ASSESSMENT OF ACTIVITIES' CRITICALITY

TO CASH-FLOW PARAMETERS

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ABSTRACT

ASSESSMENT OF ACTIVITIES' CRITICALITY

TO CASH-FLOW PARAMETERS

Marwa Hussein Ahmed

Cash flow modeling is a very useful financial management tool that contractors use to run a sustained business. Contractors manage multiple activities within a single project. The activities' start times are the inherent variables which determine the values of periodical negative cumulative balances and the other cash-flow parameters of cash flow model. Since the start times of activities vary while the dependency is maintained, in any given schedule the maximum value of the negative cumulative balance varies, as do the values of the other cash-flow parameters. This work reveals a system that can identify those activities that have the most influence on cash flow.

The Monte Carlo Simulation technique has been employed here to generate schedules and their associated cash flow models for a case study by randomly specifying the activities' start times between their respective early and late start times. Uniform discrete probability distributions are assumed for the activities' start times, with the minimum and maximum values representing the early and late start times, respectively. 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 in the cash flow model by adjusting their values to account for the impact of 43 qualitative factors identified in an earlier study.

The @RISK commercial software was used to implement the simulation of the cash flow model built in an MS-Excel environment. Upon completing the specified number of runs, @RISK displays the probability distributions for the cash-flow parameters including the financing costs, maximum negative cumulative balance, project duration, and project profit.

In addition, three scenarios are defined; each incorporating a different number of qualitative factors which impact the project cash inflow and cash outflow transactions. Scenario I incorporates none, Scenario II incorporates six factors impacting cash inflow transactions and nine factors impacting cash out flow transactions, and scenario III incorporates all of the qualitative factors that impact cash inflow and cash outflow transactions. Moreover, the ranges of the activities' start times have been extended by supplementing the total floats with extension increments for the three scenarios.

The results are presented and analyzed based on the three scenarios. The activities' criticality to cash-flow parameters is assessed by evaluating the number of times a given activity determined a particular cash-flow parameter over the number of runs. This criticality measurement offers project managers very useful criteria with which to identify the activities that are most urgent to be completed on time.

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A warm love to my great mother for all her efforts throughout my entire life, my mom is really an amazing mother. A great love to my sisters, brothers and deepest missing to my wonderful father, I will never forget his supporting words, his warm smile. He encouraged me to study very hard since I was in the elementary school. He really was one of the best, may Allah bless him.

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CHAPTER 1
INTRODUCTION

1.1. PROBLEM STATMENT

Cash is the most important resource for construction companies. Contractor's cash flow modeling involves the determination and presentation of cash inflow and cash outflow transactions that occur over a project's duration. Cash outflow represents the project disbursements while cash inflow constitutes the payments received from the project owner. Cash flow management, which involves planning and control, is very essential for contractors' stability, profitability and sustainability. The improper planning and management of cash resources constitutes one of the major causes of contractor failure in the construction industry (Navon, 1996).

Construction projects are composed of specific activities, and it is the activities' start times that 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 for each project.

Cash-flow forecasts should incorporate the impact of the stochastic variables that influence the cash inflow and outflow transactions. This 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. The accurate estimation of the cash outflow and inflow transactions is very crucial to realistically forecast cash flow. Non-realistic cash flow forecasting is the main cause of financial failure for contractors (and for other businesses as well).

Cash-flow parameters, including the maximum value of the cumulative negative balance, financing cost, project profit and project duration, vary according to the specified values of the stochastic activities' start times. The criticality of these activities to the cash-flow parameters is assessed by stochastically assigning different start times while considering the uncertainty of the cash outflow and inflow transactions. Currently, there is a lack of a tool in the literature that practitioners can use to assess an activity's criticality to cash flow parameters.

1.2. RESEARCH OBJECTIVE

The main objective of this research is to establish an illustrated methodology and develop a model to assess the impact of stochastic activities' start times on cash flow parameters, in particular the uncertainty of cash inflow and outflow.

1.3. RESEARCH METHODOLOGY

The Critical Path Method (CPM) schedule of the case study project is built on an Excel spreadsheet integrated with a cash flow model so that the cash outflow, cash inflow, and the remaining cash flow parameters are readily calculated. The impacts of the factors that affect the cash inflow and cash outflow are incorporated in the proposed model. The @RISK commercial simulation software is used to generate a number of alternate schedules by randomly specifying the start times of activities, from early to late start times, while fulfilling the dependency requirements. Three scenarios are defined based on the number of qualitative factors that are incorporated; factors which impact the project cash inflow or the cash outflow transactions. Scenario I incorporates none, Scenario II incorporates six factors impacting cash inflow transactions and nine factors impacting cash outflow, and scenario III incorporates all of the qualitative factors that impact cash inflow and cash outflow transactions. Moreover, the ranges of the activities' start times have been extended by supplementing the total floats with extension increments for the three scenarios. Using @RISK to simulate and implement a large number of iterations, the probability distributions of the cash flow parameters, including the total project duration, the financing cost, the maximum negative cumulative balance and the project profit are defined. A sensitivity analysis was carried out to assess the criticality of each activity's start times to the cash-flow parameters.

1.4. THESIS OVERVIEW

The first chapter introduces the problem statement, the main objective, and the research methodology. The second chapter contains a comprehensive literature review of previous models as well as of research efforts related to cash flow forecasting models, the factors that affect project cash flow, the scheduling problems with cash flow, and the Monte Carlo simulation technique. The proposed methodology is elaborated chapter three, where the three scenarios, based on a test bed project of 15 activities are described in detail. The fourth chapter contains the analysis of the results based on the three scenarios. Moreover, it contains a detailed sensitivity analysis of scenario III, designed to assess the criticality of the activities' start times on cash flow parameters. The fifth chapter presents the conclusion, along with the contributions, limitations and recommendations.

CHAPTER 2
LITERATURE REVIEW

2.1. OVERVIEW

The literature review consists of five sections, indicated below in figure 2-1. Section 2.2 contains a literature review of cash flow forecasting models. Section 2.3 reviews the literature related to the factors that affect project cash flow. Section 2.4 reviews the literature related to the scheduling problems with cash flow. The literature related to the application of Monte Carlo simulations is summarized in section 2.5. Section 2.6 identifies the research gap addressed in the current study.

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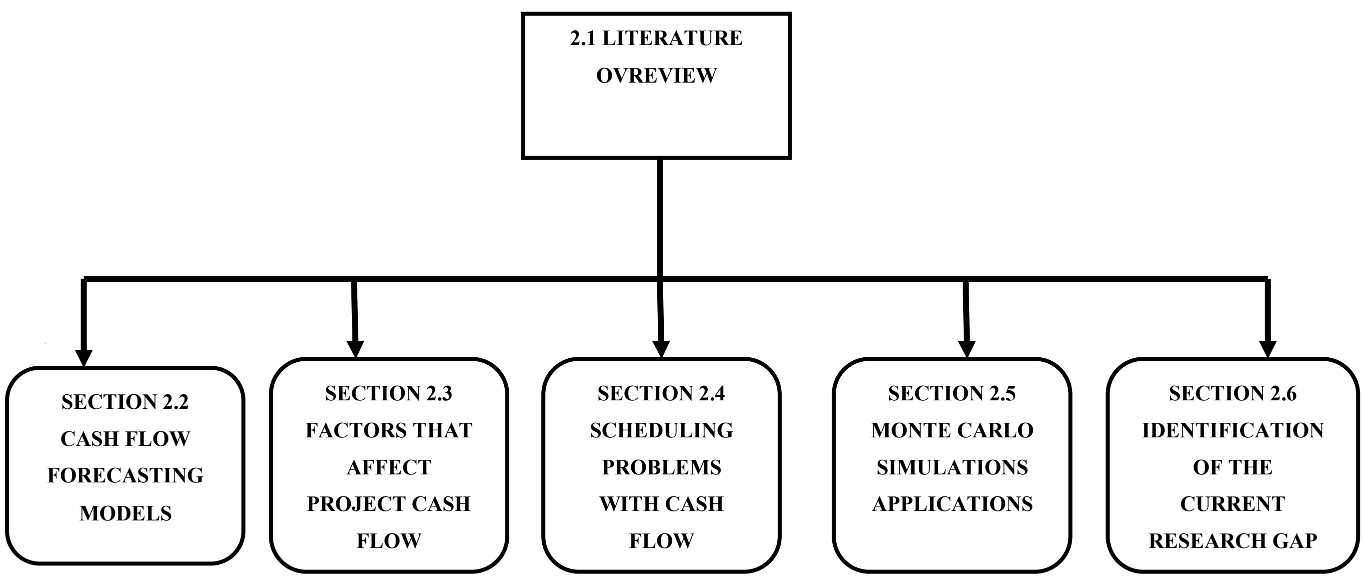

Figure 2-1: An overview of the literature review sections.

2.2. CASH FLOW FORECASTING MODELS

Generating an automated cash flow forecast at the project level is a very important and difficult task. In order to ensure the accuracy of cash flow forecasting models, the cost and earned value estimates have to be as accurate as possible (Navon, 1996; Park et al., 2005). The S curve theory has been adopted as the basis for cash flow prediction and is used as the foundation of forecasting. The cost flow curve can be simulated accurately if all of the monthly cost values are available. The cost values are used to fit the S curve, a process which can be used to update all the monthly cost values for a project contract (Hwee and Tiong, 2002; Kaka and Lewis, 2003).

Cash flow forecasting models should be developed before submitting tenders, as a means to preview the distribution of cash flow and the amount of equity required. Cash flow forecasting models are used to preview fund-related requirements and they can be used to manage the fluctuation of the project cash balance. An increase in the cash flow variation increases the target cash balance. This variation is related to the sample size of the tender (Cheng et al., 2010). Cash flow forecasting models must incorporate the factors that impact cash inflow and cash outflow. The qualitative impact of these factors needs to be quantified and integrated with the cash-in and cash-out mathematical models. The impact of each factor is reflected in its weight and effect (Liu and Zayed, 2009).

Many researchers have studied cash flow forecasting. Au and Hendrickson (1986) developed a cash flow forecasting model. Their model determines the cumulative cash flow at the end of a set period, the net balance (defined as net cash flow at the end of a set period and after receiving a payment), the total financing cost, the accumulated financing cost, the cumulative negative balance at end of a period and the net cumulative cash flow or the project's profit. Hwee and Tiong (2002) developed a model that has a cash flow forecasting ability. The model uses a program to predict the trend of cash flows in a project, and accounts for a degree of uncertainty. The Internal Rate of Return (IRR) is presented as the performance of the project's profit, due to the lost cost of interest. Throughout a project's duration, the cumulative cash level usually shows a positive cash flow in the latter part of a project. With more information about a project, the model readjusts itself to give a better prediction of the I.R.R. Kaka and Lewis (2003) presented a dynamic cash flow forecasting model that would assist contractors to effectively plan and manage the cash flow of individual projects at a company level. The authors showed the relationship between 30% and 50% completion on one hand, and between 50% and 70% completion on the other. The results showed that 50% and 70% completions of a project could be predicted from the actual cost of that project at the 30 % and 50% completion levels, respectively.

Park et al. (2005) proposed a model to forecast cash flow during construction based on the planned earned value. This study introduced moving weights of cost categories, dependent upon the progress of a project. Their model adopts the moving weight of cost categories, which are variable depending on the progress of the construction, into a budget that is updated on a regular basis. The authors defined moving weight as the weight that can be applied to the next month. This moving weight is adjusted and calculated by deducting the actual cost from the initial budget for an individual cost in each month, so the weight of each individual cost category in relation to the remaining budget changes every month. Park et al. stated that this developed model can be used as a simple tool to forecast cash flow at the jobsite; however, it has some shortcomings as it depends on managing the cost and earned value each month, and it ignores the inherent difficulties involved in obtaining reliable variables at the jobsite. The estimates of both the cost and earned values have to be accurate for this model to be reliable.

Navon (1996) developed a cash flow management model for the organizational level, using a detailed computer program which can be used at both the company and the project level to compute the expected capital cost and determine the loans needed. Navon's model incorporates a time lag, so it is considered to be a tool for forecasting cash flow, thanks to its flexibility. It is based on the project's resources. The system can determine the difference between the actual cash flow and the forecasted cash flow. However, this model does not consider the uncertainty environment.

Cheng et al. (2010) developed a cash flow forecasting model. Their model uses the average values of construction scheduling predictions to decrease variation, reduce costs and increase earnings, but this use of averaged figures can be considered one of its shortcomings. The authors collected cost estimate data from 42 infrastructure project tenders: 20 for MRT Projects, 14 highway tenders and 8 for public projects. This data, was collected for the cash flow analysis and used to build cash flow models. Liu and Zayed (2009) developed a cash flow mathematical model that considers uncertainty. Their model can be used as an automated tool to forecast cash flow. It should be noted that, this cash flow forecasting model has been defined by parameters W, P, and E which indicate to the weight of each factor, percentage of cash involved and effect of each factor respectively. Moreover, it is assumed that interest would only be applied to negative cash outflows.

2.3. FACTORS AFFECTING PROJECT CASH FLOW

Many factors that affect project cash flow have been identified in the literature. 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). Hwee and Tiong (2002) studied the impact of five factors that impact 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, time lag, frequency, and payment component. Kaka and Lewis (2003) studied 20 variables that affect cash flow. These variables were divided into characteristic variables and classification variables, and are presented in Table 2-1.

AlIssa and Zayed (2007) identified 43 factors that affect project cash flow in highway construction project. These factors are divided into seven groups: Financial management, Subcontractors, Suppliers, Prior to construction, During construction, Communication skills, and other factors, and are so indicated in Table 2-2. Liu and Zayed (2009) quantified the impact of the 43 factors that affect highway construction projects.

Table 2-1: Characteristic and classification variables for cash flow analysis (Kaka and Lewis, 2003)

Characteristic variables	Classification variables
1- Profit	1- Location
2- Retention	2- Client
3- Maintenance period	3- Construction Sector
4- Completion date	4- Method of procurement
5- Delay of client payment	5- Method of tendering
6- Delay of subcontractor payment	6- Contract type
7- Risk	7- Size of work
8- Percentage of subcontract	8- Type of work
9- Over measurement.	9- Consultants involved
10- Front-end loading	
11- Material Purchased	

Table 2-2: Factors that affect highway construction project cash flows (AlIssa and Zayed, 2007).

