Development of Schedule Float Calculation Program

Chi-Yun Ke and Jyh-Bin Yang

Abstract—**Schedule planning for construction projects is usually performed by critical path method, by which critical path(s) and activity floats in a schedule are generated for performing necessary management actions. Some project managers do not make good use of the critical path(s) and floats, because they might have misunderstanding on obtained information or incorrect results. Schedule floats is handily for use through commercial project management software (PMS). However, available PMSs provide total float and free float only. This study first reviews various float types in literature and PMSs, and then clarifies the correct float calculation methods. After that, a schedule float calculation program is developed in this study. The developed float calculation program is the basis for possible float management applications. With that, project managers can manage schedule more correctly and efficiently.**

Index Terms—**Project management, critical path method, float, float management.**

I. INTRODUCTION

Construction projects with large-scale or complex interfaces is a global trend. It might be difficult for project managers to control project schedule when a project has lots of activities with complicated logical relationships. Nowadays there are plenty of project management software (PMS) to help project managers plan project schedule and they could update the proportion of project activities to control the variety of a schedule. Generally, PMS calculates the schedule by critical path method (CPM) and project managers control critical path(s) and floats to manage project progress. The changes of critical path(s) and the consumption of schedule floats are the key for completing a project on schedule.

Schedule delays are common for construction projects. Although managing a project schedule through a PMS is a fundamental work for a construction project manager, many project managers did not make good use of it. They might ignore the warning message on critical path(s) changes or float consumption. When a project is far behind schedule or really delays project completion date, it is too late to rescue project schedule and costs. Most PMSs do not provide a function for managing critical path(s) changes or float consumption. However, there is a need to have an easy-to-use float management function in available PMSs.

Total float (TF) and free float (FF) are the main types of floats in available PMSs. It is insufficient to manage a complex project so far. Therefore, this research attempts to develop a float analysis system that provides various floats calculation with visualization. With the system, project managers can perform a better schedule management.

The paper is organized as follows. In the next section, at literature review on schedule floats is conducted. Through a discussion on available float types, this study determines to select seven types for developing a schedule float calculation program. Section three illustrates float calculation methods and the developed program. Section four illustrates a test case. The last section draws a conclusion and clear claims the limitations and further research suggestions of this study.

II. LITERATURE REVIEW

A. Why to Manage Float is Necessary

When the project schedule is calculated by CPM, there are floats in each activity. The value of float may be positive, negative or zero. Float is the time which the current activity can delay but the completion of the whole project will not be delayed [1]. In all type of floats, both of theory and practice only focuses on TF and discuss about its ownership generally. The contractor commonly claims the float should belong to the schedule planner, because it is a part of the schedule. In such a case, if an activity is delayed, the resource can be dispatched without influencing the finish date of the project. In contrast, the owner also claims the ownership of the project based on a viewpoint of the owner is the real owner of the project. So float can be used for buffering owner's schedule delays.

One researcher once said that "Time is money," so he suggested that the TF, which is owned by contractor, can be considered as a commodity with explicit contract language. If the owner need the float to buffer the delay of the task, they must deal with the contractor [2]. Thus, the project manager should clarify and allocate total float ownership to avoid the subsequent disputes before they use it to implement project control [3]. If project managers want to do above mentioned works, to have a complete float calculation program is necessary.

B. Float in Different Scheduling Methods

When the ownership of floats is determined, the progress management can be performed according to the float amount that can be allocated. In the construction industry, advanced scheduling methods have been developed to solve complex project schedule problems. The float also be used to control in these different methods.

A previous study [4] has discussed the floats in linear scheduling (using time float and rate float), resource-constrained scheduling (using scheduled total float and scheduled free float) and critical chain scheduling (using project buffer/float, feeding buffer/float and resource buffer/float). Although the definition of each float type mighis different, there is no significant difference on floats between in traditional CPM and other methods. The floats in

above three scheduling methods come from the popular float in CPM. This study focuses on the floats in CPM only, but it is possible to extend the research results to other scheduling types in the future.

