A STUDY ON CONSTRUCTION SCHEDULE OPTIMIZATION INTEGRATING WITH CASH-FLOW

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ABSTRACT: This paper presents a system called a Cash-flow based Construction Schedule Optimization system(CfSO). The existing CPM effectively handles schedule and cost management. However, funding strategy should be considered to obtain maximum profit and to progress a project favorably. One of measures is to coordinate the contract terms between owner and subcontractors (or suppliers). Contractor may decrease the interest cost attributed to project financing by adjusting the timing of cash-inflows and cash-outflows. It is an excellent method maximizing profits. This paper presents a method to estimate the amount of a cash-flow occurred periodically by integrating the terms of contract into scheduling. The proposed method is implemented as a system prototype in Microsoft Excel. This system provides a user an automated tool that identifies an optimal schedule that secures maximum profit by adjusting start and finish times of non-critical activities' free-floats without affecting on the project completion time. This system supports a project manager to establish an optimum project schedule and identifies profitable contractual conditions against to a construction owner.

Keywords: S*cheduling, Cash-Flow, Net Present Value, Optimization, Contract Terms*

1. INTRODUCTION

1.1 Background and purpose of research

Cash inflows and outflows of the construction project occur periodically in accordance with contract terms agreed by the project participants. If the contractor request a progress payment during a certain period based, the owner pay for it after reviewing the documents of job-site progress. The subcontractors spend money on purchasing materials and paying labor costs. As mentioned earlier, the expenditure occurs in everyday. Then, cumulative monthly amount is paid by the contractor to the subcontractor. The time difference between cash inflows obtained from owner and cash outflows released to subcontractor requires a constructor who needs to take smooth construction progress and maximum profit to establish strategic funding strategy.

The means to regulate the cash inflow and outflow is divided into two groups. One is that the contractor finances the project by borrowing funds from financial institutions. The other is that the terms of contract between project participants that are associated with the payment agreement are coordinated.

At first, one strategy that the contractors use is to finance project by borrowing from a financial institution. It has element of risk, because the contractors have to shoulder the time value of money. The bank loan would be expensive sometime when construction economy enters into deep recession. In that case, the project profit in Net Present Value(NPV) would be very much affected by the interest cost. On the other hand, other advantageous strategy is to coordinate contract terms. This is possible to rearrange detailed payment condition of contract terms. For example, contractor can request owner to provide mobilization or subcontractors to apply retainage. In this way, the contractor may reduce the burden of loan interest. This strategy may contribute to maximize the project earning.

This paper presents a method by which a project is rescheduled so as to have maxim NPV by timing cash-inflows and cash-outflows. The method makes use of the contract terms between project participants. The method is implemented an automated system.

1.2 Differentiation strategy of research

This study advances the existing researches in the same subject as follows; 1) The open-ended contract terms between project participants is considered as a major component (the deciding factor) in the cash-flow modeling and analysis, 2) the method that reschedules a baseline schedule is proposed to maximize project NPV while holding the project completion time (PCT) bounded by contract, 3) the proposed method is implemented as decision support system (DSS) in Microsoft Excel.

The system analyzes functional requirements and provides the information for making decision on user interface. It integrates the necessary functions into one system as follows; calculating CPM computation, computing cash inflow and outflow by reflecting contract terms, suggesting advantageous contract terms for a contractor (What-If analysis), searching an optimum construction schedule that maximizes NPV under the specific contract terms, presenting cash-flow analysis table that summarizes the income and expenditure in times, and plotting the report of cash flow diagram.

2. Cash-flow based Construction Scheduling Optimization system (CfSO)

Cash flow based Schedule Optimization System (CfSO) implements three operation processes as follows; 1) Importing schedule data from commercial project scheduling software (i.e., P3, MS Project), and calculating CPM, and computing the primary NPV of the baseline schedule, 2) Searching the combination of start times of non-critical activities which computes the maximum project cost in NPV using optimization program(Evolver 5.0), and 3) Analyzing the output data obtained from cash flow based scheduling. The method is implemented as a system prototype in Microsoft Excel programming. The algorithm of CfSO is presented Figure 1 with detail explanations.