Category	Factors	
Financial Management	F1-Change of progress payment duration (I) F2-Change of progress payment conditions (I) F3- Receiving front payment (I) F4-Large retention percent (I) F5-Delay in releasing retention (I) F6-Finanical position (O)	F7-Loan repayment (O) F8-Payments of material (before/after arrival) (O) F9-Over work measurement (I&O) F10-Under work measurement(I&O) F11-Change of labor and staff wages (O) F12-Bank interest (O)
Sub-contractor	Sub1-Decisions to sub-contract (O) Sub2-Over/under measurement (O)	Sub3-Failure of sub-contractor (I&O) Sub4-Renting vs. buying equipment (O)
Suppliers	Sup1-Delay of making payments (O) Sup2-Procurement problems (O)	Sup3-Delay in delivery (I&O) Sup4-Price change (O)
Prior to Construction	P1-Poor design (O) P2-Inaccurate bid items (I&O) P3-Estimating strategies (O)	P4-Cash flow forecasting (O) P5-Competitors (I)
During Construction	D1-Mistakes in executing the work (I&O) D2-Lack of adequate insurance (O) D3-Replacement of defective work (I&O) D4-Large project's duration increase/decrease (I&O)	D5-Small project's duration increase/decrease (I&O) D6-Project delayed (I&O) D7-Material and equipment shortages (O) D8-Lack of skilled labor (O) D9-Improper planning and management (I&O)
Communication Skills	C1-Disputes between contractor and owner (I&O) C2-Poor communication –contractor staff (I&O)	C3-Relations with owner (I&O) C4-Relations with consultant team (O)
Others	O1-Weather condition (I&O) O2-Positive change order (addition work) (I&O)	O3 -Negative change order (I&O) O4-Inability to manage change orders (I&O) O5-Number of claims (I&O)

Note: (I): affects cash-in; (O): affects cash-out; (I&O): affects cash-in and cash-out

2.4. SCHEDULING PROBLEMS WITH CASH FLOW

Faced with high interest rates and high costs, the maximization of a project's present value is the objective of project scheduling, in addition to minimizing project duration. The early scheduling of activities with high positive cash flows combined with delaying activities with high negative cash flow can increase net present value (Russell, 1986; Zhu and Padman, 1999; Waligóra, 2008).

Scheduling a resource-constrained project to minimize cash flow problems can be done by scheduling the activities subject to constraints on the precedence requirements, activity duration and resource limitations. Scheduling activities should be done so that cash inflow occurs early and cash outflow occurs later. The activities must be scheduled with respect to any precedence constraints (Padman and Zhu, 2006; Kimms, 2001; Vanhoucke et al., 2001). The Resource Investment Problem (RIP) is defined as the problem of minimizing renewable resource costs subject to a project due date. The objective is to obtain a schedule aligned with the resource requirements such that the total cost of the resource utilization can be minimized (Najafi and Azimi, 2009).

The cost–schedule integration technique assumes that cash flows for a project are a function of the project schedule makes extensive use of the project estimate and schedule data. The expense flow and the income flow depend on the number of working days per month. The cost flow is calculated on a daily basis, and can be translated into monthly sums according to the actual working days per month. The integration between scheduling and cash flow requires detailed information such as the bill(s) of quantities and detailed schedules, including activity descriptions and activity durations, with all the resources needed for these activities (Chen et al., 2005; Navon, 1996).

Many researchers have focused on the domain of resource-constrained scheduling problems with cash flow. Russell (1986) evaluated six heuristic scheduling rules on 80 test problems. That study consisted of a schedule of five activities, with the assumption that all activities are scheduled at their earliest start times. To maximize the net present value in a project, the author considered a project's scheduled activities, as they have known durations. An activity cannot start until all predecessor activities have finished. Cash flow can be negative, positive or zero, as incurred at the completion of each activity in series.

Zhu and Padman (1999) applied tabu search Meta heuristics procedures to produce the best schedules in over 85% of the projects. They showed that a general purpose heuristic is better than single pass heuristic at adapting to the complex interactions of many critical parameters found in resource-constrained scheduling problems with cash flow. Tabu search is an iterative procedure that combines multiple modes of switching activities over many iterations to select the best schedule. The advantages of the Meta heuristic procedure allow the investigation of the best solutions to complex problems solution. The author illustrated that tabu searches had been applied to a variety of domains to solve difficult problems.

Waligóra (2008) considered discrete-continuous project scheduling with discounted cash flows, illustrating that activities require discrete and continuous resources for their processing. The main objective of Waligóra's work is the maximization of the net present value. He elaborates the properties of an optimal schedule and formulates a mathematical programming problem for optimal resource allocation. Waligóra describes an application of a local search Meta heuristic-tabu search. His results showed that the tabu search method seems to be an efficient algorithm for solving the problem; however, the limitation in these studies is that, the study was exclusively focused on positive cash flow, which makes the solution a much less general-purpose one. Moreover, other payment models were not considered.

Padman and Zhu (2006) presented a problem space computational model to solve the scheduling problem with cash flow. They illustrated that the problem space structure makes compiling knowledge easier than independently solving project scheduling problems. The authors' objective was to propose a framework for integrating the multiple knowledge sources that exist in project management. Kimms (2001) focused on the resource-constrained project scheduling problem (RCPSP) with a net present value objective. His contribution was to use the upper bounds, based on a Lagrangian relaxation of the resource constraints. This approach has been used as a basis for a heuristic and its solution gives very close-to-the-optimum results. Its upper bounds are not well researched; one of the reasons why Kimms used this approach. Vanhoucke et al. (2001) developed a depth branch and bound algorithm to study the RCPSP with a discounted cash flow situation. These authors focused on scheduling the activities subject to a fixed deadline, with precedence and resource constraints set to maximize the net present value (N.P.V). The authors illustrated that positive cash flow should be scheduled as early as possible, while negative cash flow should be scheduled as late as possible, within precedence constraints. The procedure was coded in visual C++ and presents a branch and bound algorithm to maximize the N.P.V. The authors illustrated that scheduling problems have a known deterministic cash flow and a constant resource requirement for each renewable resource type, which together assure that the financial aspects of a project are taken into consideration. The results showed that the branch-and-bound procedure is able to solve up to 30 activities and four resource types in a reasonable time.

Najafi and Azimi (2009) studied the resource investment problem with discounted cash flow. They mathematically formulated the problem as one in which tardiness is permitted with delay penalty. The authors defined the project scheduling problem as the combination of precedence constraints and resource constraints, such as project duration, project total cost and optimization of net present value. They focused on observing the minimum and maximum time lags between activity starting and completion times. The net present value (N.P.V) of a project was maximized by using the sum of the positive and negative discount cash flow throughout a project's life cycle. The authors found that setting a penalty mechanism at the deadline of the project is a usual measure taken by clients. If the project completion date is delayed beyond the deadline of the project, the total amount of the payment will be reduced by a certain extent as a penalty. In a project with a set of activities, each of which needs resources, a constant cost is incurred for each unit of time delay from the respective deadline.

Navon (1996) developed automatic cost/schedule integration, which allows the cost of each resource to associate automatically with its appropriate activity. Chen et al. (2005) introduced two contributions from their studies to provide an ability to assess the accuracy of cash flow models. They presented a methodology to assess the accuracy of Cost Schedule Integration (CSI) models and their components. Their analysis indicated that payment lags, components and frequency have to be included in CSI models to provide adequate cost flow predictions. Moreover, these studies provided a detailed evaluation of existing and proposed models. Their work will help managers to forecast cash flow using a catalog.

2.5. MONTE CARLO SIMULATION

Simulation techniques study the uncertainty that affects values. The Monte Carlo simulation generates random variables for inputs and then gives the possible values for the outputs. The outcomes are presented as a probability distribution. The major significance of the Monte Carlo simulation technique lies in its application to examining stochastic models, such as models representing construction problems. Monte Carlo simulation is used to define inputs as a probability distribution to generate random variables. The outputs of Monte Carlo simulations are called random generated variates. The scheduling algorithm can be subjected to Monte Carlo simulation by pseudo-randomly generating jobs. Such simulation is not only more realistic, but also provides another analysis method, one which covers the many possible behaviors of a system. Thousands of iterations can be done quickly, along with the rank correlation of variables. With Monte Carlo simulation, these variables are random in order to better reflect the uncertainty environment (Ölveczky and Caccamo, 2006; Javid and Seneviratne, 2000; Kaka and Lewis, 2003; Liu and Zayed, 2009).

Many researchers have used the Monte Carlo simulation technique to solve problems related to cash flow. Ölveczky and Caccamo (2006) focused on a cash algorithm to maximize system performance, while guaranteeing that critical tasks are executed in a timely manner. This was achieved by reusing the unused execution budgets. The authors have used real time mode to analyze the modified algorithm and some additional design alternatives. Moreover, extensive

Monte Carlo simulation indicates that a critical missed deadline would be difficult to find using traditional testing.

Javid and Seneviratne (2000) constructed a financial model to evaluate net present value using Monte Carlo simulation to evaluate the impact of alternative financing structures. They used Monte Carlo simulation to estimate the impact of cash flow uncertainties on project feasibility and they discussed some of the economic and technical factors that affect cash flow. These factors influence the variables that affect cost and revenue. The authors defined investment risk as the probability of the net present value (N.P.V) to be less than the target value. They presented the sources of uncertainty as project cost, competitive risk and market risk. Their results showed that the project cost has the most significant impact on increasing the risk.

Kaka and Lewis (2003) developed a dynamic cash flow forecasting model to help contractors to plan and manage the cash flow of individual projects at a company level. The model took into account many variables because it considered the uncertainty. They used the Monte Carlo simulation technique to consider many variables. The authors illustrated that the model generates a given number of contracts; each assigned a random start date within the budget period. The number of contracts can be given by the user or can be generated from a probability distribution. The model randomly generates individual contracts and integrates the output to present the company's budget. The model updates its forecast by taking actual data into account. In this way, the authors developed a fully stochastic simulation model to randomly generate individual projects.

Liu and Zayed (2009) considered the factors that affect highway construction project cash flow and the impact of these factors on the cash flow as random variables. 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 forecasting project cash flow under uncertainty. The authors determined the weight and the effect of each factor using Monte Carlo simulation and the AHP, as presented in Table 2-4 and Table 2-3 .

Table 2-3: Statistical analysis of main categories' weights (Liu and Zayed, 2009)

Criteria Weights		F	Sub	Sup	D	P	C	O
Average	μ	0.285	0.089	0.089	0.209	0.111	0.079	0.138
Standard Deviation	σ	0.024	0.015	0.015	0.021	0.018	0.012	0.02
Variance	ε	0.0006	0.002	0.0002	0.0004	0.0003	0.0001	0.0005
95% Confidence	**Low limit**	0.283	0.088	0.088	0.207	0.11	0.078	0.137
	High limit	0.286	0.09	0.09	0.21	0.113	0.08	0.139
Normal Distribution	**Skewness**	-0.077	-0.04	0.005	0.027	0.059	-0.15	-0.17
	Kurtosis	2.976	3.06	3.139	2.847	2.988	2.764	3.03
Chi-Sq Test	**Test value**	27.01	24.4	32.28	26.17	19.47	32.57	16.16
	P value	0.518	0.665	0.263	0.538	0.883	0.252	0.963
	CV = 0.25	32.62	32.62	32.62	32.62	32.62	32.62	32.62
A-D Test	**Test value**	0.352	0.322	0.408	0.351	0.311	0.625	0.354
	P value	> 0.25	>0.25	> 0.25	> 0.25	> 0.25	<= 0.15	>0.25
	CV = 0.25	0.47	0.47	0.47	0.47	0.47	0.47	0.47

Table 2-4: Statistical analysis of factors' effect "Normal Distribution" (Liu and Zayed, 2009)

Factors	μ	σ	**95% confidence**		**Chi-Sq Test**		**A-D Test**	
			Upper	**Lower**	**Test**	**P-value**	**Test**	**P-**
F1	0.81	0.17	0.801	0.836	20.280	0.854	0.296	> 0.25
F2	0.71	0.16	0.696	0.730	11.760	0.301	0.440	> 0.25
F3	0.75	0.14	0.744	0.772	7.360	0.691	0.390	> 0.25
F4	0.70	0.16	0.688	0.720	15.500	0.115	0.580	≤0.15
F5	0.62	0.18	0.608	0.644	6.260	0.793	0.316	> 0.25
F6	0.79	0.12	0.784	0.809	6.040	0.812	0.309	> 0.25
F7	0.65	0.18	0.640	0.678	6.040	0.812	0.495	≤0.25
F8	0.72	0.06	0.722	0.735	4.060	0.945	0.192	> 0.25
F9	0.66	0.22	0.644	0.688	4.280	0.934	0.320	> 0.25
F10	0.66	0.21	0.642	0.685	18.140	0.053	0.784	≤0.25
F11	0.60	0.12	0.593	0.617	6.260	0.793	0.273	> 0.25
F12	0.61	0.17	0.594	0.629	12.200	0.272	0.480	≤ 0.25
Sub1	0.62	0.16	0.608	0.640	5.820	0.830	0.710	≤ 0.1
Sub2	0.65	0.19	0.639	0.677	4.940	0.895	0.303	> 0.25
Sub3	0.69	0.18	0.677	0.714	12.420	0.258	0.385	> 0.25
Sub4	0.58	0.22	0.560	0.605	5.380	0.864	0.175	> 0.25
Sup1	0.65	0.18	0.633	0.671	4.500	0.922	0.254	> 0.25
Sup2	0.62	0.17	0.610	0.645	3.620	0.963	0.175	> 0.25
Sup3	0.71	0.20	0.698	0.739	7.580	0.670	0.434	> 0.25
Sup4	0.55	0.21	0.533	0.577	5.380	0.864	0.414	> 0.25
D1	0.70	0.23	0.685	0.731	5.600	0.848	0.338	> 0.25
D2	0.53	0.23	0.508	0.555	13.080	0.219	0.491	≤0.25
D3	0.52	0.19	0.506	0.544	5.820	0.830	0.252	> 0.25
D4	0.71	0.17	0.697	0.733	13.520	0.196	0.502	≤0.25
D5	0.63	0.20	0.615	0.656	6.260	0.793	0.285	> 0.25
D6	0.81	0.13	0.799	0.827	3.840	0.954	0.118	> 0.25
D7	0.73	0.22	0.717	0.762	10.440	0.403	0.296	> 0.25
D8	0.65	0.21	0.630	0.673	5.380	0.864	0.253	> 0.25
D9	0.85	0.10	0.845	0.867	18.360	0.049	0.628	≤ 0.1
P1	0.73	0.19	0.714	0.754	7.140	0.712	0.282	> 0.25
P2	0.57	0.21	0.551	0.594	9.120	0.521	0.356	> 0.25
P3	0.65	0.17	0.641	0.675	6.920	0.733	0.325	> 0.25
P4	0.74	0.19	0.728	0.767	4.060	0.945	0.256	> 0.25
P5	0.61	0.23	0.590	0.636	5.160	0.880	0.272	> 0.25
C1	0.68	0.15	0.674	0.705	2.520	0.991	0.079	> 0.25
C2	0.64	0.19	0.626	0.665	4.720	0.909	0.165	> 0.25
C3	0.73	0.18	0.719	0.757	7.140	0.712	0.458	> 0.25
C4	0.55	0.18	0.536	0.572	8.240	0.605	0.435	> 0.25
O1	0.63	0.18	0.614	0.652	4.060	0.945	0.192	> 0.25
O2	0.61	0.17	0.592	0.627	10.880	0.367	0.260	> 0.25
O3	0.51	0.18	0.493	0.530	8.240	0.605	0.265	> 0.25
O4	0.71	0.19	0.700	0.739	3.620	0.963	0.335	> 0.25
O5	0.68	0.24	0.661	0.710	10.440	0.403	0.332	> 0.25

2.6. IDENTIFICATION OF THE RESEARCH GAP

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 evaluated the criticality of activities to the cash-flow parameters by stochastically assigning different start times while considering the uncertainty of the cash outflow and inflow transactions. This research focuses on this gap with the goal of allowing contractors to assess the impact of delaying activities' start times on cash flow parameters, including the financing cost, maximum negative cumulative balance, project duration, and project profit. This impact represents a metric with which to assess the activities' criticality related to the cash flow parameters.

