S11-5

# STOCHASTIC CASHFLOW MODELING INTEGRATED WITH SIMULATION BASED SCHEDULING

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**ABSTRACT:** This paper introduces stochastic cash-flow modeling integrated with simulation based scheduling. The system makes use of CPM schedule data exported from commercial scheduling software, computes the best fit probability distribution functions (PDFs) of historical activity durations, assigns the PDFs identified to respective activities, simulates the schedule network, computes the deterministic and stochastic project cash-flows, plots the corresponding cash flow diagrams, and estimates the best fit PDFs of overdraft and net profit of a project. It analyzes the effect of different distributions of activity durations on the distribution of overdrafts and net profits, and improves reliability compared to deterministic cash flow analysis.

*Keywords: Cash-flow; Simulation; Scheduling; Project financing*

## 1. INTRODUCTION

A major constraining factor for managing projects is the availability of capital finance. Financing is one of the most important concerns in the overall success of a contractor [1]. Today's challenging project environment demands the project manager to balance the impact of cash flows on the project plan, schedule and performance [2]. Contractors will not be able to deliver the project within the deadline specified in the contract if adequate and timely funds have not been secured to cover the expenditures of the scheduled activities. Therefore, it is important to integrate the scheduling and financing functions of construction project management [1]. Unfortunately, these two are not effectively integrated in current practice, nor is there any commercial scheduling software that provides such integration.

## 2. LITERATURE SURVEY

Integrating project scheduling and financing into a single system is an essential component of project management in the construction community. However, the existing systems are deterministic systems.

After Russell [3] introduced the concept of net present value of project cash flow into scheduling, Doersch and Patterson [4] put emphasis on maximizing the net present value by adjusting the timings of the settlement of cost accounts, other researchers propose advanced approaches such as a hybrid approach to predict cash flows [5,6], a simulated annealing-based optimization model which maximizes the net present value by considering incentive payments or penalties for early and late event occurrences and of changes in costs over time [7], an artificial neural network model that forecasts the cost flow of construction projects [8], and a cash-flow modeling and analysis system that considers all the cash flow input factors in a spreadsheet environment [9]. The existing systems are taken into account the timings of cash inflows and outflows as specified in the contracts between the construction owner and the contractor, and between the contractor and subcontractors [10], when computing the overdraft size to remove the unbalance of cash flow. However, these existing cash-flow modeling and analysis systems are deterministic.

## 3. METHODOLOGY

This section presents how the system called “stochastic cash-flow modeling integrated with simulation based scheduling system” performs cash flow modeling and analysis in deterministic and stochastic modes. It imports the schedule data exported from Primavera Project Planner. The schedule data are converted into an appropriate data structure for simulation runs. The complete precedence relationships are established by identifying the predecessors of activities. The payment considerations (i.e., period, markup, retainage, interest rate (%/period), advance payment for mobilization, supplier's credit, daily indirect cost ($/day)) specified in the contracts between the project participants (i.e., construction owner, contractor, subcontractors, suppliers, and financial institutions) are input by the user. The historical activity durations stored in spreadsheet format are read by the system. The historical activity duration are generated by assuming random distributions using random number generators.

Depending upon the mode(i.e., the deterministic or the stochastic) of operation selected by the user, the system computes activities’ duration. In the deterministic mode of operation, the means of all activity durations are computed and used as activity durations**.** In stochastic mode of operation, the best-fit-PDFs and their parameters ($\rho_1$, $\rho_2$, $\rho_3$, $\rho_4$) are computed using the best-fit-PDF algorithm. The user selects one out of the two hypothesis testing methods, (1) likelihood ratio test or (2) chi-square test. Then, the system user sets the number of simulation iterations (*SimN*).

Cash flow inputs (e.g., activity durations and costs) are generated using the random number generator which produces random variates following the best-fit-PDFs and their parameters estimated previously. The random variates are updated in each simulation run. CPM calculations are performed to compute the PCT using the schedule data and the activities' durations and costs obtained in previously. The total indirect cost ($TotIdC = PCT \times IdC$) is computed by using the PCT and the daily indirect cost (*IdC*: $/day) provided previously. The user may select one of two options to compute total indirect cost. One of the options computes the indirect cost either by multiplying the deterministic activity duration with the daily indirect cost or by multiplying the random variate of activity duration with the daily indirect cost. The total indirect cost is used to plot the S-curve of expenses. The individual indirect cost of an activity ($IdC_{act} = TotIdC \times (DC_{act} / \sum DC_{act})$) is also computed. Where, *IdCact* is the indirect cost of an activity; *TotIdC* is the total indirect cost; and *DCact* is the direct cost of an activity.