2.1 The system Algorithm

- Step 1: The system imports baseline schedule data (i.e., activity IDs, precedence relationship, activity cost, activity duration, etc) from Primavera Project Planner (P3).
- Step 2: CPM calculation is executed using the data obtained in step1. The outputs are Early Start (ES), Early Finish (EF), Late Start (LS), Sate Finish (LF), and Total Float (TF), etc. Then, the system adjusts the timings of the ESs of the non-critical activities using their floats. This enables the system to changes the cash-flow. It is noteworthy that the PCT obtained by baseline schedule and bounded by contract agreement does not change. Many NPVs are computed while changing the combinations of the timings of the ESs of the non-critical activities.
- Step 3: A contractor inputs contract terms (i.e., period, mark up, retainage, interest rate, Mobilization, supplier credit, etc) bounded between project participants. These terms also influences on the timing of cash-flows.
- Step 4: Periodical cash-flows is calculated using the CPM computation outputs and contract terms.
- Step 5: The primary NPV is obtained by executing steps 1 to 4. The NPV is saved for comparing with other NPV found by the optimization process.
- Step 6: Evolver 5.0, which is the optimization program, is initiated for searching maximum NPV.
- Step 7: The objective function is defined in advance. To search the maximum NPV, optimization goal of Evolver is selected as maximum and cell value is decided as cell name “NPV” on Excel sheet.
- Step 8: A set of ESs of non-critical activities that computes the maximum NPV without changing PCT are sorted as decision variable.
- Step 9: A range of the non-critical activities' period is set up. The minimum value is filled as “0” and the maximum value is filled as TF value in the blank. The ES of an activity is modified on a daily basis.
- Step 10: After designating the decision variable and objective function, iteration number is defined.
- Step 11: The optimization program is operated until the iteration number is met.
- Step 12: The maximum NPV and the optimal combination of ESs of non-critical activities are saved.
- Step 13: The optimal combinations are exported to P3. Then, the improved NPV is presented to the system user.