CHAPTER 3
RESEARCH METHODOLOGY

3.1. OVERVIEW

A system of steps, illustrated in Figure 3-1, were designed to satisfy our main goal, to determine the impact of activities' start times on 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, a commercially available software package, was used to implement the Monte Carlo simulation.

The methodology assesses the criticality of activities to cash flow parameters. It 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. A sensitivity analysis was carried out to assess the criticality of various activities to the cash flow parameters. In this chapter, the methodology will be explained in detail. Figure 3-1 shows a flow chart of the main sections and subsections of the model development.

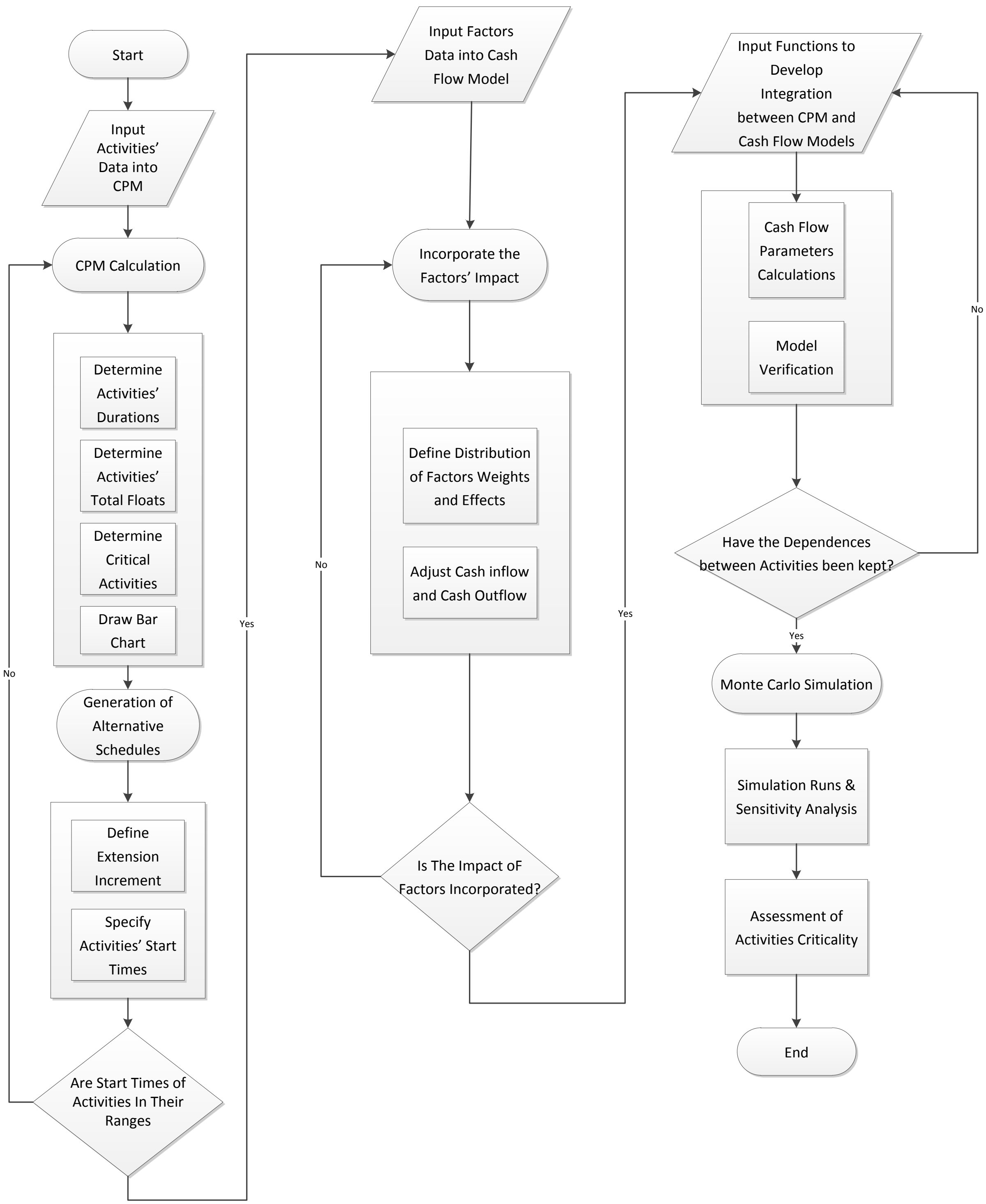

Figure 3-1: The model development

Assumptions:

- The direct cost includes the cost of labor, material, equipment and sub-contractors.
- The relationship between the direct cost and the time is assumed linear.
- The direct costs of activities are linear distributed over the activities' duration from start to finish. The time lag of the subcontractors' payments is not considered.
- The overhead costs of the project were assumed to be 15% of the direct cost.
- 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.

3.2. MODEL DEVELOPMENT

The methodology presents a system with which to assess the impact of activities' start times on cash flow parameters. It generates alternative schedules from an initial schedule, built on an Excel spreadsheet, using the critical path method (CPM) as a project management tool integrated with the cash flow model. This setup assures that the financial parameters' calculations are integrated with the CPM model. The model consists of four sections: the CPM model, the cash flow model, the integration between the cash flow model and the CPM model, and the implementation of a Monte Carlo simulation. A sample project is used to illustrate the proposed methodology. This project consists of 15 activities with the durations indicated in working days.

3.2.1. THE CPM MODEL

The CPM model provides a graphical illustration of the project schedule and a visual representation of the activities' durations from start to finish. It lays out the activities in the order they are to be carried out. Moreover, it maintains the dependencies between activities. The CPM model consists of two sections: the CPM calculations and alternative schedule generation. In this case study, the CPM model consists of 15 activities.

3.2.1.1. CPM Calculations

The CPM model, which is built in an Excel environment, takes the activity data as inputs and 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 between activities. Table 3-1 shows the Excel model of the project activities, the direct cost, the duration, the early start times, the early finish times, the late start times, the late finish times and the total float for each activity. Activities C, F, G, J, M and O exhibited total float values of zero and thus were considered the critical activities. Figure 3-2 shows the CPM network of the project activities' durations with all the CPM calculations.

Table 3-1**:** CPM model of the 15-activities project

Activity	Activity Cost	Activity Duration	ES	EF	LS	LF	TF
A	5000	10	0	10	3	13	3
B	10000	6	0	6	5	11	5
C	6000	12	0	12	0	12	0
D	6000	4	10	14	13	17	3
E	4000	3	6	9	11	14	5
F	9000	5	12	17	12	17	0
G	2000	5	17	22	17	22	0
H	3000	8	9	17	14	22	5
I	6000	7	17	24	20	27	3
J	9000	6	22	28	22	28	0
K	10000	5	17	22	22	27	5
L	6000	9	24	33	27	36	3
M	4000	8	28	36	28	36	0
N	7000	5	22	27	31	36	9
O	7000	4	36	40	36	40	0

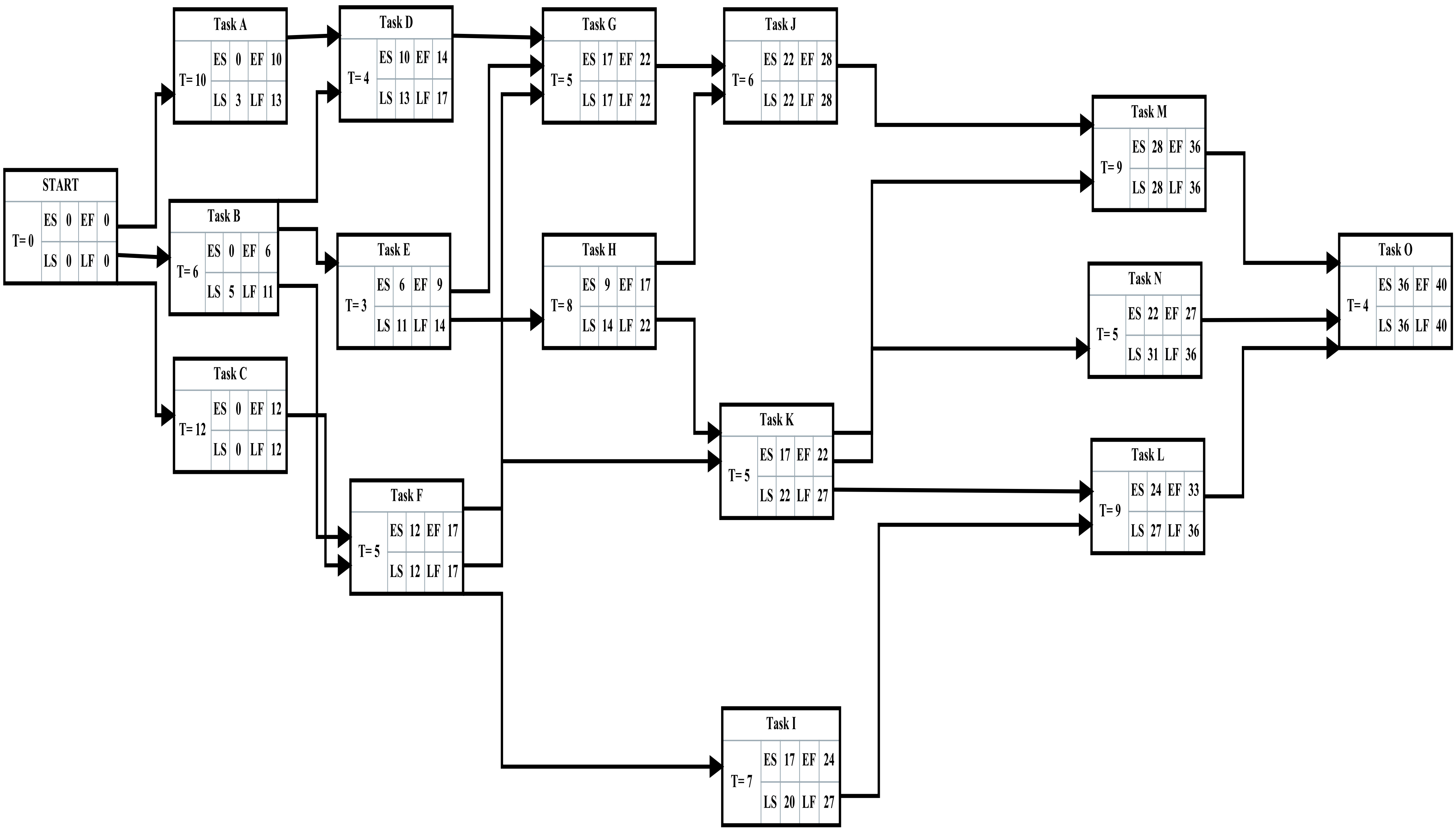

Figure 3-2 : Activities network

3.2.1.2. Alternative Schedule Generation

In this section, the start times of activities are defined in specific ranges. These specific ranges are determined based on the extension scheme. Different 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 an early to a late start, plus an extension increment, while maintaining the dependencies between activities.

(i) Extension Scheme Definition

The extension scheme is a special framework for extending a project's duration while keeping the networking basics intact. This modification in the original schedule allows a definite extension increment to be added to the original total duration. This extension increases the total float of all the activities. The increased total float of the combined activities is defined as the adjusted total float, or as the time space within which activities can be shifted without affecting the extended total duration. The extension scheme has been used to allow delaying of the early start times by the value of the adjusted total float (Elazouni and Gab-Allah, 2004).

Figure 3-3 shows the adjusted total floats, which can be expressed as a summation of the total float of all the activities, plus an extension increment of five days. The final duration is the original duration of forty days plus the extension increment of five days. Therefore, the start time of each activity can be shifted within the range of the early to the late start, plus the extension increment, while maintaining the dependencies between activities. For instance, activity N can be shifted to start on day 36 and finish on day 41, without delaying activity O that can start on day 41 and finish on day 45. Three extension increments, of five, ten and fifteen days were used in this study.