Cash flow outputs (i.e., overdrafts and net profits) are computed using the schedule and payment information, the total indirect cost (TotIdC), and indirect costs of activities computed in each payment period (IdCact). When the user defined number of simulation iterations are completed, the sets of cash flow outputs are obtained and saved in respective vectors. Cash flow analysis requires computing three variables including expense, income, and overdraft in each payment period [13].

Depending upon the mode selected, the system executes and outputs the cash flow diagram. The system checks if the iteration counter is greater than the number of simulation runs set by the user. When the simulation experiments reach the predefined number of simulation iterations, the best-fit-PDFs and parameters of cash flow outputs (i.e., overdraft and net profit) saved in the vectors are identified by using the automated distribution fitting tools. Then the PDFs and their parameters are saved in the computer's memory.

The user may query the probability to cover potential overdraft with a user defined $ amount or the probability to achieve a user defined $ amount as net profit using the dialogue box prompted by the system. The system computes the financial risk involved in the user defined Overdraft and Net Profit and provides the cash flow outputs in a cash flow diagram and table for both deterministic and stochastic modes.

## 4. CASE STUDY

The network shown in Figure 1 was reproduced from Feng et al.'s [11] and Hegazy's [12] work to demonstrate the procedure described in the preceding section. It consists of an activity-on-node network composed of 18 activities. Project completion time (PCT) and total direct cost are 169 days and $99,740, respectively. The schedule data created by P3 is exported using the data export function of P3.

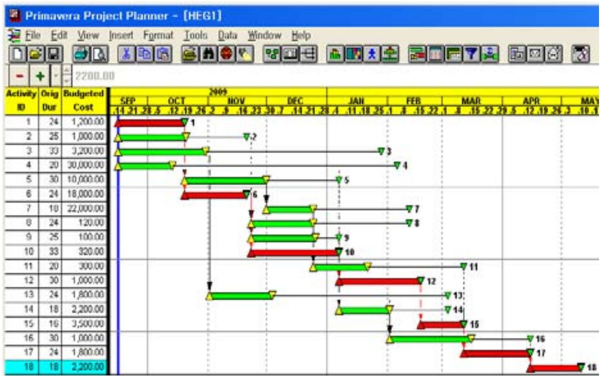


**Figure 1.** Network for Case

Using the schedule data exported from P3, the fictitious historical activity duration data, and the contract conditions relative to payment terms (refer to Table 1), the deterministic and stochastic modes of cash flow modeling and analysis are engaged.

| Terms of Contract | Value |
|---|---|
| Payment intervals (days) | 30 |
| Markup charged by contractor (% of contract amount) | 8 |
| Retainage withheld by owner (% of contract amount) | 10 |
| Retainage returned to contractor (days after completion) | 30 |
| Interest (% per month) | 0.7 |
| Advance payment for mobilization (% of contract amount) | 30 |
| Advance payment returned in equal payments to owner (days after start) | 30 |
| Suppliers' credit (% of payment due) | 30 |
| Indirect cost ($ per day) | 60 |

**Table 1.** Payment terms in the contract

### 4.1. Result in deterministic mode of cash flow modeling and analysis

The deterministic mode plots the cash flow diagram as shown in Figure 2. The contractor records a surplus at the end of the first period, 30 days after the project starts, because $35,601 is paid to the contractor as an advance payment for mobilization. But expenses start to exceed incomes at the end of the second period and continue until project completion. A net profit of $8,041 is expected at the end of the seventh period, i.e., 210 days after project commencement. Existing deterministic project financing analysis systems [13] do not effectively handle the randomness and uncertainty of a construction project. Therefore, the system performs cash flow modeling and analysis in stochastic mode as described in the next section.

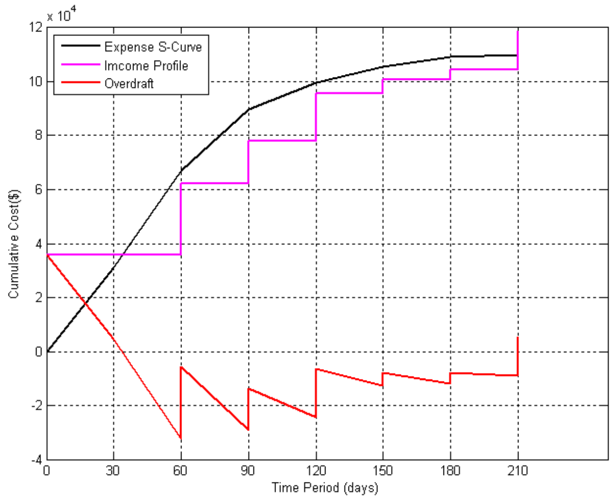


**Figure 2**. Cash flow output in deterministic mode

### 4.2. Results in stochastic mode of cash flow modeling and analysis

The stochastic mode plots the cash flow diagram in stochastic terms as shown in Figure 3.