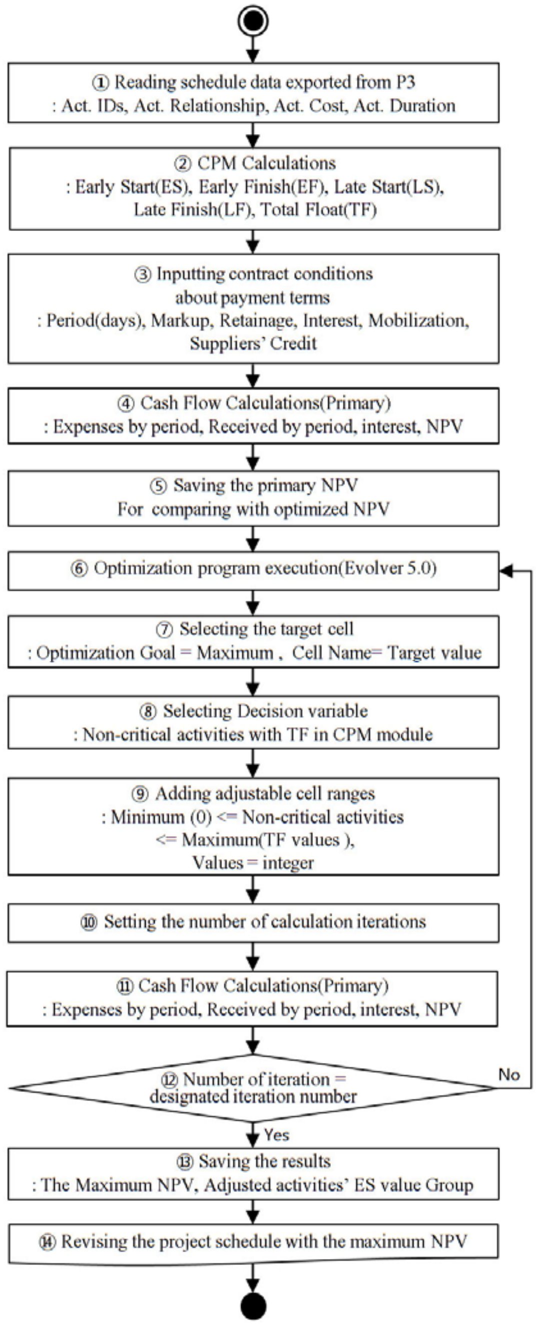

Figure 1. Algorithm of Cash-flow based Construction Scheduling Optimization

2.2 The system User interface

The system user interface of CfSO is shown in Figure 2. This system adapts the CPM algorithm (Hegazy 2002) in Microsoft Excel. The system functions discussed in sections 1 and 2 are implemented into individual modules and they were integrated into one. The system functions are discussed in detail to increase the readability and the understandability of system user interface. This section explains how the author's method is different from other existing researches as follows;

First, the section Ⓐ of "CPM operation module" imports baseline schedule data (i.e., activity IDs, precedence relationship, activity cost, activity duration, etc) administered by project scheduling software (i.e., P3, MS Project, etc). It computes CPM algorithm using the data and plots the output (i.e., ES, EF, LS, LF, TF, etc).

Second, the section Ⓑ of "Optimal solution search module" computes the non-critical activities' TFs using CPM module and modifies the set of TFs, chromosome for optimization.

The module computes as follows; non-critical activities' TF in baseline schedule are selected as decision variables by the system. Construction period adjustment range of activity establishes from the minimum (0) to the maximum(TF). Then, the system modifies the ESs of the activities on a daily basis. This module displays bar chart base on the undertaking and completion time information on the right side. In the next module, they are incorporated with optimization algorithm (i.e., genetic algorithm). NPV calculated the bottom of section Ⓓ "cash-flow summary chart" is designated as objective function. The system searches the maximum value for obtaining best contract terms. By using the contract terms, The system operates optimized activity's scheduling function in keeping PCT condition.

Third, section Ⓐ of "CPM operation module" is possible to check the construction cost occurred (i.e., expense-S curve) periodically considering activities' order and duration. However, the net profit to contractor is available by integrating contract terms and project schedule and by calculating the actual size of cash inflow and outflow. The section Ⓒ operates considering time to occur cash-inflow from owner to contractor or cash-outflow from contractor to subcontractors and reflecting contract terms' variables.

Fourth, Report module (I), section Ⓓ "Cash-flow summaries chart" This module offers summaries of information every time cash-flow is occurred after the results from What-If analysis module according to the contract terms. In addition, NPV of contractor and the interest from financial institutions are offered as of the pre-construction phase. This information makes it possible to mark net profit which is changeable with adjustment of contract terms the present value quickly.

Fifth, Report module (II), section Ⓔ "Cash-flow diagram" provides cash-flow diagram visualized such as periodical cash-flow circumstance from the point of view of a contractor using section Ⓓ "Cash-flow summaries chart". The contractor easily recognizes the situation of incomings and outgoings through the cash-flow diagram. The report module expands as new module compares two contract terms later.

3. A CASE STUDY

The case study verifies the system performance using small project of Hegazy[3] and contract terms. The project has 11 activities. Contract terms are presented in section Ⓒ.