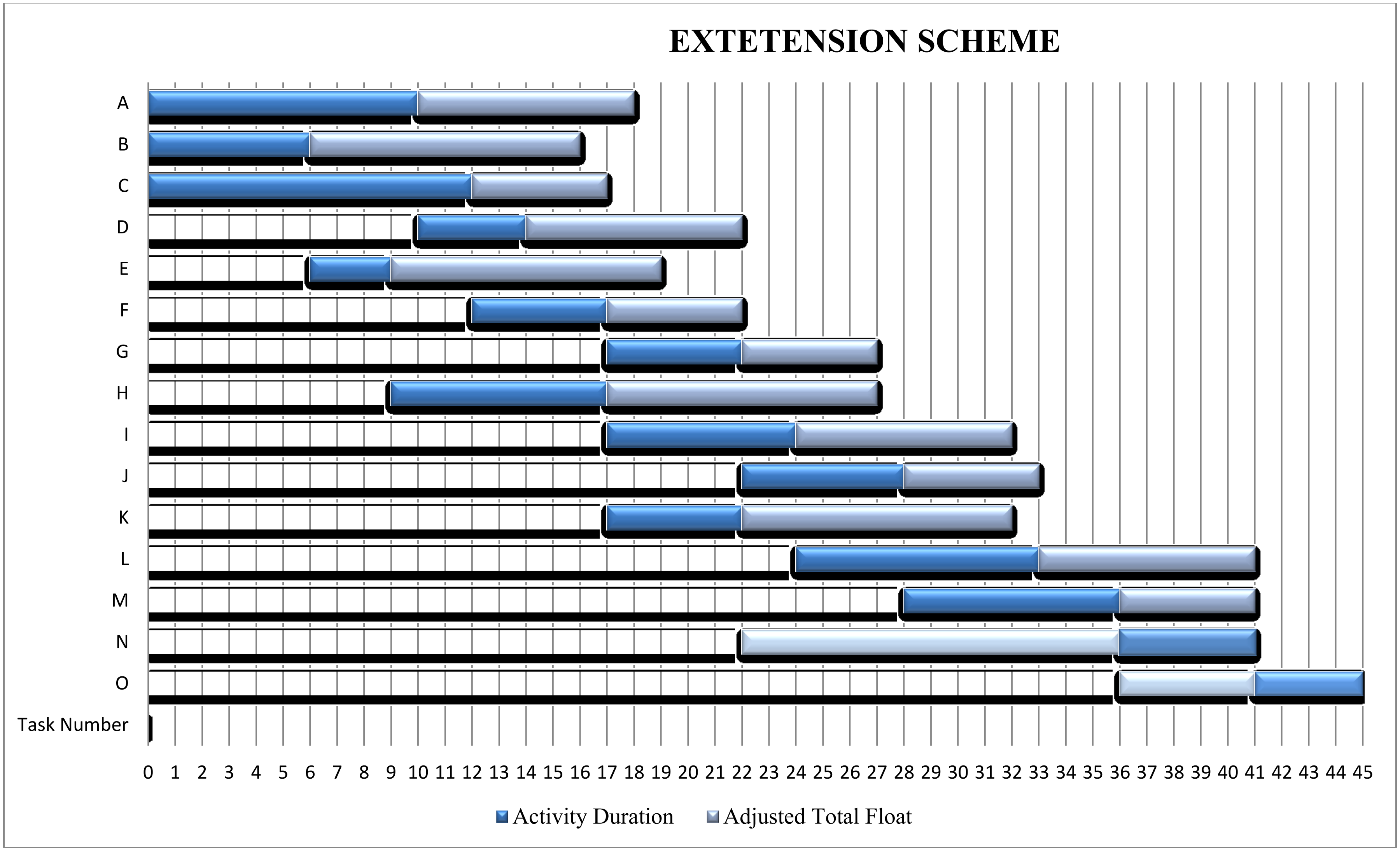

Figure 3-3: The adjusted total float with a five-day extension.

(ii) Specify the Activities' Ranges of Start Times

The start time values range from the early start time value to the late start time value, plus the specified extension increment. This range has been assumed to have a discrete uniform probability distribution such that all the values will have the same probability to occur. Discrete random variables are used to describe random phenomena in which the random variables can take only the integer values. 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 alternative schedules. Table 3-2 shows the start times' ranges for an extension increment of five days. For each activity range, the Monte Carlo simulation takes a random activity start time value of the specified range and then the Excel model performs the other CPM calculations.

Table 3-2: The ranges of activities' start times for an extension increment of five days

Activity	Early Start	Late Start	Ranges of Start Times
A	0	3	0 min - 8 max
B	0	5	0 min - 10 max
C	0	0	0 min - 5 max
D	10	13	10 min - 18 max
E	6	11	6 min - 16 max
F	12	12	12 min - 17 max
G	17	17	17 min - 22 max
H	9	14	9 min - 19 max
I	17	20	17 min - 25 max
J	22	22	22 min - 27 max
K	17	22	17 min - 27 max
L	24	27	24 min - 32 max
M	28	28	28 min - 33 max
N	22	31	22 min - 36 max
O	36	36	36 min - 41 max

3.2.2. CASH FLOW MODEL

The cash outflow of each week is calculated based on the total direct cost of each week plus the overhead. The cash inflow of each week is the cash outflow of each week plus the mark up. The impact of the factors that affect the project cash inflow and outflow is incorporated to improve forecasting accuracy. Each factor's impact is a product of its weight and effect. The impact of these factors increases the weekly cash outflow and decreases the weekly cash inflow.

3.2.2.1. Cash Inflow and Cash Outflow Calculations

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.

3.2.2.2. The Impact of the Quantitative Factors

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. 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.

(i) The Distributions of Factors' Weights and Effects

AlIssa and Zayed (2007) identified 43 factors that affect project cash flow. Liu and Zayed (2009) defined the probability distributions of the weights and the effects of the factors that influence the project cash inflow and outflow transactions using AHP and Monte Carlo simulation. Each factor's weight has been defined as normal probability distribution using the mean and the standard deviation values. Each factor's effect has been defined as normal probability distribution using the mean and the standard deviation values. The factors identified in Table 2-2 and the distributions of factors' effects and weights that are presented in Table 2-4 and Table 2-3 respectively in chapter 2, have been used in this study.

(ii) Adjusting Cash Inflow and Outflow

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.

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

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 $C_{in\text{-}m}$ is the owner payment at specific time period m.

Cash outflow model $= (1+\sum_{k=1}^{n} \boldsymbol{W_k} * \boldsymbol{E_k} * \boldsymbol{P}) * \boldsymbol{Cash\ out_m}$ **Eq. 2**

where W_k is the weight of factor k, and E_k is the effect of factor k. $C_{out\text{-}m}$ 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, which is estimated based on the opinion of the construction experts according to a triangular distribution of mean 30%, lower limit of 0% and upper limit of 50%. In order to get the accurate value of the p percent, 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% as shown in Figure 3-4. 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 as demonstrated in Table 3-3 and Table 3-4

The cash outflow of each week is calculated based on the total direct cost plus 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, incorporating the impact of all the qualitative factors that affect the cash inflow. Table 3-3 shows that the impact of the qualitative factors that affect the cash inflow decreases the cash inflow by 9%. In Table 3-4, 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.

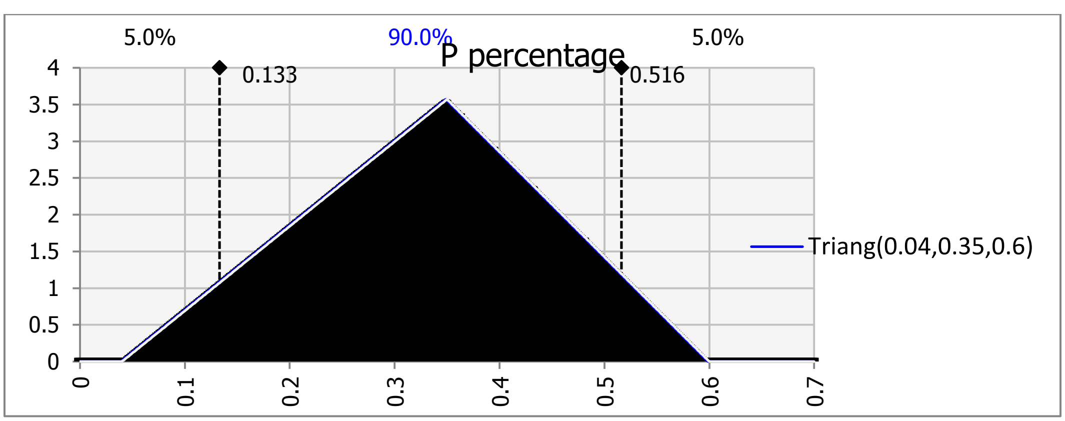

Figure: 3-4 Triangle Probability Distribution of p percentage

Table 3-3: Application of the adjustment model of the cash inflow

Factors	Weight (W)	Effect (E)	P	W*E*P
F1	0.02617	0.819	0.3	0.00643
F2	0.018995	0.713	0.3	0.004063
F3	0.019968	0.758	0.3	0.004541
F4	0.018021	0.704	0.3	0.003806
F5	0.013871	0.626	0.3	0.002605
F9	0.015617	0.666	0.3	0.00312
F10	0.014745	0.664	0.3	0.002937
P2	0.011678	0.572	0.3	0.002004
P5	0.011448	0.613	0.3	0.002105
D1	0.017889	0.708	0.3	0.0038
D3	0.01139	0.525	0.3	0.001794
D4	0.018397	0.715	0.3	0.003946
D5	0.012533	0.635	0.3	0.002388
D6	0.022081	0.813	0.3	0.005386
D9	0.02268	0.856	0.3	0.005824
C1	0.016145	0.689	0.3	0.003337
C2	0.013209	0.645	0.3	0.002556
C3	0.015893	0.738	0.3	0.003519
Sub3	0.019504	0.695	0.3	0.004067
Sup3	0.017976	0.719	0.3	0.003877
O1	0.01765	0.633	0.3	0.003352
O2	0.017296	0.61	0.3	0.003165
O3	0.010495	0.511	0.3	0.001609
O4	0.02141	0.719	0.3	0.004618
O5	0.020461	0.686	0.3	0.004211
1**- Sum W*E*P =**				0.910941

Table 3-4: Application of the Adjustment Model of the Cash Outflow

Factors	Weight (W)	Effect (E)	P	W*E*P
F6	0.02192	0.796	0.3	0.005234
F7	0.01648	0.659	0.3	0.003258
F8	0.018614	0.729	0.3	0.004071
F9	0.015617	0.666	0.3	0.00312
F10	0.014745	0.664	0.3	0.002937
F11	0.011054	0.605	0.3	0.002006
F12	0.01094	0.611	0.3	0.002005
P1	0.019067	0.734	0.3	0.004199
P2	0.011678	0.572	0.3	0.002004
P3	0.014461	0.658	0.3	0.002855
P4	0.019148	0.747	0.3	0.004291
D1	0.017889	0.708	0.3	0.0038
D2	0.0095275	0.532	0.3	0.001521
D3	0.01139	0.525	0.3	0.001794
D4	0.018397	0.715	0.3	0.003946
D5	0.012533	0.635	0.3	0.002388
D6	0.022081	0.813	0.3	0.005386
D7	0.017897	0.739	0.3	0.003968
D8	0.005282	0.652	0.3	0.001033
D9	0.02268	0.856	0.3	0.005824
C1	0.016145	0.689	0.3	0.003337
C2	0.013209	0.645	0.3	0.002556
C3	0.015893	0.738	0.3	0.003519
C4	0.0089609	0.554	0.3	0.001489
Sub1	0.014268	0.624	0.3	0.002671
Sub2	0.012922	0.658	0.3	0.002551
Sub3	0.019504	0.695	0.3	0.004067
Sub4	0.013296	0.582	0.3	0.002321
Sup1	0.016153	0.652	0.3	0.00316
Sup2	0.014114	0.627	0.3	0.002655
Sup3	0.017976	0.719	0.3	0.003877
Sup4	0.01203	0.555	0.3	0.002003
O1	0.01765	0.633	0.3	0.003352
O2	0.017296	0.61	0.3	0.003165
1 + Sum W*P*E				1.106362

3.2.3. THE INTEGRATION BETWEEN CPM MODEL AND CASH FLOW MODEL

The integration between the CPM model and the cash flow model is established in order to study the impact of the stochastic start times of activities on the cash flow parameters' value calculations. This integration was 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 activity A is shown here in equation 3.

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

Eq. 3

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 total direct cost of each day is calculated as the sum of the direct costs of all the activities ongoing that day. The total direct cost of each week is calculated as the sum of the total direct cost of the five days comprising the week. Cash outflow is the total direct cost of each week plus the overhead. Cash inflows are the cash outflow of each week plus the mark up.

3.2.3.1. Cash Flow Parameter Calculations

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%.

Figure 3-5 presents one of the generated schedules with an extension increment of five days. The total duration of this schedule is 42 days. The direct costs of the activities are indicated on the activities' bars. Accordingly, the weekly cash outflow and cash inflow transactions were determined and adjusted to incorporate the impact of the qualitative factors as presented in Table 3-5. 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.

