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# Application of Monte Carlo simulation with activity start times to determine cash flow parameters

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**Abstract:** Cash flow modeling is a very useful financial management tool that contractors use to run sustained business. The activities' start times are the inherent variables which determine the values of the periodical negative cumulative balance and the other cash-flow parameters. The Monte Carlo simulation technique has been employed here to generate schedules and their associated cash flow for a small project by randomly specifying the activities' start times within the range between their early and late start times. In addition to the randomness of the activities' start times, the simulation model considered the stochastic nature of the periodic cash in and cash out transactions by adjusting their values to account for the impact of 43 qualitative factors identified in an earlier study. Accordingly, two scenarios were defined each incorporating a different number of qualitative factors. The simulation outputs probability distributions for the project duration, the financing cost, maximum negative cumulative balance, and project profit. Generating random activities' start times in addition to considering the stochastic periodic cash in and cash out leads to a better accuracy of forecasting the cash flow parameters.

## 1 Introduction

The activities' start times are the inherent variables which determine the cash inflow and cash outflow transactions of a project's cash flow. The cash inflow and outflow transactions in turn determine the other cash flow parameters including the negative cumulative balance, which constitutes the contractor's cumulative debt, financing cost, and profit. Non-realistic cash flow forecasting is the main cause of financial failure for contractors, thus the incorporation of the impact of the stochastic variables improves the accuracy of forecasting the cash flow parameters, which makes contractors more prepared to deal with real encounters. Accordingly, Cash flow forecasting models need to incorporate the factors that affect cash inflow and cash outflow to achieve a reasonable accuracy with their project cash flow forecast (Hwee and Tiong, 2002; Chen et al.2005; Kaka and Lewis, 2003; Liu and Zayed, 2009). Many factors that affect project cash flow have been identified in the literature. Hwee and Tiong (2002) studied the impact of five factors on project cash flow: project duration, over and under estimation of risk measurement, risk variation and material cost. Chen et al. (2005) considered three factors that affect cost flow forecasting including time lag, frequency, and payment component. Kaka and Lewis (2003) studied 20 variables that affect cash flow which were divided into characteristic variables and classification variables. Al Issa and Zayed (2007) identified 43 factors that affect project cash flow in highway construction project which are divided into seven groups: Financial management, Subcontractors, Suppliers, Prior to construction, During construction, Communication skills, and other factors. Further, Liu and Zayed (2009) quantified the impact of the 43 factors that affect highway construction project cash flow and the impact of these factors on the cash flow. A cash flow model was established by integrating the Analytic Hierarchy Process (AHP) and a Monte Carlo simulation to examine the impact of various factors on cash flow. The model was developed to help contractors forecast project cash flow under uncertainty. The authors determined the weight and the effect of each factor using Monte Carlo simulation and the AHP.

From the literature review, it is clear that the existing models in the different areas such as cash flow forecasting have some shortcomings, one of which is that the majority of the scheduling schemes with cash flow problems neglect the financing cost as a project cost component. Moreover, none of the studies determined the cash-flow parameters by stochastically assigning different start times while considering the uncertainty of the cash outflow and inflow. This research focuses on this gap with the goal of allowing contractors to determine the cash flow parameters, including the financing cost, maximum negative cumulative balance, project duration, and project profit with better accuracy.

The main objective of this research is to Apply Monte Carlo simulation using the activities' start times as the stochastic input variable to determine cash flow parameters, considering the uncertainty of cash inflow and outflow.

## 2 Research Methodology

Excel model of steps outlined in Figure 1 was developed to determine the cash flow parameters. A Monte Carlo simulation was used to generate random variables for inputs, which are the start times of the activities. The outputs of the model are the cash flow parameters, including the total project duration, financing cost, maximum negative cumulative balance, and project profit. @RISK, commercial simulation software, was used to implement the Monte Carlo simulation. The methodology generates alternative schedules that are modeled in the MS Excel environment. The developed critical path method (CPM) model is integrated with a cash flow model to calculate the cash flow parameters. In addition, the impacts of various qualitative factors are taken into consideration. Figure 1 shows a flow chart of the main sections and subsections of the model development.