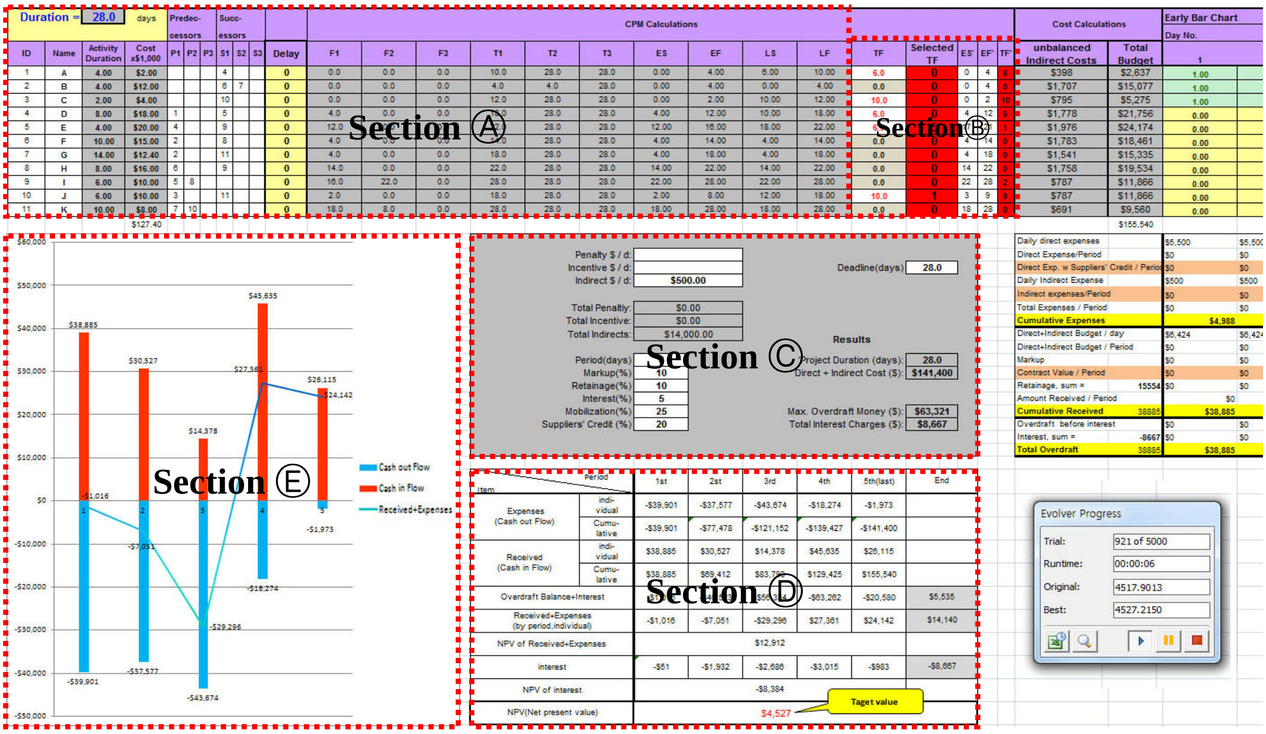

Figure 2. User Interface of Cash-flow based Construction Scheduling Optimization system

Figure 2 shows parts of 50 optimal solutions obtained by operating Evolver (V5.0). ESs of non-critical activities of which TF is not "0" is postponed at a rate of the number of selected days. Net profits in NPV before and after adjusting the ESs of non critical activities are $4,518 and $4,527, respectively. The outcome was obtained by executing the optimization algorithm under same contract terms as shown Figure 3.

	Result	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17
1	4527.21..	0	0	0	0	5	0	0	0	0	1	0
2	4527.21..	1	0	2	0	6	0	0	0	0	1	0
3	4527.21..	0	0	0	0	6	0	0	0	0	1	0
4	4527.21..	1	0	1	0	5	0	0	0	0	1	0
5	4527.21..	1	0	1	0	6	0	0	0	0	1	0
6	4527.21..	1	0	0	0	5	0	0	0	0	1	0
7	4527.21..	0	0	0	0	4	0	0	0	0	1	0
8	4527.21..	4	0	0	0	6	0	0	0	0	1	0
9	4527.21..	1	0	4	0	6	0	0	0	0	1	0
10	4527.21..	2	0	6	0	4	0	0	0	0	1	0
11	4527.21..	1	0	2	0	4	0	0	0	0	1	0
12	4527.21..	2	0	2	0	5	0	0	0	0	1	0
13	4527.21..	0	0	1	0	4	0	0	0	0	1	0
14	4527.21..	0	0	2	0	6	0	0	0	0	1	0
15	4527.21..	4	0	1	0	6	0	0	0	0	1	0
16	4527.21..	1	0	3	0	5	0	0	0	0	1	0

Figure 3. Results of the case study

4. CONCLUSIONS

This study incorporates construction contract terms with existing CPM method, which means, integrates schedule and cost management to maximizes net profit. The system is modularized using Microsoft Excel. It supports a systematic decision-making by adjusting activities and contract terms to maximize project profit NPV at the pre-construction phase. However, the system has limitation in handling large size network schedule because a prototype system using MS Excel is limited in accommodating certain numbers of activities. It is recommended to develop a new system that may handle large projects.

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