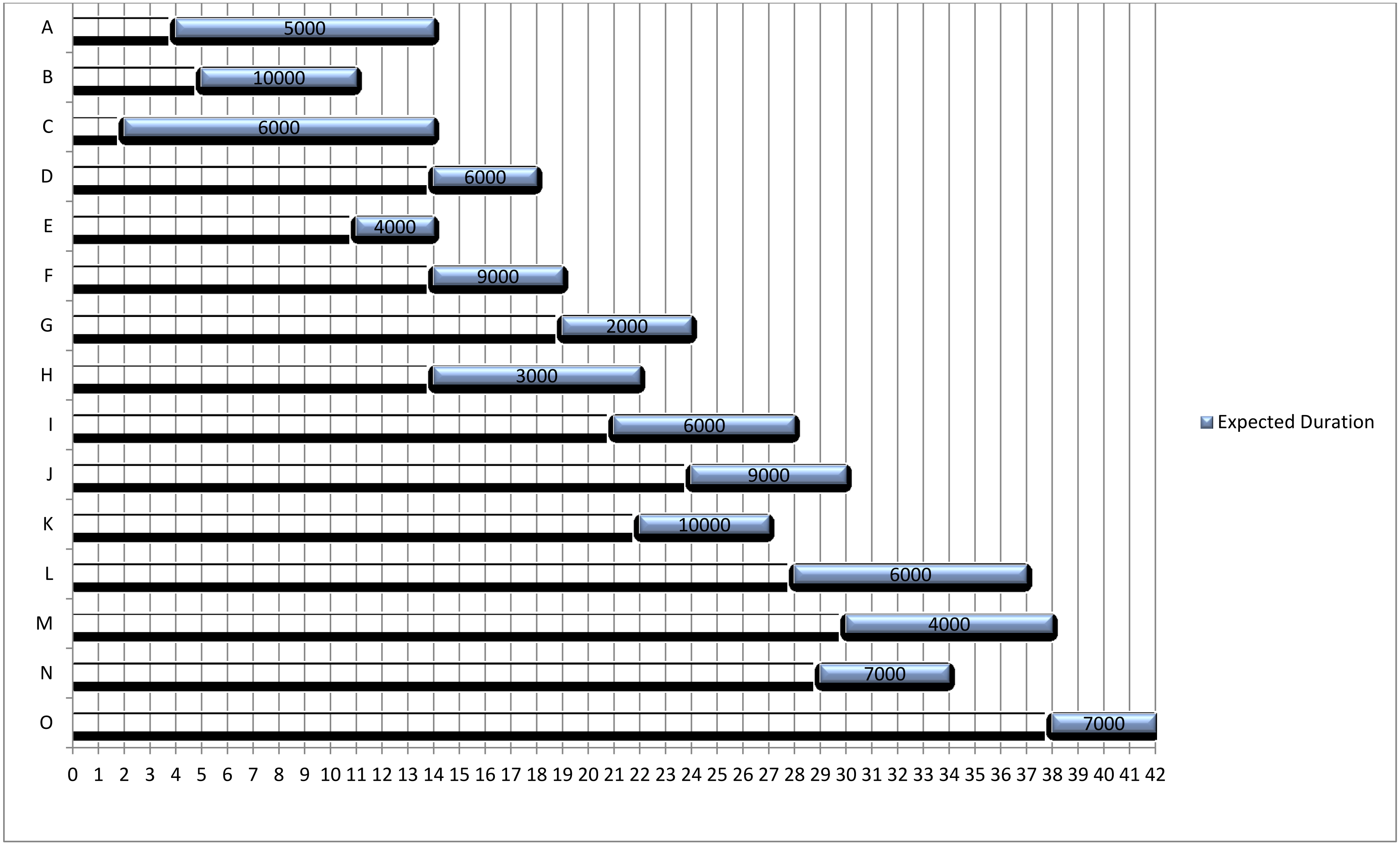

Figure 3-5: A generated schedule with a five-day extension increment

Table 3-5: Cash flow parameters with an extension increment of five days

Cash Flow Parameters	WEEKS												
	Week0	**Week 1**	**Week2**	**Week3**	**Week4**	**Week5**	**Week6**	**Week7**	**Week8**	**Week9**	**Week10**	**Week11**	**Week12**
E	**E(0)**	**E(1)**	**E(2)**	**E(3)**	**E(4)**	**E(5)**	**E(6)**	**E(7)**	**E(8)**	**E(9)**	**E(10)**	**E(11)**	**E(12)**
	0	-2544.63	-16964.22	-16974.82	-17780.62	-16894.54	-21380.97	-14546.82	-8058.00	-4453.11	0.00	0.00	0.00
P	**P(0)**	**P(1)**	**P(2)**	**P(3)**	**P(4)**	**P(5)**	**P(6)**	**P(7)**	**P(8)**	**P(9)**	**P(10)**	**P(11)**	**P(12)**
	0	0	0	2781.61	18816.03	20368.65	21250.63	20368.15	25177.70	18186.55	10363.07	5728.99	475.91
F	**F(0)**	**F(1)**	**F(2)**	**F(3)**	**F(4)**	**F(5)**	**F(6)**	**F(7)**	**F(8)**	**F(9)**	**F(10)**	**F(11)**	**F(12)**
	0	-2544.63	-19508.85	-36483.67	-51482.67	-49833.14	-50573.51	-43869.70	-31559.56	-10834.97	7351.58	17714.65	23443.64
N	**N(0)**	**N(1)**	**N(2)**	**N(3)**	**N(4)**	**N(5)**	**N(6)**	**N(7)**	**N(8)**	**N(9)**	**N(10)**	**N(11)**	**N(11)**
	0	-2544.63	-19508.85	-33702.06	-32666.65	-29192.54	-29322.89	-23501.56	-6381.86	7351.58	17714.65	23443.64	23919.54
I	**I(0)**	**I(1)**	**I(2)**	**I(3)**	**I(4)**	**I(5)**	**I(6)**	**I(7)**	**I(8)**	**I(9)**	**I(10)**	**I(11)**	**I(12)**
	0	-2.39	-20.68	-52.49	-79.86	-77.09	-74.78	-68.62	-51.62	-16.14	0.00	0.00	0.00
$\hat{I}_t$	**I'(0)**	**I'(1)**	**I'(2)**	**I'(3)**	**I'(4)**	**I'(5)**	**I'(6)**	**I'(7)**	**I'(8)**	**I'(9)**	**I'(10)**	**I'(11)**	**I'(12)**
	0	-2.39	-23.065	-75.601	-155.604	-232.984	-308.202	-377.398	-429.725	-446.672	-447.509	-448.348	-449.189
$\hat{F}_t$	**F'(0)**	**F'(1)**	**F'(2)**	**F'(3)**	**F'(4)**	**F'(5)**	**F'(6)**	**F'(7)**	**F'(8)**	**F'(9)**	**F'(10)**	**F'(11)**	**F'(12)**
	0	-2547.02	-19531.91	-36559.27	-51638.28	-49794.17	-50881.71	-44247.10	-31989.28	-11281.64	6904.07	17266.30	22994.45
$\widehat{N}_t$	**N'(0)**	**N'(1)**	**N'(2)**	**N'(3)**	**N'(4)**	**N'(5)**	**N'(6)**	**N'(7)**	**N'(8)**	**N'(9)**	**N'(10)**	**N'(11)**	**N'(12)**
	0.00	-2547.02	-19531.91	-33777.66	-32822.25	-29425.53	-29631.09	-23878.95	-6811.59	6904.91	17267.14	22995.29	23470.36

As an example of disbursement calculations, for week 1, the total direct cost for all the activities for days 1 and 2 equal 0. The total direct cost for day 3 is equal to the direct cost of activity C, which is $500. The total direct cost of day 4 is equal to the direct cost of activity C, $500. The total direct cost of day 5 is equal to the direct cost of activity A, which is $500 plus the direct cost of activity C, which is also $500; the resulting total value is $1000. Cash inflow and Cash outflow can be calculated using equations 4, 5 and 6q

$$E_t = \sum_{i=1}^{i=n} D_i * (1 + O.H) * Cout\,factor \qquad \textbf{Eq. 4}$$

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, O.H is the overhead, and C *out factor* is stochastic variable, it is the cash outflow factors' impact.

$$P_t = [E_{t-2} * (1 + markup)] * C\,infactor \qquad \textbf{Eq. 5}$$

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 factor* 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 deduction. For example, the deduction of week 3 can be added in the fourth week and the deduction 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

$$P_t = [E_{t-2} * (1 + markup)] * C\,infactor + [E_{t-3} * (1 + markup)] * (1 - C\,infactor)$$

Eq. 6

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 factor* is the cash inflow factors' impact, it is stochastic variable and E_{t-3} is the cash outflow at time period t-3.

The cash-flow 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 the costs of overhead in addition to the direct costs that include 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 where;

$$F_t = N_{t-1} + E_t \qquad \textbf{\textit{Eq. 7}}$$

where, E_t is the cash outflow during a typical period t, and N_{t-1} is the cumulative net balance at the end of period t-1.

The cumulative net balance at the end of period t after receiving payment P_t is defined as N_t. At the end of period t-1, N_{t-1} can be calculated from equation 8

$$N_{t-1} = F_{t-1} + P_{t-1} \qquad \textbf{\textit{Eq. 8}}$$

where F_{t-1} is the cumulative balance, P_{t-1} is the payment received, and N_{t-1} is the cumulative net balance.

Typically, cash procurement via bank credit lines incurs financing costs. The financing cost charged by the bank at the end of period t is I_t , is calculated using Equations 9 to 11. For period t, if the cumulative net balance of the previous period N_{t-1} is positive, this implies that the contractor debit is null and the contractor can use the surplus cash to finance activities during the current period. If the surplus cash completely covers the amount of E_t, the contractor borrows no cash and Equation 11 applies; otherwise, the contractor will pay financing costs only for the amount of borrowed money in excess of the surplus cash, as in Equation 10. If N_{t-1} is negative or zero, Equation 9 applies for calculating the financing cost.

$$I_t = rN_{t-1} + r\frac{E_t}{2} \quad \text{If } N_{t-1} \leq 0 \qquad \textit{Eq. 9}$$

where I_t is the financing cost charged by the bank at the end of period t, and N_{t-1} is the cumulative net balance at time period t-1, and E_t is the cash outflow at time period t.

$$I_t = r(\frac{E_t - N_{t-1}}{2}) \quad \text{If } N_{t-1} > 0 \text{ and } N_{t-1}-E_t < 0 \qquad \textit{Eq. 10}$$

$$I_t = 0 \quad \text{If } N_{t-1}-E_t \geq 0 \qquad \textit{Eq. 11}$$

The first term in Equation 9 represents the financing costs per period on the cumulative net balance N_{t-1} at interest rate r per period, and the second term approximates the financing costs on the cash outflow E_t during period t.

When contractors decide to pay the financing costs at the end of the project, the periodical financing costs are compounded by applying Equation 12:

$$\hat{I}_t = \sum_{l=1}^{t} I_l (1+r)^{t-l} \qquad \textbf{\textit{Eq. 12}}$$

where $\widehat{I_t}$ is the cumulative financing cost, r is the stochastic weekly interest rate with triangle probability distribution and minimum value of 0.125, maximum value of 0.25 and mean value of 0.19.

Thus, the cumulative balance at the end of period t, including accumulated financing costs, is represented by $\hat{F}_t$ which is calculated as:

$$\hat{F}_t = F_t + \hat{I}_t \qquad \textbf{\textit{Eq. 13}}$$

The cumulative net balance including the financing cost is thus $\hat{N}_t$:

$$\hat{N}_t = \hat{F}_t + P_t \qquad \textbf{\textit{Eq. 14}}$$

The positive value of $\hat{N}_t$ at the end of the last period *L* represents the corporate profit.

The calculations of the cash flow parameters are based on the values of the cash inflows and outflows, as presented in Table 3-5. The cash flow parameters considered to be the model outputs which are the following:

- Total project duration D.
- Maximum negative cumulative balance $\widehat{F}_t$
- Project profit $\widehat{N}_t$
- Financing cost $\widehat{I}_t$

3.2.3.2.Model Verification

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

$$f(x) = \mathrm{x} \qquad x \in \{0,1,2,3,4,5,6,7,8\} \quad ; \qquad \textbf{Eq. 15.}$$

the start time of activity B as

$$f(x) = \mathrm{x} \qquad x \in \{0,1,2,3,4,5,6,7,8,9,10\} \; ; \qquad \textbf{Eq. 16.}$$

the start time of activity C as

$$f(x) = \mathrm{x} \qquad x \in \{0,1,2,3,4,5\} \quad ; \qquad \textbf{Eq. 17}$$

And the start time of activity D as

$$f(x) = \begin{cases} FA, & if\ FA > FB \\ FB & otherwise \end{cases} \qquad \textbf{Eq. 18}$$

$$x \in \{10,11,12,13,14,15,16,17,18\} \, ,$$

where 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

$f(x) = FB \qquad x \in \{6,7,8,9,10,11,12,13,14,15,16\}$, **Eq. 19**

where FB is a deterministic variable it represents the finish time of activity B.

The start time of activity F is defined as

$$f(x) = \begin{cases} FB & if\ FB > FC \\ FC & otherwise \end{cases} \qquad x \in \{12, 13,14,15,16,17\}$$, **Eq. 20**

where 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

$$f(x) = \begin{cases} FD & if\ FD > FE\ and\ FD > FF \\ FE & if\ FE > FD\ and\ FE > FF \\ FF & if\ FF > FD\ and\ FF > FE \end{cases}$$ **Eq. 21**

$$x \in \{17,18,19,20,21,22\}$$,

where 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

$f(x) = \mathrm{FE} \qquad x \in \{9,10,11,12,13,14,15,16,17,18,19\}$; **Eq. 22**

the start time of activity I as

$f(x) = \mathrm{FF} \qquad x \in \{17,18,19,20,21,22,23,24,25\}$; **Eq. 23**

And the start time of activity J is defined as

$$f(x) = \begin{cases} FG & if\ FG > FH \\ FH & if\ FH > FG \end{cases} \qquad x \in \{22,23,24,25,26,27\}$$ **Eq. 24**

where 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

$$f(x) = \begin{cases} FF & if\ FF > FH \\ FH & if\ FH > FF \end{cases}$$ **Eq. 25**

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

where 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

$$f(x) = \begin{cases} FI & if\ FI > FK \\ FK & if\ FK > FI \end{cases} \qquad \textbf{Eq. 26}$$

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

where 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

$$f(x) = \begin{cases} FJ & if\ FJ > FK \\ FK & if\ FK > FJ \end{cases} \qquad \textbf{Eq. 27}$$

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

where 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

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

And the start time of activity O is defined as

$$f(x) = \begin{cases} FL & if\ FL > FM\ and\ FL > FN \\ FM & if\ FM > FL\ and\ FM > FN \\ FN & if\ FN > Fm\ and\ FN > FL \end{cases} \qquad \textbf{Eq. 29}$$

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

where 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: the financing cost, the maximum negative cumulative balance and the project profit.

3.2.4. MONTE CARLO SIMULATION

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. Sensitivity analysis is carried out in order to rank the activities based on their impact on the project duration and on the cash flow parameters.

3.2.4.1. Simulation Runs

Upon running the simulation iteratively, 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. The probability distributions of the cash flow parameters can also be displayed in a cumulative form.