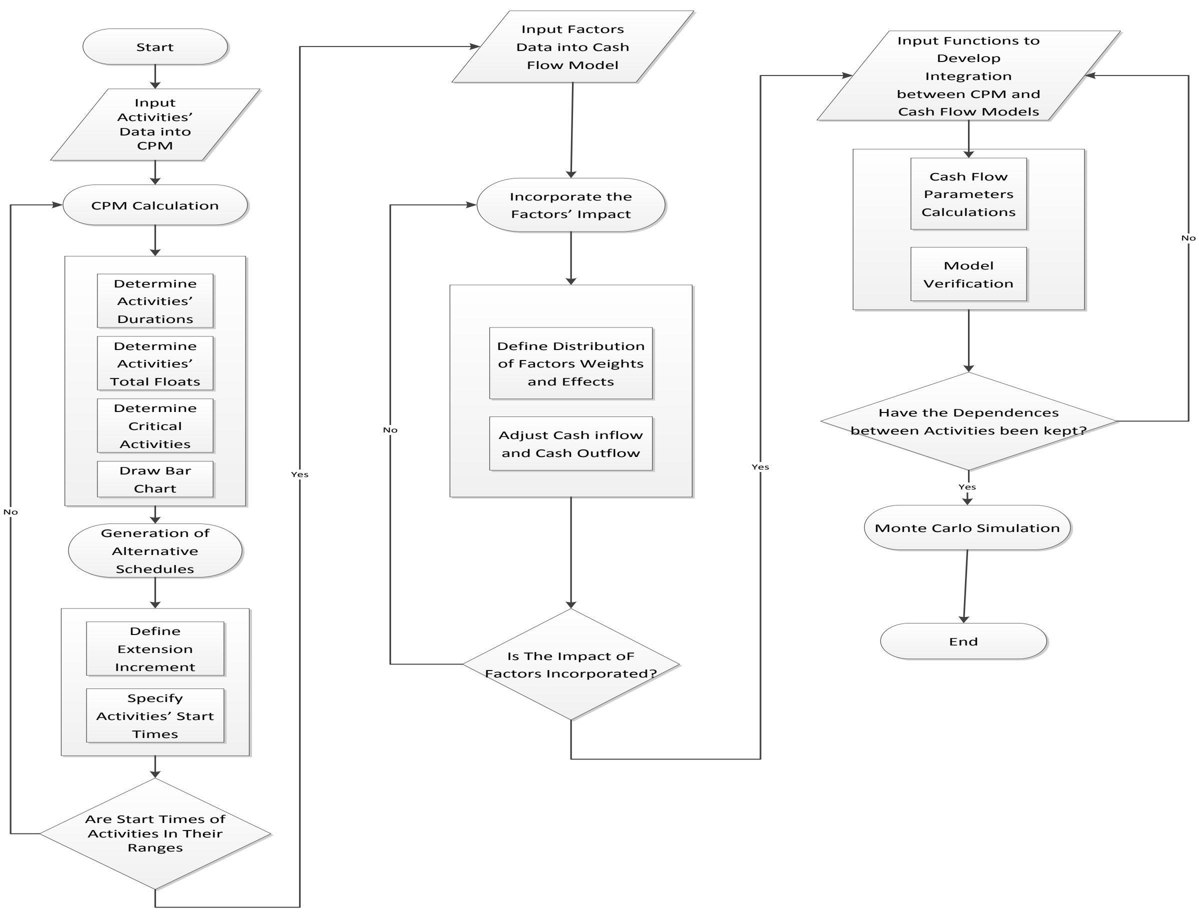


Figure 1: The model development

### 2.1 Model Development

### 2.1.1 CPM Model

A sample project is used to illustrate the proposed methodology. This project consists of 15 activities with the durations indicated in working days as shown in Figure 2. The overhead costs of the project were considered to be 15% of the direct cost, and the cash inflow calculations resemble a typical cost-plus fee contract with a 20% fee percentage. A 5-day week period was used for this project. The payments were made 2 weeks after submission of the weekly pay requests, with no advance payment. The CPM model, which is built in Excel environment, calculates the early start, early finish, late start, late finish and the total float of the activities based on the activities' durations and on the dependencies amongst activities. The start times of activities are defined in specific ranges which are determined based on the extension scheme. Multiple schedules are generated by assigning different activity start times, within their respective ranges. The start time of each activity can be shifted within a range defined by the early to the late start plus the extension increment, while maintaining the dependencies between activities. This range has been assumed to have a discrete uniform probability distribution such that all the values will have the same probability to occur. The start times of the activities have been defined using the @RISK software, which employs the Monte Carlo simulation. Upon running the model for 500 iterations, the @RISK application generates 500 different schedules.