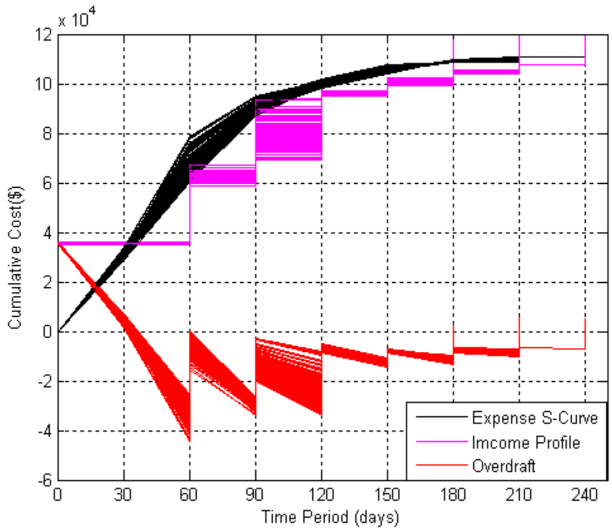


**Figure 3**. Cash flow output in stochastic mode

Cash flow computations are performed for the user-defined number of simulation runs using the random variates following the best-fit-PDFs of the historical activities' durations and costs. In each simulation run, a graph representing the variability of cash flow outputs (e.g., expense, income, overdraft, and net profit) is plotted. The cash flow outputs and PCT are changed, since the random variates of activity duration and cost are regenerated in each simulation run.

As shown in Figure 4, expenses and overdrafts follow a lognormal distribution while net profits follow a gamma distribution and incomes are normally distributed. The system identifies that the maximum overdraft occurs at the end of the second period, i.e., 60 days after project commencement.

In the Query panel, if the user asks "What is the probability of covering potential overdrafts with $31,632?", the stochastic mode responds with 53.45%, which means that if the contractor is able to secure $31,632, the company will not experience financial difficulty with 53.45% confidence. In addition, if the user queries "What is the probability of achieving $8,041 net profit?", the stochastic mode calculates a probability of 74.61%. A financial manager should therefore be able to make a better informed decision. The findings in this case indicate that the existing deterministic cash flow modeling and analysis method may mislead project financial managers since these do not consider the variability of cash flow inputs and outputs.

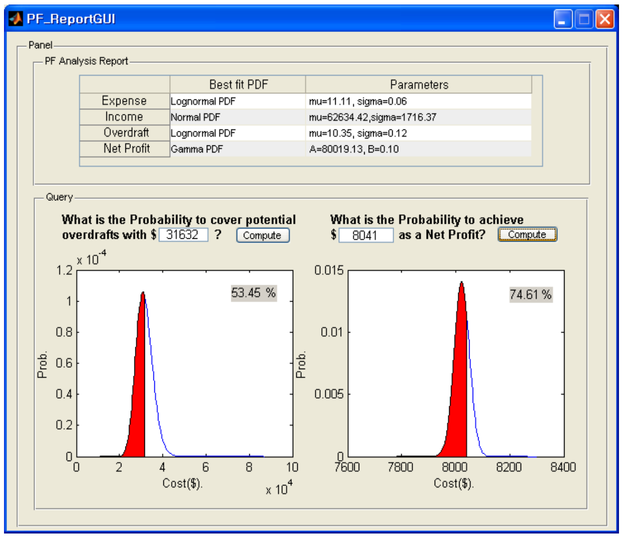


**Figure 4.** Statistical analysis in stochastic mode

## 5. CONCLUSION

This study presents a stochastic cash-flow modeling and analysis tool that efficiently deals with cash flow analysis of network. It achieves lateral and vertical integration. Lateral integration is achieved by analyzing a cash flow of a schedule in two different modes, namely deterministic and stochastic modes. Vertical integration is achieved by performing several operations in an automated process that includes: (1) consolidating schedule data generated by a commercial CPM package, historical activity duration and cost data, and contract conditions about payment terms; (2) estimating the best-fit-PDFs of historical activity data using a built-in facility and assigning the PDFs to the corresponding activities; (3) simulating the network and cash flow diagram for many iterations, (4) estimating the PDFs of cash flow outputs (i.e., overdraft and net profit) obtained from the simulation runs, (5) calculating the probability of achieving a given net profit at completion, and (6) calculating the probability of covering an overdraft when a given amount of funds is secured. The integration achieved by the system in the two directions should appeal to practitioners who may now use a stochastic simulation-based cash flow analysis system more willingly than in the past.

It provides the user with a tool to very rapidly model and analyze project financial risk by integrating the two modes into one system. It facilitates the use of stochastic simulation-based cash flow modeling and analysis and makes more convenient and appealing to practitioners. It allows financial managers to make more informed decisions than existing deterministic cash flow analysis systems.

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