(i) The Outputs with an Extension Increment of 5 Days

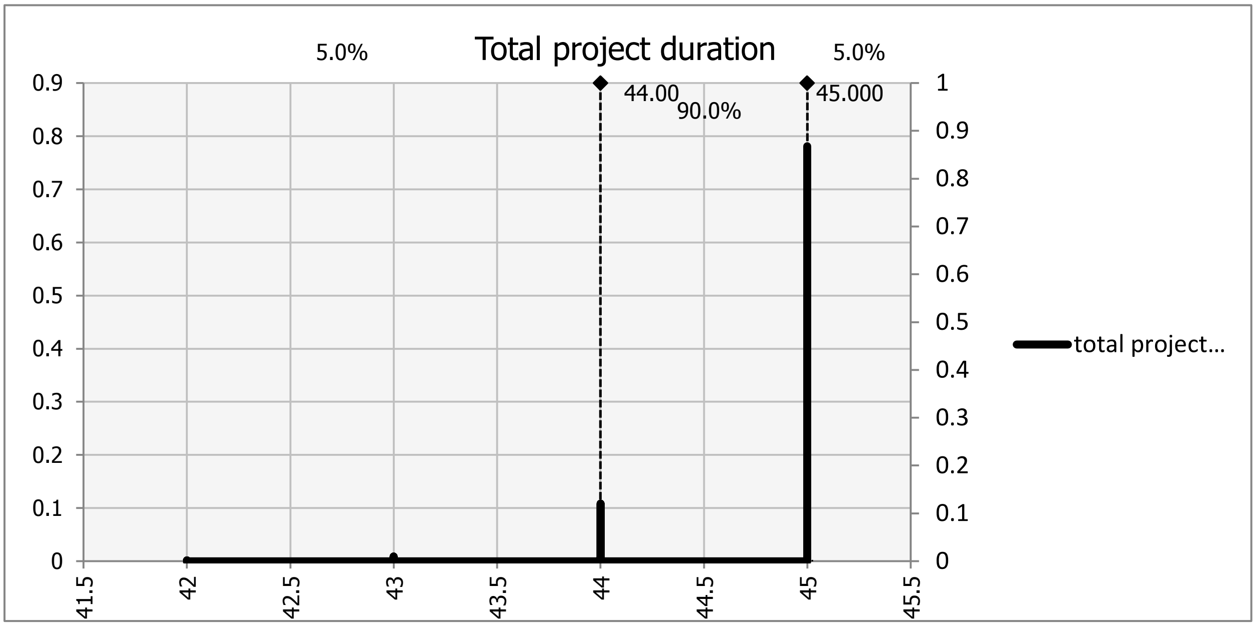

Figure 3-6 : The total project duration range with a 5-day extension increment.

Figure 3- 6 shows the project duration with the days in a given interval from 41.5 to 45.5 days in the horizontal axis. It shows the frequency distribution in the vertical axis, which is the number or frequency of values from 0 to 0.9 occurring in the specified project duration interval. This figure shows the possible outcomes of the final project duration upon running the simulation for 500 runs. The minimum project duration is 42 days, the maximum duration is 45 days and the mean duration is 44 days. Moreover, the figure shows the certainty range with the 90% chance that the project duration would fall within the specified range from 44 to 45 days.

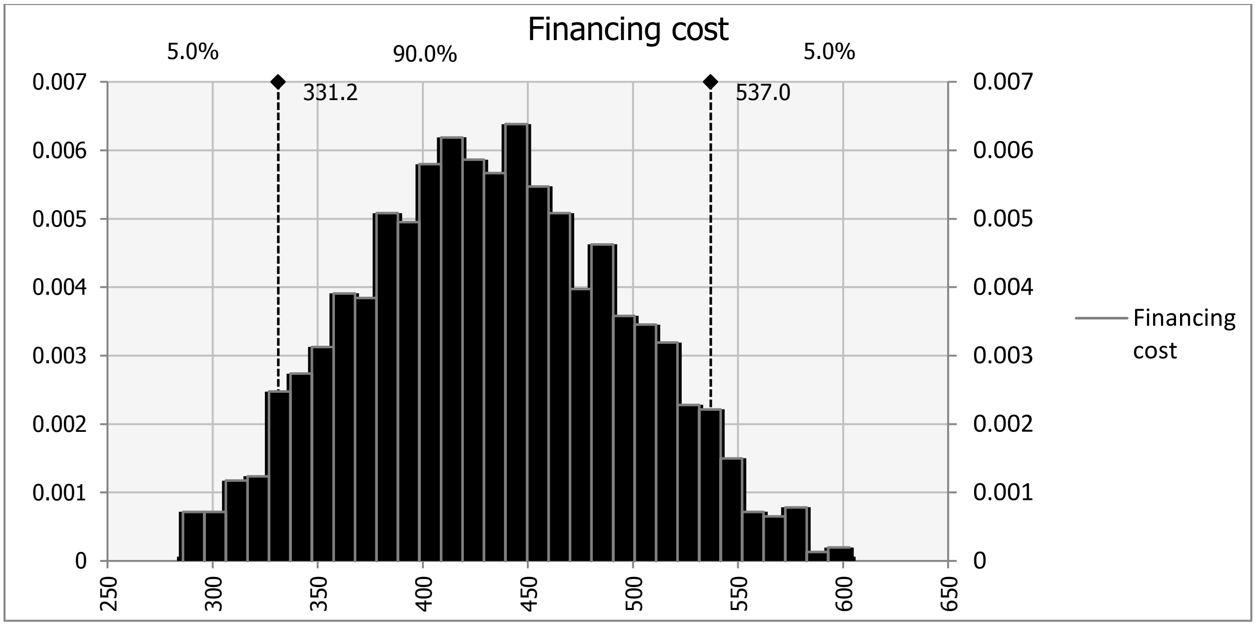

Figure 3-7: The probability distribution of the financing cost with an extension of 5 days

Figure 3-7 shows the financing cost in a given interval from $250 to $650 in the horizontal axis. It shows the frequency distribution in the vertical axis, which is the number or frequency of values from 0.000 to 0.007 that occur in the specified interval of the financing cost. The figure shows the possible outcomes of the financing cost with a five-day extension increment. It indicates that the minimum financing cost is $285.8, the maximum is $603.1 and the mean financing cost is $432.67. Moreover, this figure shows the certainty range with the 90% likelihood that the financing cost would fall within the specified range from $331.2 to $537.

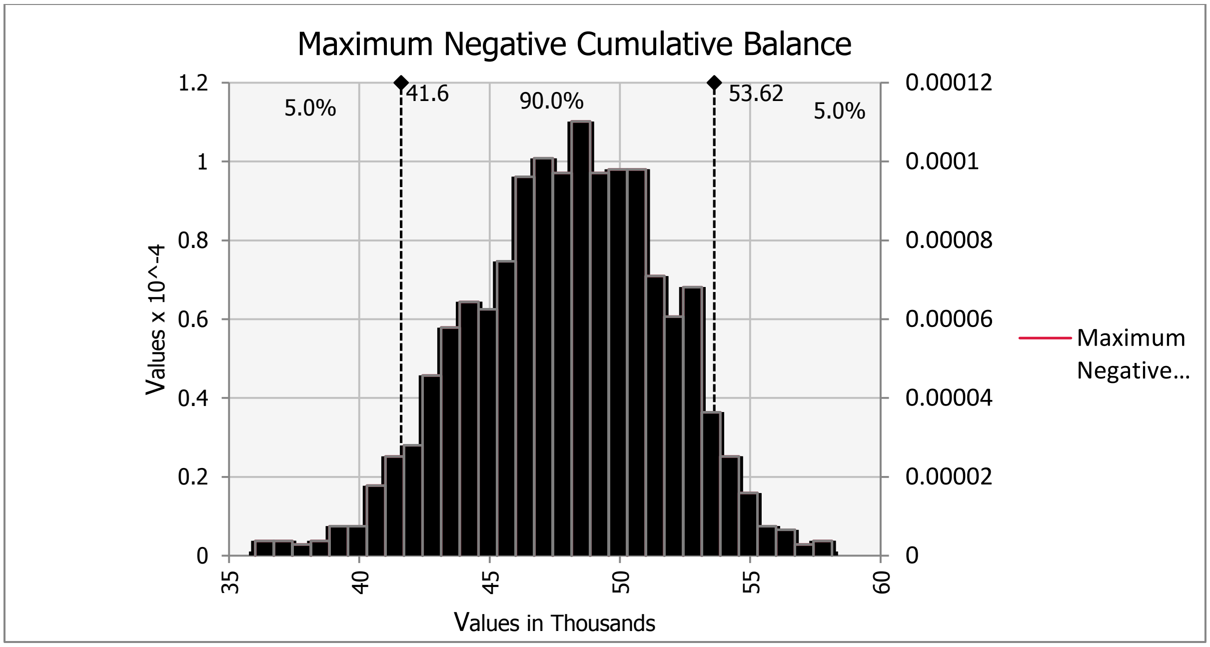

Figure 3-8: The probability distribution of the maximum negative cumulative balance with extension of 5 days

Figure 3-8 shows the maximum negative cumulative balance in a given interval from $35,000 to $60,000 in the horizontal axis. It shows the frequency distribution in the vertical axis, which is the number or frequency of values from 0.0 to 1.2 that occur in the specified interval. This figure shows the possible outcomes of the maximum cumulative negative balance with a five-day extension increment. It reveals that the minimum value of the cumulative negative balance is $35,999, the maximum is $58,137and the mean value is $47,958.5. Moreover, this figure shows the certainty range with the 90% chance that the maximum negative cumulative balance would fall within the specified range from $41,600 to $53,620.

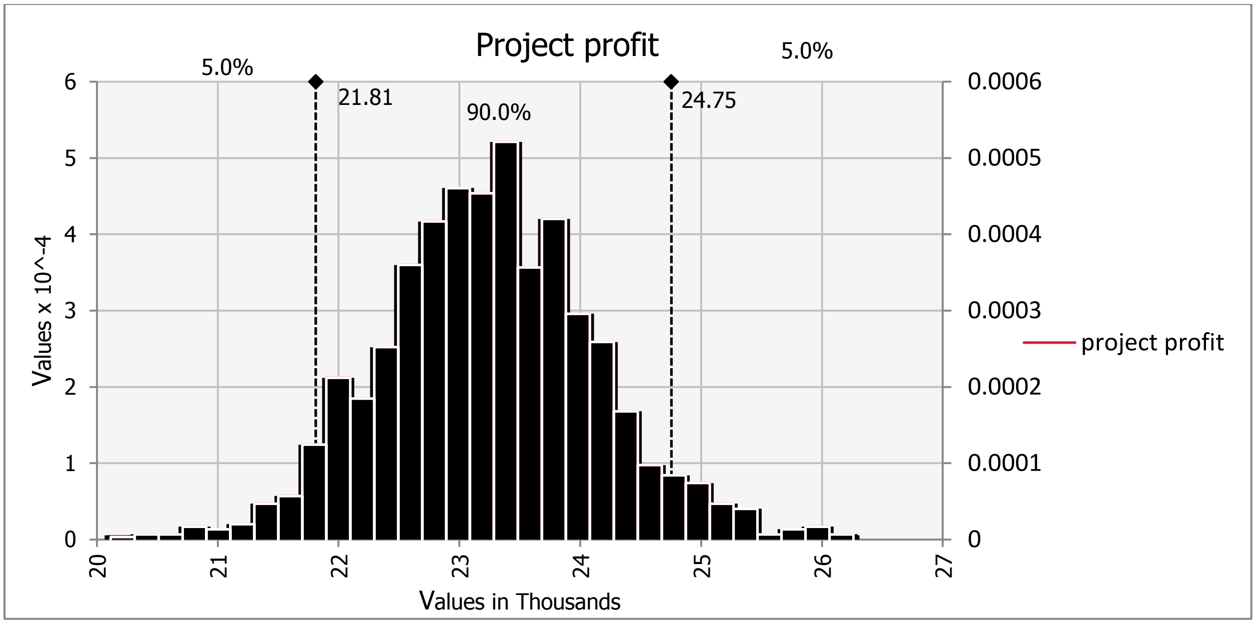

Figure 3-9: The project net profit with the extension of 5 days

Figure 3-9 shows the net profit in a given interval from $20,000 to $27,000 in the horizontal axis. It shows the frequency distribution in the vertical axis, which is the number or frequency of values from 0.0 to 6 that occur in the specified interval. The figure indicates the possible outcomes of the project net profit with a five-day extension increment. It reveals that the minimum net profit is $20,113.6, the maximum is $26,260.6 and the mean is $23,239.22. Moreover, this figure shows the certainty range with the 90% chance that the net profit would fall within the specified range from $21,810 to $24,750.

(ii) Output Results of a 10-Day Extension Increment

Upon running the simulation for 500 iterations, the results showed the possible outcomes on the project duration with an extension of 10 days. The minimum project duration is 46 days, the maximum project duration is 50 days and the mean duration is 49 days. The possible outcomes of the financing cost are: a minimum value of $284.6, maximum value of $587.3 and a mean value of 425$. The possible outcomes of the maximum cumulative negative balance are: a minimum value of $32,989.3, a maximum value of $58,372.4 and a mean value of $46,128.7. The possible outcomes of the project net profit are: a minimum value of $22,573, a maximum value of $24,054 and a mean value of $23,238.

(iii) Output Results of a 15-Day Extension Increment

Upon running the simulation number of iterations, the results show the possible outcomes of the project duration with a 15-day extension. The minimum duration is 49 days, the maximum is 55 days and the mean duration is 54 days. The possible outcomes of the financing cost are: a minimum cost of $278, maximum of $565, and mean cost of $418. The possible outcomes of the maximum cumulative negative balance are: a minimum value of $31,846.9, a maximum value of $57,329.97 and a mean value of $44,581.6. The possible outcomes of the project net profit have a minimum value of $22,742.5, a maximum of $23,831 and a mean value of $23,245.6.

3.2.4.2. Criticality Assessment

@RISK allows simulation data to be collected for individual iterations for both input distributions and output variables. It analyzes this data to identify the input distributions that have the most effect on determining the output variable values. The activities that have the highest impact on the outputs, comprised of the total project duration, the financing cost, the project profit and the maximum negative cumulative balance, are identified as the critical activities. The criticality assessment is carried out with two different analytical techniques:

1- Regression analysis: Sampled input variable values are regressed against output values. The calculated regression coefficient for each input variable thus measures the criticality of each output to that input.

2- Correlation calculation: Correlation coefficients are calculated for the relationship between the output values and each sampled input value. The higher the correlation between the inputs and outputs, the more significance the inputs have on the output values. The results of the criticality analysis are displayed as a "tornado" chart with longer bars at the top representing the most significant inputs' variables, i.e., those that have the highest impact on the outputs.