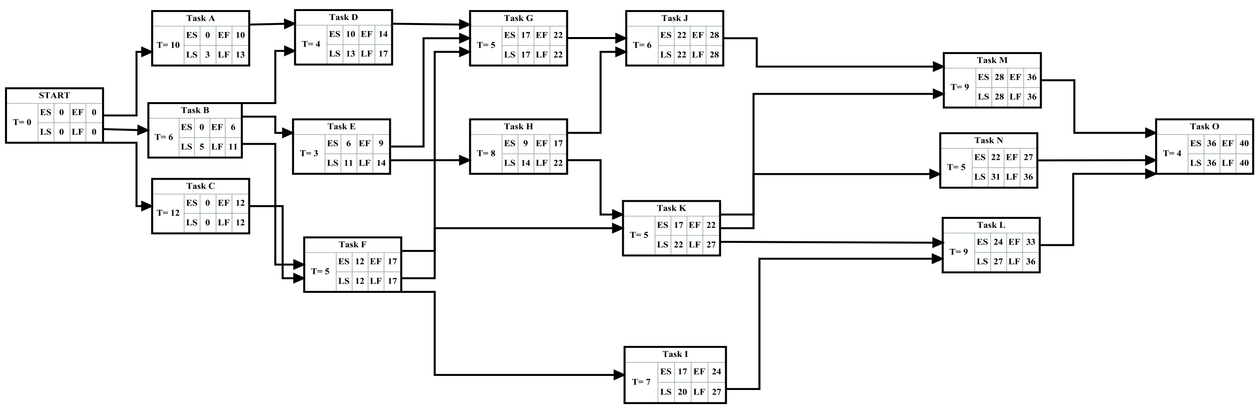


Figure 2: Activities network

### 2.1.2 Cash Flow Model

The cash-flow profile as shown in Figure 3, is developed from the contractors' perspective. Contractors often procure funds from banks by establishing credit-line accounts. A project cash out during a typical project period t is represented by $E_t$ and encompasses costs of overheads and taxes in addition to the direct costs including the costs of materials, equipment, labor, and subcontractors. On the other hand, the contractors' cash in, represented by $P_t$, includes the payments contractors receive, at the ends of periods, as the earned values of the accomplished works calculated based on the contract prices. Contractors normally deposit the payments into the credit-line accounts to continually reduce the outstanding debit (cumulative negative balance). The cumulative balance at the end of period t is defined by $F_t$. The total direct cost of each day was calculated as the sum of the direct costs of all the activities ongoing that day. The total direct cost of each week was calculated as the sum of the total direct cost of the five days comprising that week. Cash outflow is the total direct cost of each week plus the overhead. Cash inflow is the cash outflow of each week plus the mark up. To stochastically incorporate the impact of the quantitative factors on the cash inflow and outflow transactions, the probability distribution of the weight and the effect of each factor defined by Liu and Zayed (2009) were used.