C. Float in PMS

Although controlling all types of floats can make schedule management much easier, to do it in practice is rare. The main reason is that it is not easy and waste time which manually calculating various types of floats, and it is impossible to consider the consumption of the before and after when the schedule updating. Commercial PMSs usually only calculate the total float and free float. Now, there are many professional PMSs, this study discuss the definition and function of floats in three popular systems for construction projects: Microsoft® Office Project, Oracle® Primavera® P6™ and Deltek® Open Plan™, which were discussed in a textbook introducing the CPM for construction management [5] and in a previous study [4]. Based on the discussion in the previous study [4], the information of floats in discussed PMSs is summarized in Table I

TABLE I: COMPARISON OF FLOATS IN PMSs

Software	Used float types	Definition for TF	Definition for FF	Key difference compared to other PMSs
Microsoft® Office Project	TF, FF, start float and finish float	The amount of time that an activity's finish date can be delayed without delaying the project's finish date	The amount of time that an activity can be delayed without delaying any successor activity	It defines the negative total float to display the amount of negative total float for an activity on the Gantt Chart
Oracle® Primavera P6™	TF, FF, finish total float, finish free float, relationship total float and relationship free float	The amount of time the selected activity can be delayed without delaying the project's finish date	The amount of time the selected activity can be delayed without delaying the immediate successor activities	It defines the float path to representing the path made of activities that drive the activity with the least TF/FF
Deltek® Open Plan™	TF, FF, start float and finish float	The difference between the early and late start dates measured in working periods of the activity calendar	The maximum amount by which an activity can be delayed beyond its early dates without delaying any successor activity beyond its early dates	It defines the schedule float to the difference between the late finish date and the scheduled finish date of the activity

a. Microsoft® Office Project

Float is called "slack" in Microsoft® Project. Apart from total float and free float, Microsoft® Project also defines start float and finish float, which the smaller one is total float. Notably, the behavior of TF can differ depending on the link type. For example, if you're working with a start-to-start relationship, the TF can change when you update process of the predecessor. With progress entered on the predecessor, the start date of the successor is now known and becomes part of the TF calculation [6].

Excluding above floats, Microsoft® Project 2016 provides the negative slack (negative total float). It shows the amount of negative TF on the Gantt Chart, indicating the time must be saved so that the successor are not delayed [6]. If a negative float occurs in the schedule planning process, the duration of activity may be not enough, or the logic relationship with other activities may be problematic. So, the project managers can consider it as a warning, and make adjustments on schedule.

b. Oracle® Primavera P6™

Primavera® P6™ uses TF, FF, start float and finish float for representing the time buffer for delay activity. Different from Microsoft® Project, Primavera® P6™ allows the user to choose one of three options: (1) start float; (2) finish float; and (3) the smallest of start float and finish float [7], to make sure a consistent value for TF.

Noted that Primavera® P6™ also allows the user to define critical activities by on the longest path or with total float less than or equal to a customized value. In addition, Primavera® P6™ provides users with new function for float path by managing the most critical paths (and sub-critical paths) in the project schedule by considering TF/FF values. Noted that when computing multiple critical float paths, critical activity might be not real critical activity, just remained tagged as critical [7].

c. Deltek® Open Plan™

Deltek® Open Plan™ uses TF, FF, finish TF, finish FF, relationship TF and relationship FF for schedule control management. The relationship TF is the amount by which the lag in a relationship would have to be increased to either cause a delay in the project completion or a late target date; the relationship FF is the amount by which the lag in a relationship would have to be increased to cause the delay of a successor activity [8]. Therefore, the project manager can use the relationship TF/FF to determine which relationship is responsible for controlling the critical status of the successor.

III. DEVELOPMENT OF COMPUTER PROGRAM FOR FLOAT CALCULATION

A. Float Calculated in Developed Program

The purpose of this study is to develop a float calculation program. Based on literature review on float [4], this study first reviews and defines float and formula used in the program. This study uses symbol i to represent current activity, symbol j to represent activity's predecessor and symbol k to represent activity's successor. Furthermore, time lag from i to j is represented as $Lag_{i\text{-}j}$ and the lag from k to i is $Lag_{k\text{-}i}$.