3.2.4.3. Using Correlation Coefficients to Assess Criticality

Critical activities are those activities that allow the total float to equal zero. The start times of the critical activities cannot be delayed because the early start times of these activities are equal to the late start times. A delay in a critical activity causes delay in the completion date of the project. Critical activities have the highest impact on the total project duration.

In this research, correlation coefficients are used to assess the criticality of activities in relation to the financial parameters, including the total project duration. Correlation coefficients are used to rank activities' start times – identifying those with the highest impact on the total project duration and the financial parameters. In order to ensure that correlation coefficients can be used to assess activities' criticality, five extension increments were used in the CPM model. The start times of activities are defined with a uniform discrete probability distribution in the range of the early start time to the late start time, plus any specified extension increment. Five extension increments were used in this procedure one, two, three, four and five days. @RISK was used to generate stochastic schedules, employing Monte Carlo simulation. Sensitivity analysis was carried out to assess the activities that have the highest impact on the total project duration.

The results showed that the activities with the highest impact on the total project duration are activities C, G, F, J, M and O, which exhibit a total float equal to zero. As shown in Figure 3-10 the activities' start times with an extension increment of one day are ranked according to the values of the correlation coefficients. The critical activities C, F, G, J, M and O have the highest positive correlation coefficient values. These activities are considered the critical activities for the project duration. Figure 3- shows the activities' start times with a 2-day extension increment. The critical activities C, G, J, F, M and O have the highest positive correlation coefficients values. In Figure 3-, the activities' start times with an extension increment of three days are ranked according to the values of their correlation coefficients. The critical activities G, C, O, M, J and F have the highest positive correlation coefficients. The correlation coefficients for activities G, C, O, M, J and F are 0.15, 0.13, 0.12, 0.11, 0.11 and 0.09, respectively. In Figure 3-, the activities' start times with an extension increment of four days are ranked. The critical activities J, M, G, C, F and O have the highest positive correlation coefficients. The correlation coefficients for activities J, M, G, C, F and O are 0.17, 0.15, 0.13, 0.13, 0.11 and 0.10, respectively. Figure 3- shows the ranking of activity start times with an extension increment of five days. The critical activities O, G, J, M, F and C have the highest positive correlation coefficients. The correlation coefficients for activities O, G, J, M, F and C are 0.17, 0.16, 0.13, 0.13, 0.12 and 0.12, respectively.

From these five experiments, the activities C, G, F, J, M and O have the highest impact on the total project duration. According to the correlation coefficient values, these activities are the critical activities for the total project duration. Moreover, these activities are the critical activities of this project based on their total float values that equal zero. The results affirm that correlation coefficients can be used to assess criticality.

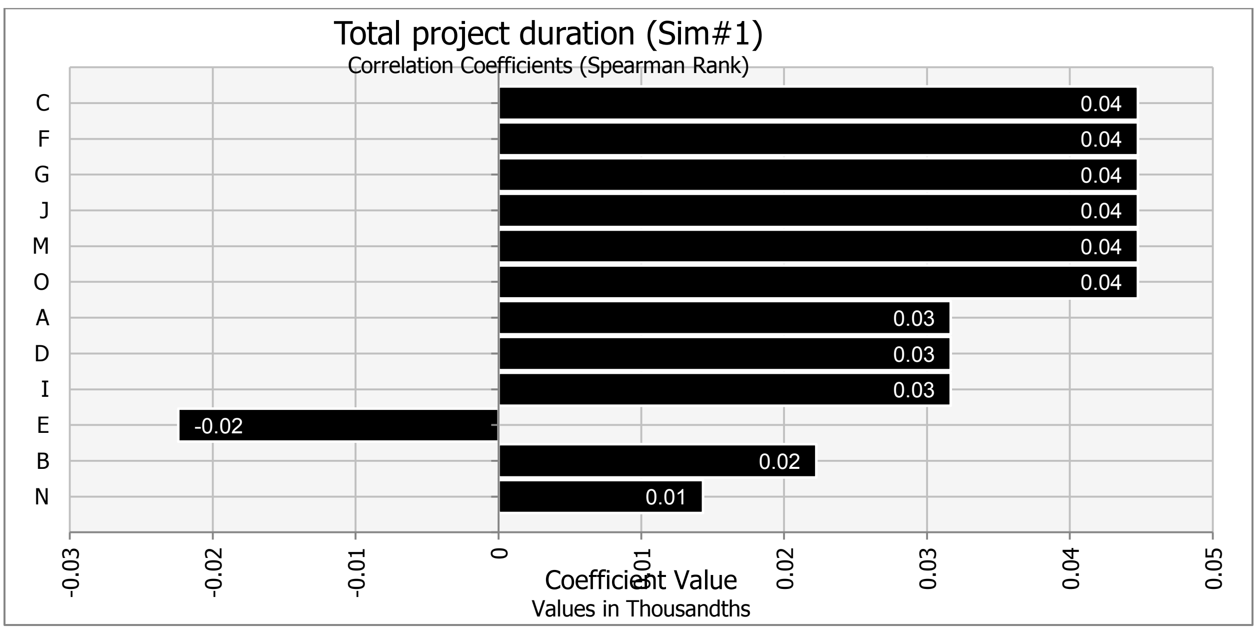

Figure 3-10: The impact of activities' start times on the total duration with an extension of one day

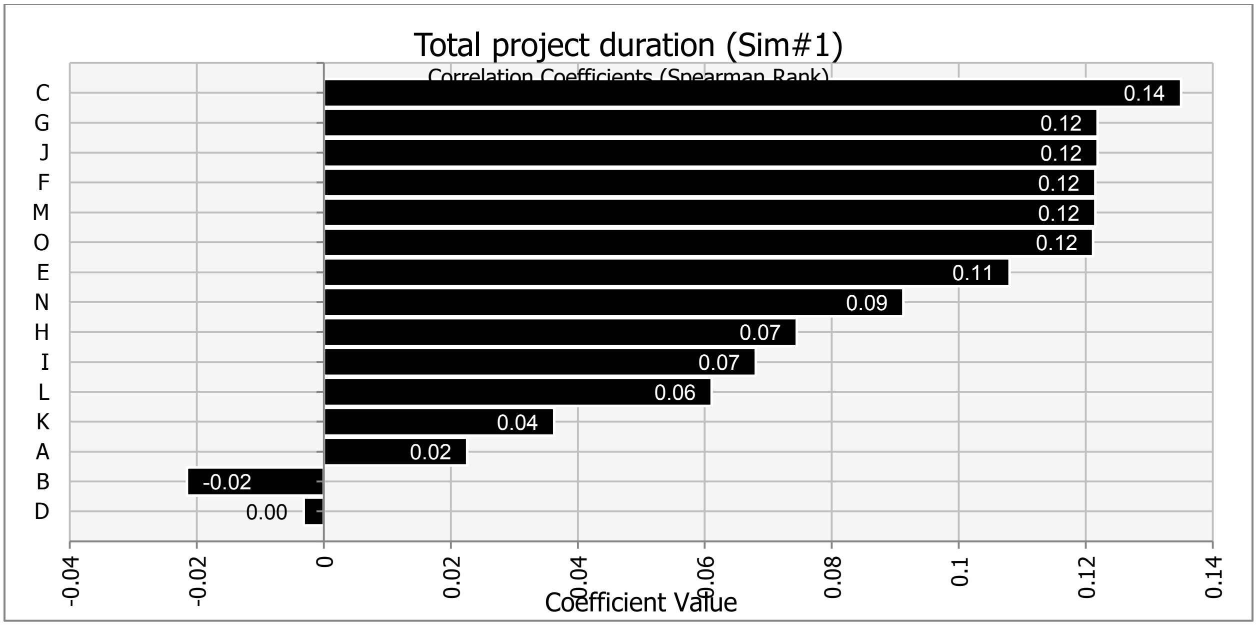

Figure 3-11: The impact of activities' start times on the total duration with a two-day extension

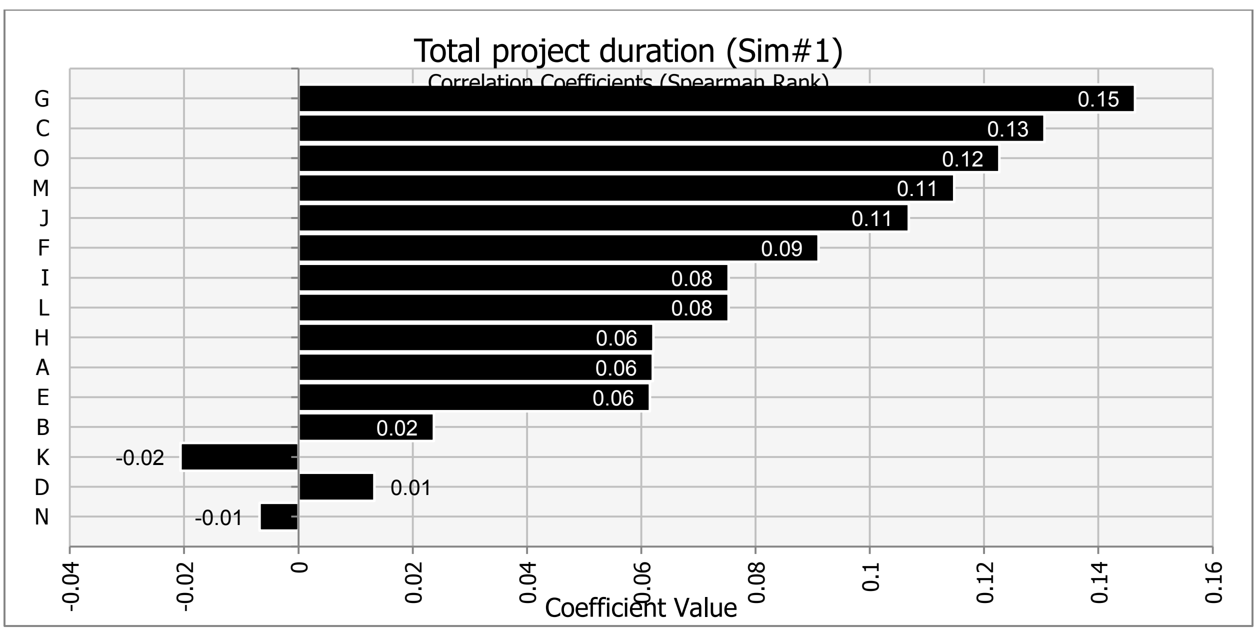

Figure 3-12: The impact of activities' start times on the total duration with a three-day extension

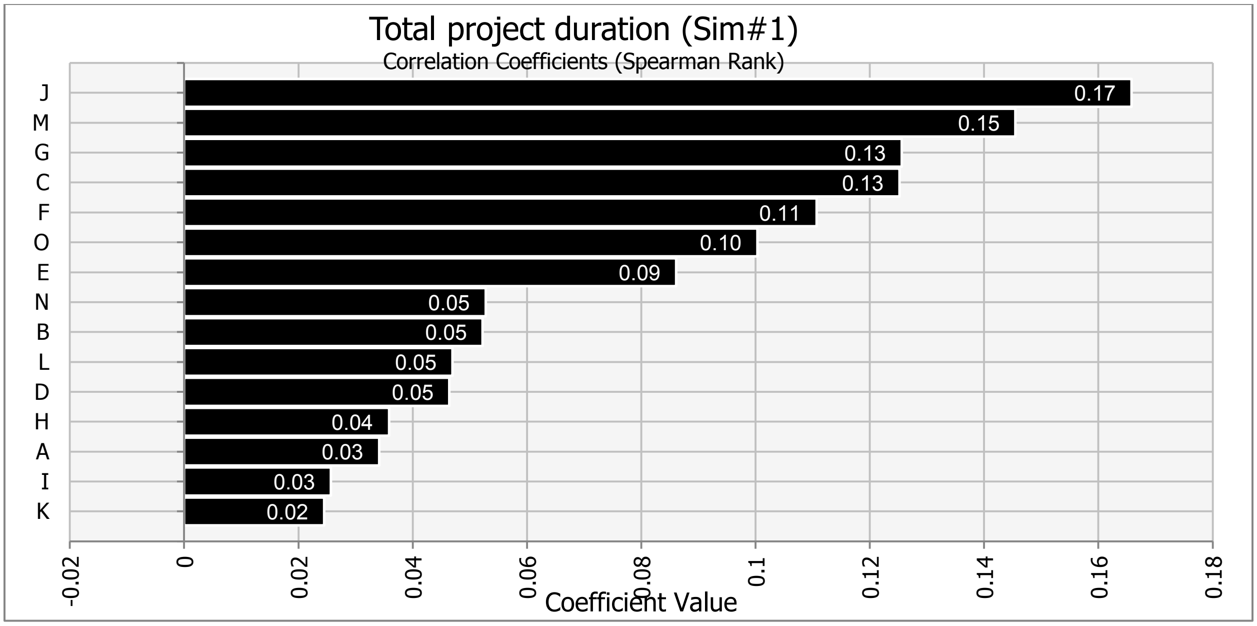

Figure 3-13: The impact of activities start times on the total duration with a four-day extension

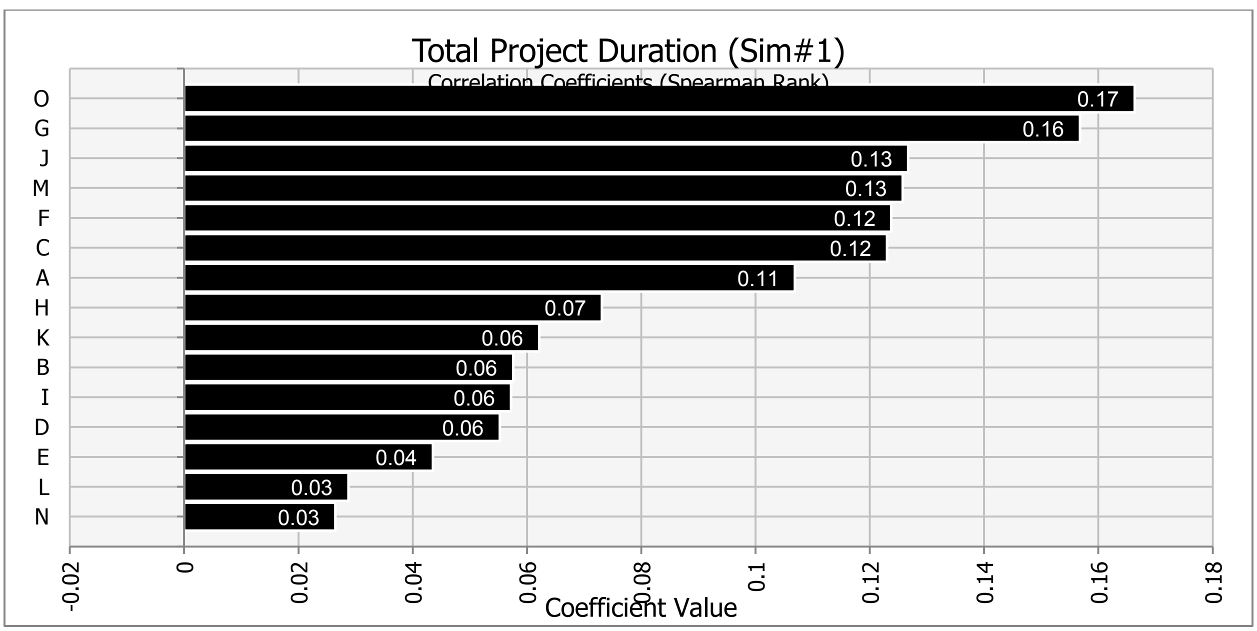

Figure 3-14: The impact of activities' start times on the total duration with a five-day extension

3.2.4.4. Advanced Analysis

In this step, we measure the impact of activities on the cash flow parameters. Studying the impact on the outputs of changing the start times of activities in a specific range will lead to the assessment of these activities' criticality in relation to cash flow parameters. This advanced analysis determines the criticality of activities' start times to the cash flow parameters. It allows the criticality of the activities with the highest impact on the cash flow parameters to be ranked according to their importance. This aspect will be explained briefly in Chapter 4.