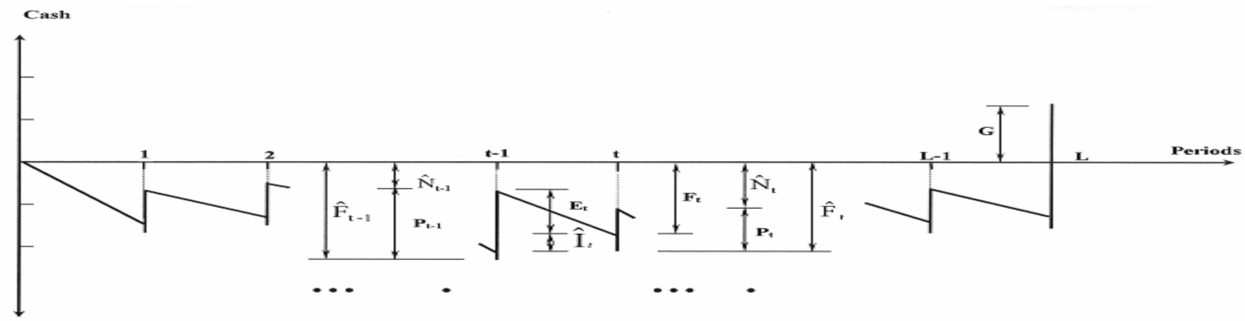


Figure 3: Project cash flow.

The cash outflow of each week is calculated based on the total direct cost plus the overhead, incorporating the combined impact of all the weights and effects of all the cash outflow qualitative factors. The cash inflow is calculated as the cash outflow plus the mark up, thereby incorporating the impact of all the qualitative factors that affect the cash inflow. Equations 1 and 2, developed by Liu and Zayed, (2009), are used to adjust cash inflow and outflow in order to incorporate the impact of the factors that affect the cash inflow and cash outflow transactions, using stochastic analysis.

[1] Cash inflow model $= (1-\sum_{l=1}^{n} \boldsymbol{W_l} * \boldsymbol{E_l} * \boldsymbol{P})*\boldsymbol{Cash\ in_m}$

Where $W_l$ is the weight of factor *l*; $E_l$ is the effect of factor *l*; P is the percent of cash that represents the factors' effect, and $C_{in-m}$ is the owner payment at specific time period m.

[2] Cash outflow model $= \left(1+\sum_{k=1}^{n} \boldsymbol{W_k} * \boldsymbol{E_k} * \boldsymbol{P}\right) * \boldsymbol{Cash\ out_m}$

where $W_k$ is the weight of factor k, and $E_k$ is the effect of factor k. $C_{out-m}$ is the estimated cash outflow of the project at a specific time m. P is the range of percentage of cash that is affected by the qualitative factors; it represents the cash involved in the calculations,. The adjustment of the cash inflow and cash outflow transactions has been achieved in the same Excel spreadsheet to directly apply the impact of the factors that affect the cash outflow and the cash inflow. The impact of the qualitative factors that affect the cash inflow decreases the cash inflow by 9%. The impact of the factors that affect the cash outflow is calculated to be 10.6 %, which means that the cash outflow transactions will be increased by this percent. In order to get the accurate value of the p percent, which is the percentage of cash that is affected by the qualitative factors' effect a special questionnaire was designed as part of the current study and sent to thirty companies in North America. Eleven companies responded which constitutes 37% of the total distributed. The results showed that P percent follow a triangle probability distribution, with a minimum value of 4%, a maximum value of 60%, and a mean value of 35%.

### 2.1.3 The Integration between CPM Model and Cash Flow Model

The integration of CPM and cash flow model is implemented based on the activities' daily direct costs, which are assumed to be associated throughout the activities' durations from their start times to their finish times. To represent the activities' daily direct costs along with their durations, the integration used functions for all of the activities' durations throughout the total project duration. To illustrate these functions, an example of the equation used for the first day of direct cost representation for activity A is shown here in equation 3.