The definition of total float (*TF*) is the longest allowable time [9] for an activity not to affect project completion date. *TF* can classify to start *TF* (*STF*) and finish *TF* (*FTF*). As the activity has actual starting time, the *STF* has no meaning in control. As the activity has actual finish time, the *FTF* also has no meaning in control. In such a situation, *STF* and *FTF* are set to zero ("Not Applicable/NA"). According to the calculation approach of STF and FTF in equations (1) and (2), it is necessary to choose smaller one as the *TF* for an activity. Noted that, *TF* is not the allowable slack time belonging to one activity only. It belongs to all activities in a path. Accordingly, if the predecessor of an activity on a same path consumes all value of *TF*, *TF* would be zero after updating schedule.

$$STF_i = LS_i - ES_i \qquad (1)$$

$$FTF_i = LF_i - EF_i \qquad (2)$$

Free float (*FF*) is the detention of the activity but not to influence the deadline of the project, include all successors [10]. In other words, *FF* is the longest allowable time of the earliest activity that could delay the activity but not to influence any successor [9]. However, if there are plenty of successors, we can obtain several gaps between the earliest finished time of the activity and the earliest starting time of successors. *FF* is the smallest gap. Equation (3) represents the formula in the program. The actual finished time of the activity will have no meaning while the value of equation (3) is greater than 0 or smaller than the gap of the original observed activity. Noted that *FF* is different to *TF*. It belongs solely to the activity, not shared to other activity [11].

$$FF_i = Min(ES_j) - EF_i - Lag_{i-j} \qquad (3)$$

Interference float *(INTF)* is the allowable time of the activity which unable to influence the deadline of the program. However, it would influence the earliest start time of successor [10]. It is the same as *FF* while the activity obtains actual finished time, both of them have no meaning. If a project only has one logic relationship (finish-to-start), *FF*, *STF* and *FTF* are identical. Therefore, INTF will be simplify to TF minus FF. This study uses original definition to calculate *INTF*, as equation (4) shows. If there are multiple successor and several gap between the last finished time of the activity and all successors, the minimum gap is the *INTF* of the activity.

$$INTF_i = LF_i - Min(ES_j) + Lag_{i-j} \qquad (4)$$

Independent float (*INDF*) is independent and only belongs to one activity, and isn't affected by the activity's predecessor or successor [10]. Therefore, it is the minimum of the earliest starting time among all successors to minus the maximum of last finished time among all predecessors. Finally, the value has to minus remained duration (*RD*). The actual starting time of the activity will not influence the value. When actual finished time occurs, the *INDF* will have no meaning. The calculation method of *INDF* in the program is shown as equation (5).

$$INDF_i = Min(ES_j) - Max(LF_k) - RD_i \\ - Lag_{i-j} - Lag_{k-i} \qquad (5)$$

Safety float (*SF*) is uncommon in general practice. It can be used as a basis for project manager to determine whether the delay of the predecessor affects the next activity. It is defined as the maximum value which the difference of the latest completion time of all predecessors and the latest finish time of current activity. That is, if the predecessor does not affect the current activity, there is a period it can delay [12]. The calculation method of SF in the program is in equation (6). When there is an actual start time, the activity has no meaning on *SF*.

$$SF_i = LS_i - Max(LF_k) - Lag_{k-i} \qquad (6)$$

Relationship float (*RF*) is the constraint of the logic relationship between two activities. The calculation method of SF shows as equation (7), which calculates the difference between the latest start time of the current activity and the earliest finish time of the predecessor, and regards the value as the *RF* of the current activity [13]. *RF* belongs to the link of activity-to-activity instead of the activity, so when there are more than one predecessor in an activity, it might have multiple *RFs*. The value of RF is the degree which the logical relationship control the start of activity [14]. When the activity has an actual start time, it loses meaning of *RF*.

$$RF_j = Min(LS_j) - EF_i - Lag_{i-j} \qquad (7)$$

B. System Development

The study selected Microsoft Project® 2013 version as the program development platform. The programming language is "Visual Basic for Applications" (VBA®) of Microsoft. In VBA, we can directly get the logic relationship of the activity and the scheduling information, which is helpful for developing desired system. Based on the above-mentioned definition and calculation of floats, a computer-based float analysis system is developed. The implementation flow of the entire system is shown in Fig. 1.

