delayed (shifted) which consumed floats for some non-critical activities and affected the monthly cash flow amounts as shown in the left part of figure 10. All cash flow information has been entered using the input form shown in Figure 9. Monthly and cumulative net cash flow of the planned and actual as illustrated in the right part of Figure 10. As shown in Figure 10 for example at month 4, the monthly planned cash value of the project is less than the monthly actual cash value by 107,017 pounds. This means that the contractor was requested to achieve more work than the monthly planned work that will require more money and more resources to be considered by the contractor.

NPV method has been used to calculate the impact of cash flow change on the project cost as difference between the planned and the actual monthly cash flow values as shown in Table 4.

Based on the Float loss impact, **NPV** calculations resulted in increase in cost of 1,983 Egyptian pounds which represents 0.0155% from the total project direct cost.

It can be noticed that, the cash flow effect has very low impact since the applied theoretical case study has small project duration (less than one year). So, the cash flow impact did not appear obviously. In reality, the real projects' duration usually ranges from 2-5 years or more so any change in cash flow amounts will have tangible impact on project direct and indirect cost.

(3) Cost impact due to material price change

For the applied case study, the price of steel work activities has been increased during the activities execution which increased the direct cost for the related activities. The effect of material price change on the direct cost for the Steel work of Roof floor slab of Building (4) will be demonstrated. Float consumption delays some activities and affected steel work activities through the period from June 2017 to July 2017, the activity direct cost has been affected by increasing the material price. Using the producer index provided by the central agency for public mobilization and statistics of Egypt shown in Figure 6. The steel material had PPI 437.7 for July-2017 and 417.7 for June-2017. So, there was an increase in the material cost from June to July of 20%. The formwork activities also, the increase in PPI was (359.2 - 349.8 = 9.4%). All materials data have been entered using the input form as shown in Figure 11 to calculate the cost impact according to Equation 5. Based on cost impact calculations, the change of material price of steel materials increased the direct cost by 60,200. The change of formwork material price increased the direct cist by 5,264. The cost impact due to material price change is 65,464 which represents 0.51% from the total project direct cost.

$$\text{Cost impact}_{\text{(price change for Steel material)}} = \{(4*20\%*270{,}000)_{\text{slab}} + (3*20\%*70{,}000)_{\text{column}}\} *(7/30 \text{ per month}) = 60{,}200\,\text{L.E}$$

$$\text{Cost impact}_{\text{(price change for formwork material)}} = \{(3*9.4\%*50{,}000)_{\text{slab}} + (3*9.4\%*30{,}000)_{\text{column}}\} *(7\,\text{days}/30\,\text{days per month}) = 5{,}264\,\text{L.E}$$

Then, $\Delta\ \text{Cost}_{\text{(Material price Change)}} = 60{,}200 + 5264 = 65{,}464$ ***Pounds.***

$\Delta\ \text{Cost}_{\text{(Material price Change)}} = 65{,}464/12{,}859{,}400 = 0.51\%$ ***of the total project Direct Cost.***

(4) Float loss impact on crews' cost

For the case study there was an increase in the duration of some activities such as steel work and form work as shown in Table 5.

Table 6. The total cost impact due to float consumption for each party.

No.	Case	Cost Impact	Responsibility
1	*Resource interruption for the Excavation of building (4)*	*6,800*	*Owner*
2	*Resource interruption for the Roof floor of building (4)*	*11,200*	*Consultant (Owner)*
3	*Cash Flow Effect for the activities of Excavation and work stop of Roof floor of building (4)*	*1,983*	*Owner*
4	*Material Price Change for the activities of Excavation and work stop of Roof floor of building (4)*	*65,464*	*Owner*
5	*Duration Increase of the Formwork slab Bl.5 -G*	*3,200*	*Contractor*
6	*Duration Increase of the Steel work slab Bl.5-G*	*6,400*	*Contractor*
Contractor Cost Responsibility			***85,447***
Owner Cost Responsibility			***9,600***

The duration for activity slab Form work for of building 5 has been increase by 2 days and steel work for the same slab has been increased by 4 days. The duration-increase related information for each activity has been defined using the input form shown in Figure 12.

The cost impact due to duration increase has been calculated as shown in Table 5 which shows the total increase in direct cost by 9600 and represents 0.075% from the total direct cost.

Total project cost impact summary: the float loss impact on the total project cost for the applied case study can be calculated as the summation of all previous calculated cost impact of total 95,047 Egyptian pounds which represents 0.74% of total project direct cost. So, it will decrease the contractor profit.

Finally, the total cost impact due to the float loss will be distributed according to the responsible party who consumed the float as shown in Table 6.

Conclusions

To achieve the optimum project cost and time, the continuity of work should be considered while the project schedule program is being prepared, and plan all resources synchronization in a smooth and continuous way where the maximum productivity rate can be achieved. During the project construction phase, the project progress is being monitored where the actual progress may deviate from the planned schedule due to interruption/problems for some activities. If this deviation caused by delays for some critical activities, the project time and cost will be affected immediately. However, in case of deviation caused by delays for some non-critical activities, the activities' float will be the refuge to decrease the effect of delays. While the effect of delays is being reduced, the float is being consumed and may be converted to critical activities. As a result, the activities' float management is very crucial to both owner and contractor. So, the authority to own the float should be identified to analyze each party responsibility for cost and time increase.

This research paper developed a simplified method to analyze the impact of float loss on the final project cost and identified the responsibility for each party for the cost impact. The paper discussed a case study of four cases of float loss and calculated their impact on project cost. First, the resource interruption due to float loss which decreased labors productivity and increased the total project direct cost by 0.14%. Second, the change in cash flow amounts due to delays of some activities which increased the project cost slightly according to NPV calculations due to short life span of the analyzed case study. In reality the float loss impact considering cash flow change will have tangible impact on the project cost. The paper also discussed the effect of material price change due to delaying or shifting some activities which increased the total project direct cost by 0.51%. finally, the paper discussed the crew cost increase due to activities duration increase resulted from float loss which increased the total project direct cost by 0.075%. The total increase in project direct cost due to float loss has been calculated as 0.74% which is significant percentage that should be considered carefully. The user-friendly VBA tool has been developed to ease the process of analyzing the impact of float loss on the project cost which can be applied in the practical field to warn the project parties to the importance of managing activities float. The proposed method should be applied in real case studies for different types of projects to test its practicality and suggest any improvements for future research.

Discussion and recommendations

The paper provided detailed analysis of float loss impact on project cost through theoretical case study to proof the concept and provided the detailed calculations that may be applied in real case studies to validate the proposed method. The proposed method should be applied to more than one real project to test its ability to detect the real impact of float loss on project time and cost and to identify the responsible parties and the associated extra cost. one more benefit from applying the proposed method in real project to warn contractors about the importance of managing non-critical activities' float which may cause extra cost to project and cause conflicts between different parties. The proposed method should be applied to different types of projects (residential, commercial, roads, tunnels, etc.,) to suggest modifications and recommendations to enhance the proposed model.

The proposed method should also apply the cost impact of float loss on both critical and non-critical activities. So, the results will be more practical to be applied on real construction projects.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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