[3]

$$f(x) = \begin{cases} (x - SA) * \frac{CA}{DA} & If\ x > SA\ and\ (x - SA) < 1\ and\ x \le FA \\ 1 * \frac{CA}{DA} & If\ x > SA\ and\ x \le FA\ and\ (x - SA) \ge 1 \\ (FA - \lfloor FA \rfloor) * \frac{CA}{DA} & If\ (x > SA) and\ (x = \lceil FA \rceil)\ and\ (x - SA) > 1\ and\ (FA - x) < 1) \\ 0 & otherwise \end{cases}$$

Where x is a deterministic variable that indicates the start time of the activity's direct cost representation. The value of the variable x can range from one day to the extended total duration. SA is a stochastic variable; it shows the start time of activity A. FA is a deterministic variable that shows the finish time of activity A. CA is a deterministic variable and indicates the direct cost of activity A. DA is a deterministic variable that gives the duration of activity A. This equation has been defined for each day in the project duration, for each of the project's activities. After the representation of the direct cost of each activity's day, the total direct cost of each day can be calculated.

The calculation of cash flow parameters depends on the activities' cash outflow and inflow. The cash outflow for a week depends on the total direct cost of the activities in that week plus overhead. The cash inflow is the cash outflow plus the markup, as the project contract is for cost plus fees. In this research, a stochastic interest rate is defined by collecting data for the interest rate of the last 10 years and using the best-fit option in @RISK. The interest rate is defined as a triangular probability distribution with a mean value of 0.19%, minimum value of 0.125% and maximum value of 0.25%. The weekly cash outflow and cash inflow transactions were determined and adjusted to incorporate the impact of the qualitative factors. The weekly cash outflow is calculated based on the total direct cost of the activities plus overhead, multiplied by 1.106, which represents the impact of the cash outflow qualitative factors. The weekly cash inflow is calculated based on the weekly cash outflow plus markup multiplied by 0.91, which represents the impact of the cash inflow qualitative factors. Cash inflow and Cash outflow can be calculated using equations 4, 5 and 6.

[4] $E_t = \sum_{i=1}^{i=n} D_i * (1 + OH) * Cout$

where $E_t$ is the cash outflow at time period t , n is the number of days comprising the time period, $D_i$ is the sum of the total direct cost of all the activities ongoing during one unit of the time period t, OH is the overhead, and $C_{out}$ is stochastic variable, it is the cash outflow factors' impact.

[5] $P_t = [E_{t-2} * (1 + markup)] * Cin$

$P_t$ is the cash inflow transaction for the disbursements at time period t. $E_{t-2}$ is the cash outflow at time period t-2; $C_{in}$ is the cash inflow factors' impact, it is stochastic variable. The contractor can ask for reimbursement for the payment that was lost during the cash inflow transaction. These payments were lost because of the impact of the cash inflow qualitative factors. If all the cash inflow factors are incorporated, these reimbursements are valued as one minus the cash inflow factors' impact, valued here as 0.09 multiplied by the weekly cash inflow transactions. This value can be added to the contractor one week after the reduction. For example, the reduction of week 3 can be added in the fourth week and the reduction of week 4 can be added to week 5 and so on for all the weeks. In order to reimburse the contractor, the weekly cash inflow transaction should be calculated using equation 6

[6] $P_t = [E_{t-2} * (1 + markup)] * Cin + [E_{t-3} * (1 + markup)] * (1 - Cin)$

Where $P_t$ is the cash inflow transaction at time period t, $E_{t-2}$ is the cash outflow at time period t-2, C*in* is the cash inflow factors' impact, it is stochastic variable and $E_{t-3}$ is the cash outflow at time period t-3.

### 2.1.4 Model Verification and Application of Monte Carlo Simulation

The proposed methodology has been verified to perform well in the random state. This verification was carried out by using models of functions, run on @RISK. These functions were used for all the activities. The activities' start times are defined by using the following equations:
For an extension increment of five days, the start time of activity A is defined as Equation 7

[7] $$f(x) = \mathrm{x} \qquad x \in \{0,1,2,3,4,5,6,7,8\} \quad ;$$

The start time of activity B is defined as Equation 8

[8] $$f(x) = \mathrm{x} \qquad x \in \{0,1,2,3,4,5,6,7,8,9,10\} \, ;$$

The start time of activity C is defined as Equation 9

[9] $$f(x) = \mathrm{x} \qquad x \in \{0,1,2,3,4,5\} \quad ;$$

The start time of activity D is defined as Equation 10

[10] $$f(x) = \begin{cases} FA, & if\ FA > FB \\ FB & otherwise \end{cases} \qquad x \in \{10,11,12,13,14,15,16,17,18\},$$