Now, the logical relationship in the developed system is limited to finish-to-start (FS) relationship, but it doesn't limit the amount of the time lag in positive or negative. All activities are automatically updated scheduling, and the update of the project must be in accordance with its logical relationship. When the predecessor isn't completed, the successor can't be started. It can't because of the predecessor delayed, the successor start early in order to avoid the delay of the whole project.

C. Programming Codes

After entering the required information in the Microsoft® Project (including activity name, duration, and predecessors or followers), with VBA assistance, the program first creates each float field in the custom fields, and then calculates project schedule information. Furthermore, the program performs calculation to analyze floats. The first part of Table II lists the example programming codes of Microsoft Project for calculating each float.
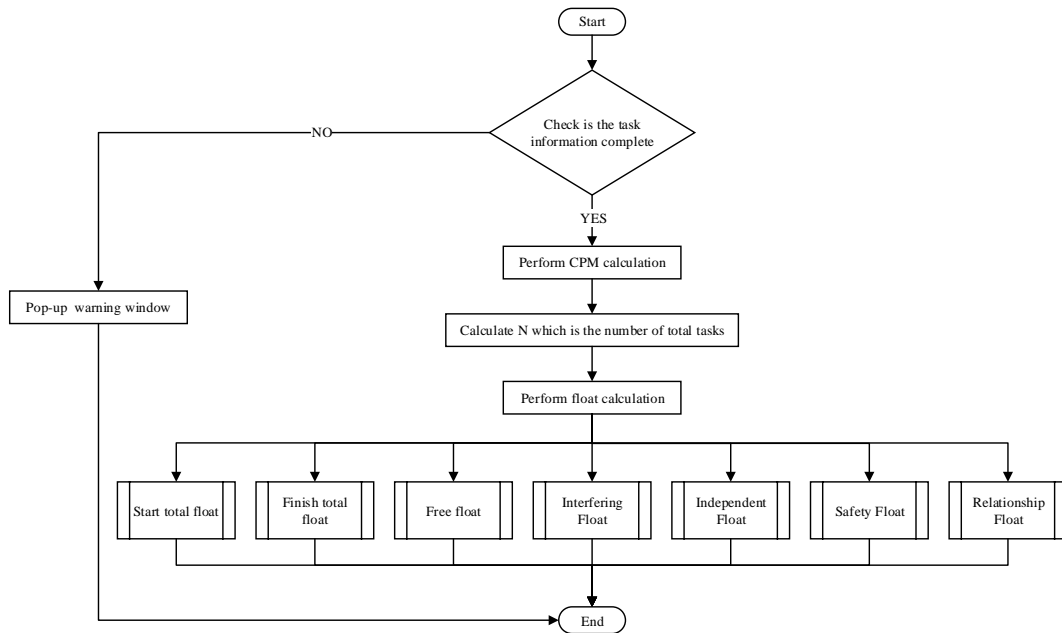
Fig. 1. The implementation flow for schedule float calculation.

TABLE II: THE EXAMPLE PROGRAMMING CODES

Purpose	Example codes in Microsoft® Project
Create float field in custom fields	CustomFieldRename FieldID:=pjCustomTaskText1, NewName:="STF"
Calculate the total number of tasks	N = Activeproject.Tasks.Count

Confirm whether there is a successor/predecessor	For i1 = 1 to N
	If Activeproject.Tasks(i1).Successors/Predecessors <> "" Then
	…
	End if
	Next i1

Calculate the total number of successors and predecessors of task	For i1 = 1 to N M = Activeproject.Tasks(i1).Dependencies.Count … Next i1