FA and FB are deterministic variables that represent the finish times of activities A and B, respectively. The start time of activity E is defined as Equation 11

[11] $$f(x) = FB \qquad x \in \{6,7,8,9,10,11,12,13,14,15,16\} \quad ,$$

FB is a deterministic variable, it represents the finish time of activity B. The start time of activity F is defined as Equation 12

[12] $$f(x) = \begin{cases} FB & if\ FB > FC \\ FC & otherwise \end{cases} \qquad x \in \{ 12,13,14,15,16,17\} \quad ,$$

FB and FC are deterministic variables that represent the finish times of activities B and C, respectively. The start time of activity G is defined as Equation 13

[13] $$f(x) = \begin{cases} FD & if\ FD > FE\ and\ FD > FF \\ FE & if\ FE > FD\ and\ FE > FF \\ FF & if\ FF > FD\ and\ FF > FE \end{cases} \qquad x \in \{17,18,19,20,21,22\},$$

FD, FE and FF are deterministic variables representing the finish times of activities D, E and F, respectively. The start time of activity H is defined as Equation 14

[14] $$f(x) = \mathrm{FE} \qquad x \in \{9,10,11,12,13,14,15,16,17,18,19\} \quad ;$$

The start time of activity I is defined as Equation 15

[15] $f(x) = \text{FF} \qquad x \in \{17,18,19,20,21,22,23,24,25\}$ ;

The start time of activity J is defined as Equation 16

[16] $f(x) = \begin{cases} FG & \text{if } FG > FH \\ FH & \text{if } FH > FG \end{cases} \qquad x \in \{22,23,24,25,26,27\}$

FG and FH are deterministic variables that represent the finish times of activities G and H, respectively. The start time of activity K is defined as Equation 17

[17] $f(x) = \begin{cases} FF & \text{if } FF > FH \\ FH & \text{if } FH > FF \end{cases}$

$x \in \{17,18,19,20,21,22,23,24,25,26,27\}$ ,

FF and FH are deterministic variables representing the finish times of activities F and H, respectively. The start time of activity L is defined as Equation 18

[18] $f(x) = \begin{cases} FI & \text{if } FI > FK \\ FK & \text{if } FK > FI \end{cases}$

$x \in \{24,25,26,27,28,29,30,31,32\}$ ,

FI and FK are deterministic variables that represent the finish times of activities I and K respectively. The start time of activity M is defined using Equation 19

[19] $f(x) = \begin{cases} FJ & \text{if } FJ > FK \\ FK & \text{if } FK > FJ \end{cases}$

$x \in \{28,29,30,31,32,33\}$ ,

FJ and FK are deterministic variables representing the finish times of activities J and K, respectively. The start time of activity N is defined as Equation 20

[20] $f(x) = Fk \qquad x \in \{22,23,24,25,26,27,28,29,30,31,32,33,34,35,36\}$ ;

The start time of activity O is defined as Equation 21

[21] $f(x) = \begin{cases} FL & \text{if } FL > FM \text{ and } FL > FN \\ FM & \text{if } FM > FL \text{ and } FM > FN \\ FN & \text{if } FN > Fm \text{ and } FN > FL \end{cases}$

$x \in \{36,37,38,39,40,41\}$

FL, FM and FN are deterministic variables representing the finish times of activities L, M and N, respectively. The advantage of using these models is that they allow the dependencies between the activities to be maintained while applying the Monte Carlo simulation. This is achieved by running the simulation through a number of iterations, suddenly stopping the simulation and saving the resulted new schedules. This procedure was repeated approximately ten times for each extension increment. We thus saved several different schedules which could then be easily checked for the dependencies between activities. Moreover, this procedure ensures that the activities' start times are within the range of the early start time to the late start time plus the extension increment. The direct cost of each activity was verified and calculated for each generated schedule based on the new start and finish times of the activities. The cash outflows and inflows were checked as well, as were the calculations of the other cash flow parameters. For each simulation run, the Monte Carlo simulation specifies the start times of activities in the CPM model and defines the weights and the effects of the factors that affect the cash outflow and inflow in the cash flow model. Upon completing the specified number of runs, the probability distributions of the project duration and the cash flow parameters are obtained. The results are recorded and displayed in graphs that show the ranges of the cash flow parameters. This type of graph uses a histogram or frequency distribution form.