Identify whether it is a successor	For j1 = 1 to M
	If Activeproject.Tasks(1).Dependencies.Item(j1).From = i1 Then
	…
	End if
	Next j1

Calculate start total float and fill in its value	STF = Activeproject.Application.DateDifference(Activeproject.Tasks(1).EarlyStart, Activeproject.Tasks(1).LateStart, Activeproject.Calendar) Activeproject.Tasks(1).Text1 = STF

IV. CASE TEST

TABLE III: CASE INFORMATION

ID	Task	Predecessors	As-planned schedule			As-built schedule		
			Duration	Start	End	Duration	Start	End
1	A	—	7	1	7	11	1	11
2	B	—	5	1	5	12	1	12
3	C	1	7	8	14	12	12	23
4	D	2	9	6	14	9	13	21
5	E	2	6	6	11	15	13	27
6	F	3	4	15	18	16	24	29
7	G	4	3	15	17	5	22	26
8	H	5FS+2	9	14	12	11	30	40
9	I	6FS+2	5	21	25	12	32	43
10	J	8FS-1	3	22	24	5	39	43

The program is tested by a simulated case. Assuming that there are 10 activities and only the FS logic relationship is used, in order to ensure the accuracy of the program, three types of time lags, including positive, negative and zero, are added in this case. After the CPM calculation performed by Microsoft® Project, the total duration is 25 days and the critical path is A→C→F→I. There is only one critical path. Assuming in advance that the case project has an actual total duration of 43 days. The detailed information of the planned start and finish time, and the actual start and finish time are shown in Table III.

The above case information including activity's name, durations, and logical relationships are entered into the Microsoft® Project, and the calendar is set to work every day and work for 8 hours a day for the intuitive calculation of the number of days worked. The estimated start time of the project is January 1, 2019. Confirm that the task is set to be completed as quickly as possible. Add and select custom fields (Text 1 to Text 7) to the screen. Then, check all the

value of float is null. The result which the preparation before program running of this stage is shown in Fig. 2. Execution the program, each type of float calculation results will be displayed on the screen, as shown in Fig. 3.

V. CONCLUSIONS

A. Conclusions

CPM has been widely used in the management of construction projects during the past six decades. Obviously, only the TF is widely used for schedule control and delay analysis. Moreover, as the construction projects become increasingly large and complex, the float is not easy to analyze. The difficulty of managing floats may increase, and

incorrect decisions may be made due to incorrect calculation or misunderstanding. In the past, project managers needed to know all floats through complicated manual calculations. Excluding TF/FF, project managers usually do not use other floats which might be more effective in schedule management. This study develops a program for wider float management.

The developed program is an automated calculation system that enables better use of floats in schedule management. Therefore, the owner and the contractor can work together to formulate a project schedule, and effectively manage the floats. It is anticipated that the project can be well executed and completed with developed program.
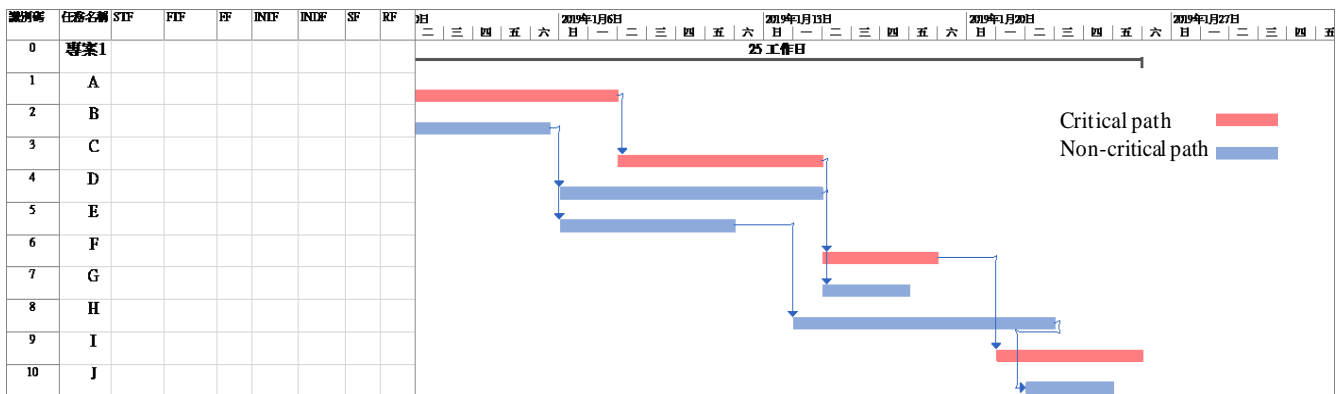