## 3 Scenarios

In order to consider the stochastic nature of the periodic cash in and cash out transactions in the cash flow model, their values were adjusted to account for the impact of 43 qualitative factors identified in an earlier study. Two scenarios were defined based on the qualitative factors that they incorporate, Scenario I incorporates six factors impacting cash inflow transaction: F1- change of progress payment duration; D4- large project duration increase/decrease; D5 - small project duration increase/decrease; D6 - project delayed; D9 - improper planning and management; and O1 - weather condition. Scenario I also incorporates nine factors that impact cash outflow transaction: F6 - financial position; F8 - payment of material before/after; F12 - bank interest; P4 - price change; D4 - large project duration increase/decrease; D5 - small project duration increase/decrease; D6 - project delayed; D9 – improper planning and management; and O1 – weather condition. Scenario II incorporates all the qualitative factors that impact cash inflow and cash outflow transactions. The qualitative factors increase cash outflow transactions and decrease cash inflow transactions. In this project, cash inflow calculations resemble a typical cost-plus fee contract. Therefore, the two scenarios are considered as scenario's I and II. However, in other types of contracts, these scenarios could be considered as the most likely case and the worst case, respectively. Upon running the simulation 500 iterations for each scenario, the output results are presented to investigate the variation of the cash flow parameters values with the variation of the extension increments. The cash flow parameters for the two scenarios are analyzed.

## 4 Simulation Results

Upon running the simulation 500 runs, we obtain the output results of the two scenarios considering three extension increments for each scenario. Table1 and Table 2 show the minimum, the maximum and the mean values of the cash flow parameters for the two scenarios. As presented in Table 1 it is clear that the mean value of the financing cost decreases with the increase of the extension. The results indicate that the mean values of the financing cost for 0, 5, 10, and 15-day extension increments are $404.71, $397.25, $390.58 and $384.47, respectively. With the increase of the duration, the number of the activities ongoing during any period decreases. Accordingly, the contractors' periodical cash out decreases because the amount of cash that a contractor borrows during any period decreases. Consequently, the maximum negative cumulative balance and the financing cost decrease. The results in Table1 indicate that the mean value of the maximum cumulative negative balance for 0, 5, 10 and 15-day extension increments are $46,298.09, $44,586.89, $42,893.05 and $41,377.81, respectively.

The results in Table1 indicate that the project profit increases with the increase of the extension increment. The mean values of the profit for the 0, 5, 10 and 15-day extension increments are $21,912.93, $21,923.3, $21,930.91 and $21,940.38, respectively. In the current project, which represents a cost plus contract, the profit varies exclusively according to the variations of the financing cost. The lower the financing cost, the higher the profit. Since the financing cost decreases with the increase of the extension increment, the profit increases with the increase of the extension increment. As presented in Table1 and Table 2 the mean value of the financing cost and the maximum negative cumulative balance decrease with the increase of the extension. Moreover, their values increase from scenario I to scenario II due to the incorporated qualitative factors, which consequently increase the cash out and decrease the cash inflow transactions. The results indicate that the mean value of the financing cost for scenarios I and

II are $397.25 and $432.67, respectively, with an extension increment of 5 days. The results also show that the mean values of the maximum negative cumulative balance for scenarios I and II are $44,586.9 and $47,972.99, respectively. The project profit increases from scenario I to scenario II; the results indicate the mean profit values for scenarios I and II are $21,912 and $23,224.60, respectively, for an extension increment of 5 days. It can be observed that the project profit has no fixed trends with the extensions of 5, 10 or 15 days for scenario II, due to the stochastic impact of the qualitative factors.