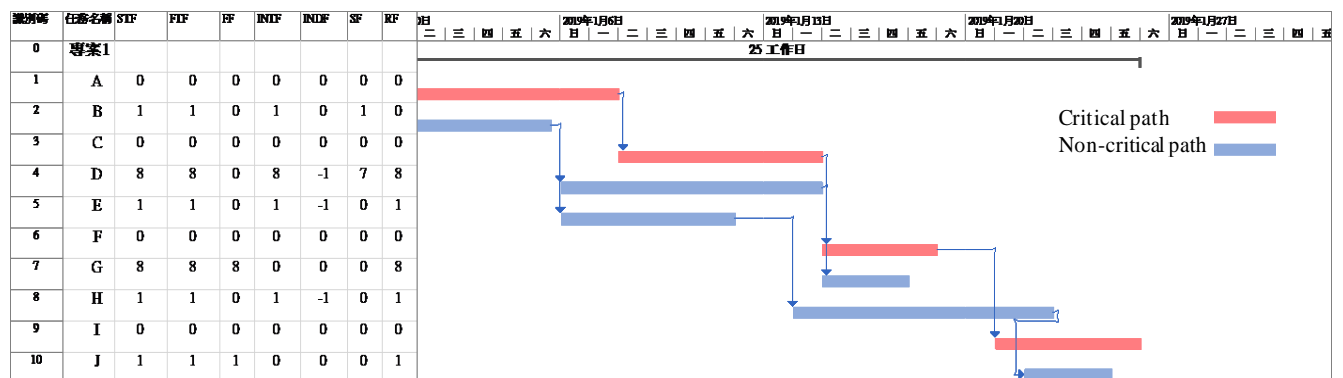Fig. 2. Project schedule before performing developed program.

識別碼	任務名稱	STF	FTF	FF	INTF	INDF	SF	RF
0	專案1							
1	A	0	0	0	0	0	0	0
2	B	1	1	0	1	0	1	0
3	C	0	0	0	0	0	0	0
4	D	8	8	0	8	-1	7	8
5	E	1	1	0	1	-1	0	1
6	F	0	0	0	0	0	0	0
7	G	8	8	8	0	0	0	8
8	H	1	1	0	1	-1	0	1
9	I	0	0	0	0	0	0	0
10	J	1	1	1	0	0	0	1

Fig. 3. The calculation results by developed program.

B. Recommendations

1) Since this study only considers the logical relationship of FS, the follower can perform similar study for other logical relationships based on the results of this study. Noted that, the float for different logical relationship might be different. If a program with considering all logical relationship types and floats is developed, it is possible to apply to practical applications.

2) This study only discusses float calculations, and doesn't add delay events to the schedule and calculate floats. Subsequent researchers can try to add new delay events and use them to record the delay event information (including actual start and end time of delay event, responsibility, etc.), and compare the consumption of float and path changes between before and after the delay event is added. The construction industry can use this tool to perform better schedule management.

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Jyh-Bin Yang is a professor in the Graduate Institute of Construction Engineering and Management at the National Central University, Taiwan. His research interests include project scheduling & delay analysis, procurement performance evaluation & performance-based contract, knowledge management system development and BIM (Building Information Modelling) implementation policy & performance evaluation.

Chi-Yun Ke is a student of Graduate Institute of Construction Engineering and Management at National Central University. She has board interest in the construction management, schedule management and BIM. Her work focus on construction schedule management and delay analysis.