Table 1: The cash flow parameters for scenario I( Most Likely)

| Cash flow Parameters | Ranges | Extension Increment | | | |
|---|---|---|---|---|---|
| | | **0 days** | **5days** | **10 days** | **15 days** |
| **$\hat{I}_t$ ($) (Financing cost)** | Minimum | 269.6 | 257.8 | 244.33 | 258.17 |
| | Maximum | 542.95 | 547.4 | 544.8 | 520.86 |
| | Mean | 404.71 | 397.25 | 390.58 | 384.47 |
| **$\hat{F}_t$ ($) (Max negative Balance)** | Minimum | 41320.12 | 33680.39 | 29549.44 | 30407.61 |
| | Maximum | 51414.773 | 56155.39 | 55991.18 | 55809.91 |
| | Mean | 46298.09 | 44586.89 | 42893.05 | 41377.81 |
| **D (Final Project Duration)** | Minimum | 40 days | 42 days | 45 days | 48 days |
| | Maximum | 40 days | 45 days | 50 days | 55 days |
| | Mean | 40 days | 44 days | 49 days | 54 days |
| **$\hat{N}_t$ ($) ( Net Project Profit)** | Minimum | 20586.59 | 20476.9 | 20318.11 | 20684.43 |
| | Maximum | 23044.9 | 23563.09 | 24571.32 | 23100.67 |
| | Mean | 21912.93 | 21923.26 | 21930.91 | 21940.38 |

Table 2: The cash flow parameters for scenario II( Worst Scenario)

| Cash flow Parameters | Ranges | Extension Increment | | | |
|---|---|---|---|---|---|
| | | **0 days** | **5days** | **10 days** | **15 days** |
| **$\hat{I}_t$ ($) (Financing cost)** | Minimum | 276 | 285.8 | 284.6 | 278.16 |
| | Maximum | 628 | 603.1 | 587.3 | 565.57 |
| | Mean | 440.9 | 432.4 | 425.22 | 418.3 |
| **$\hat{F}_t$ ($) (Max negative Balance)** | Minimum | 40753.94 | 35999 | 32989.38 | 31846.97 |
| | Maximum | 58894 | 58137 | 58372.4 | 57329.97 |
| | Mean | 50004.15 | 47958.5 | 46128.7 | 44581.67 |
| **D (Final Project Duration)** | Minimum | 40 days | 42 days | 47 days | 49 days |
| | Maximum | 40 days | 45 days | 50 days | 55 days |
| | Mean | 40 days | 44 days | 49 days | 54 days |
| **$\hat{N}_t$ ($) ( Net Project Profit)** | Minimum | 19898 | 20113.6 | 22573.27 | 22742.51 |
| | Maximum | 27430 | 26260.6 | 24054.43 | 23830.9 |
| | Mean | 23224.6 | 23239.22 | 23238.2 | 23245.6 |

## 5 Conclusion

The Monte Carlo Simulation was used to generate stochastic schedules. The @RISK commercial simulation software was used to implement the simulation while considering the stochastic nature of the cash inflow and cash outflow. Two scenarios were defined, based on the number of qualitative factors that impact the project cash inflow and cash outflow transactions that they incorporate. Moreover, three extension increments of 5, 10, and 15 days were used for each scenario. Overall, cash outflow qualitative factors increase cash outflow transactions while cash inflow transactions decrease cash inflow. The results indicate that the mean value of the financing cost and the maximum negative cumulative balance decrease with the increase of the time extension. Moreover, their values increase from scenario I to scenario II due to the incorporated qualitative factors, which consequently increase the cash outflow and decrease the cash inflow transactions. Since the financing cost decreases with the increase of the extension increment, the profit also increases with the increase of the extension increment. According to the results, the schedule generated with a 10-day extension in Case Scenario I is considered to be the best schedule. This generated schedule indicates total project duration 45 days, a maximum project profit of $24,571.32, a maximum negative cumulative balance of $55,991.18 and a maximum financing cost of $544.8.

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