CHAPTER 4
ANALYSIS

4.1. OVERVIEW

This chapter presents the analysis undertaken to assess the impact of activity start times on cash flow parameters. Project managers will have the ability to assess the criticality of activities to cash flow parameters. Three scenarios were introduced to study the impact of activities' start times. These three scenarios are defined based on the number of the qualitative factors impacting the project cash inflow and cash outflow transactions that they incorporate. Scenario I incorporates none, Scenario II incorporates six factors impacting cash inflow transactions and nine factors impacting cash out flow transactions, and Scenario III incorporates all the qualitative factors that impact cash inflow and cash outflow transactions.

The start times of the activities were defined using a uniform discrete distribution for each scenario. Three extension increments were used for each scenario. The outputs, which are the cash flow parameters project duration, maximum negative cumulative balance, project profit and the financing cost, were analyzed for each scenario. Upon running the specified number of iterations, the probability distribution for each parameter was determined. This probability distribution defines the minimum, the maximum and the mean value for each parameter. The results were analyzed based on these three scenarios. Moreover, an advanced analysis has been presented for scenario III with an extension increment of 5 days.

4.2. 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. Three scenarios were defined based on the qualitative factors that they incorporate, Scenario I does not incorporate any. Scenario II 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 II 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 III 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 three scenarios are considered as scenario's I, II and III. However, in other types of contracts, these scenarios could be considered as the best case, 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 three scenarios are analyzed below.

4.2.1. SCENARIO I

Scenario I is defined as containing none of the incorporated qualitative factors. In other types of contracts, this scenario is considered to be the best scenario as there are no factors to increase cash outflow transactions and decrease cash inflow transactions. This scenario is analyzed under the three extension increments of 5, 10 and 15 days.

Table 4-1 presents the values of the cash flow parameters for a generated schedule with an extension increment of 5 days. The cash flow parameters were calculated using equations 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14 from the methodology chapter in the section on cash flow parameter calculations. Table 4-1 indicates that the project financing cost is $388.35, the maximum negative cumulative balance is $46,427.58 and the project profit is $21,231.6. The total duration is 45 days. For a schedule generated with a 10-day extension increment, the project financing cost is $385.07, the maximum negative cumulative balance is $44,977.64 and the project profit is $21,234.9. The total duration is again 45 days. For a generated schedule with a 15-day extension increment, the project financing cost is $388.3597, the maximum negative cumulative balance is $46,427.68 and the project profit is $21,231.64. The total duration is 49 days.

4.2.2. SCENARIO II

Scenario II is defined as containing six of the incorporated qualitative cash inflow factors and nine of the incorporated qualitative cash outflow factors. In other types of contracts, this scenario is considered to be the most likely scenario, as the incorporated factors, which increase cash outflow transactions and decrease cash inflow transactions, are common to most the construction projects. This scenario is considered under the three extension increments of 5, 10 and 15 days.

For a schedule generated with an extension increment of 5 days, the project financing cost is $411, the maximum negative cumulative balance is $48,200.47 and the project profit is $21,066. The total project duration is 42 days. For a schedule generated with an extension increment of 10 days, the project financing cost is $406.90, the maximum negative cumulative balance is $47,210.17 and the project profit is $21,071.02. The total project duration is 45 days. For a schedule generated with a 15-day extension increment, the project financing cost is $238.3, the maximum negative cumulative balance is $36,898.30 and the project profit is $22,433.24. The total project duration is 55 days.

4.2.3. SCENARIO III

Scenario III is defined as containing 34 of the incorporated qualitative factors that affect cash outflow transactions and 25 of the incorporated qualitative factors that affect cash inflow transactions. In other types of contract, this scenario is considered to be the worst scenario, as the incorporated factors, which increase cash outflow transactions and decrease cash inflow transactions are all of the forty-three qualitative factors that were defined in previous studies. This scenario is considered under the three extension increments of 5, 10 and 15 days.

For a schedule generated with the extension increment of 5 days, the project financing cost is $408.66, the maximum negative cumulative balance is $48,200.47 and the project profit is $22,000.40. The total duration is 42 days. For a schedule with a 10-day extension increment, the project financing cost is $404.7, the maximum negative cumulative balance is $47,115.887 and the project profit is $22,004.34. The total duration is 45 days. For a schedule generated with a 15-day extension increment, the project financing cost is $299.63, the maximum negative cumulative balance is $44,511.2 and the project profit is $21,716.95. The total project duration is 52 days.

Table 4-1: The cash flow parameters for scenario I with an extension increment of 5 days

Cash flow parameters	**WEEKS**											
	Week 0	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**	**Week 9**	**Week 10**	**Week 11**
E	E(0)	E(1)	E(2)	E(3)	E(4)	E(5)	E(6)	E(7)	E(8)	E(9)	E(10)	E(11)
	0	-2300.00	-15333.33	-15342.92	-16071.25	-15270.36	-19325.48	-13148.33	-7283.33	-4025.00	0.00	0.00
P	P(0)	P(1)	P(2)	P(3)	P(4)	P(5)	P(6)	P(7)	P(8)	P(9)	P(10)	P(11)
	0	0	0	2760.00	18400.00	18411.50	19285.50	18324.43	23190.57	15778.00	8740.00	4830.00
F	F(0)	F(1)	F(2)	F(3)	F(4)	F(5)	F(6)	F(7)	F(8)	F(9)	F(10)	F(11)
	0	-2300.00	-17633.33	-32976.25	-46287.50	-43157.86	-44071.83	-37934.67	-26893.57	-7728.00	8050.00	16790.00
N	N(0)	N(1)	N(2)	N(3)	N(4)	N(5)	N(6)	N(7)	N(8)	N(9)	N(10)	N(11)
	0	-2300.00	-17633.33	-30216.25	-27887.50	-24746.36	-24786.33	-19610.24	-3703.00	8050.00	16790.00	21620.00
I	I(0)	I(1)	I(2)	I(3)	I(4)	I(5)	I(6)	I(7)	I(8)	I(9)	I(10)	I(11)
	0	-2.16	-18.69	-47.45	-71.72	-66.61	-64.52	-58.80	-43.60	-10.72	0.00	0.00
I'	I'(0)	I'(1)	I'(2)	I'(3)	I'(4)	I'(5)	I'(6)	I'(7)	I'(8)	I'(9)	I'(10)	I'(11)
	0	-2.16	-20.848	-68.333	-140.184	-207.052	-271.957	-331.268	-375.486	-386.907	-387.632	-388.359
F'	F'(0)	F'(1)	F'(2)	F'(3)	F'(4)	F'(5)	F'(6)	F'(7)	F'(8)	F'(9)	F'(10)	F'(11)
	0	-2302.16	-17654.18	-33044.58	-46427.68	-43364.91	-44343.79	-38265.93	-27269.06	-8114.91	7662.37	16401.64
N'	N'(0)	N'(1)	N'(2)	N'(3)	N'(4)	N'(5)	N'(6)	N'(7)	N'(8)	N'(9)	N'(10)	N'(11)
	0.00	-2302.16	-17654.18	-30284.58	-28027.68	-24953.41	-25058.29	-19941.51	-4078.49	7663.09	16402.37	21231.64

4.3. SIMULATION RESULTS

Upon running the simulation 500 runs, we can summarize the output results in the following three tables for the three scenarios, considering three extension increments for each scenario. Table 4-2, Table 4-3 and Table 4-4 show the minimum, the maximum and the mean values of the cash flow parameters for the three scenarios.

Table 4-2: The cash flow parameters for scenario I

Scenarios	Cash flow Parameters	Ranges	Extension Increment			
			0 days	**5days**	**10 days**	**15 days**
Scenario I	**$\hat{I}_t$ ($) (Financing cost)**	Minimum	263.37	259.57	251.92	243.35
		Maximum	512	507.93	492.78	495.22
		Mean	386.7	379.45	373.252	366.9
	$\hat{F}_t$ ($) (Max negative Balance)	Minimum	39865.3	33460.26	30497	27895.09
		Maximum	48267.2	48552.88	52973.29	52303.96
		Mean	44580	43057.65	41636.14	40043.20
	D (Final Project Duration)	Minimum	40 days	42 days	45 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	21108.12	21112.06	21127.22	21124.8
		Maximum	21356.4	21360.42	21368.08	21376.6
		Mean	21233.2	21240.54	21246.74	21253.09

Table 4-3: The cash flow parameters for scenario II

Scenarios	Cash flow Parameters	Ranges	Extension Increment			
			0 days	**5days**	**10 days**	**15 days**
Scenario II	**$\hat{I}_t$ ($)** **(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 4-4: The cash flow parameters for scenario III

Scenarios	Cash flow Parameters	Ranges	Extension Increment			
			0 days	**5days**	**10 days**	**15 days**
Scenario III	**$\hat{I}_t$ ($)** **(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

As presented in Table 4-2 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 $386.7, $379.45, $373.25 and $366.90, respectively. With the increase of the duration, the number of the activities ongoing during any period decreases. Accordingly, the contractors' periodical cash out and negative cumulative balance decreases and consequently the financing cost decreases.

The results in Table 4-2 indicate that the mean value of the maximum cumulative negative balance decreases with the increase of the extension increment. The mean values of the maximum cumulative negative balance for 0, 5, 10 and 15-day extension increments are $44,580, $43,057.65, $41,636.14 and $40,043.20, respectively. Whenever the duration is increased, the number of activities that are ongoing during any period decreases. Accordingly, the amount of cash that a contractor borrows during any period decreases and consequently the maximum negative cumulative balance decreases.

The results in Table 4-2 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 $21,233.20, $21,240.54, $21,246.74 and $21,253.09, 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

Table 4-3 and Table 4-4 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 III 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, II and III are $379.45, $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, II and III are $43,057.65, $44,586.9 and $47,972.99, respectively. The project profit increases from scenario I to scenario III; the results indicate the mean profit values for scenarios I, II and III are $21,233, $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 III, due to the stochastic impact of the qualitative factors.

4.4. ACTIVITIES' CRITICALITY

Sensitivity analysis was carried out to determine the impact of the activities' start times on cash flow parameters. The results were analyzed based on extension increments of 5, 10, and 15 days for the three scenarios. The results of the sensitivity analysis are displayed as "Tornado" charts, the activities with the highest regression and correlation coefficient values are those with the highest impact on the output parameters. The positive value of the regression coefficient indicates a directly proportional relationship between an activity and an output.

With sensitivity analysis, rank correlation coefficients are calculated between each input and output while the simulation is running. A correlation coefficient provides a meaningful measure of the degree to which the input and output change together. If an input and output have a high correlation coefficient, it means that that input has a significant impact on this output. The larger the value of the correlation coefficient the stronger the relationship between the start times of activities and the cash flow parameters. The correlation coefficient number describes the relationship between two variables. The coefficient values range between -1 to 0 for negative correlations and from 0 to +1 for positive correlations.

The results from scenario I with a 5-day extension are shown in Figure **4-1**, with the activities listed on the vertical axis starting with activity O with coefficient value 0.17. That activity has the highest sensitivity ranking and can be considered the activity with the highest positive coefficient value. The vertical axis ends with activity N with the lowest coefficient value, 0.03. These positive coefficient values indicate that an increase of activity O's start time is associated with an increase in the project duration. Activities O, G, and J have the highest impact on the project duration, and activities E, L, and N have the lowest.

As presented in Table 4-5, the result of scenario I with a 5-day extension, the activities are listed starting with activity B, whose coefficient value of 0.07 indicates the highest sensitivity ranking and so can be considered the activity with the highest positive coefficient value. The list of activities ends with activity J with coefficient value 0. The positive value of activity B's coefficients indicates that an increase in its start time is associated with an increase in the financing cost. The zero value of activity J's coefficient indicates that there is no correlation between the start time of activity J and the financing cost. Activities B, A, and C have the highest impact on the financing cost and activities G, H, and J have the lowest.

The results of scenario I with a 5-day extension are presented in Table 4-6, which lists the activities starting with activity B and its coefficient value -0.07, which is the highest negative coefficient value. Activity B can thus be considered the activity with the highest sensitivity ranking. The list of activities' axis ends with activity J and its coefficient value 0. The negative value of a coefficient indicates that an increase in the start time of activity B is associated with a decrease in the project profit. The zero value of the coefficient indicates that there is no correlation between the start time of activity J and the project profit. Activities B, A, and C have the highest impact on the project profit, whereas activities G, H, and J have the lowest impact.

The results of scenario I with a 5-day extension are shown in Figure 4-2; the activities are listed on the vertical axis starting with activity B with its coefficient value of -0.47. Activity B has the highest sensitivity ranking and so can be considered the activity with the highest negative coefficient value. The vertical axis ends with activity D and its coefficient value of -0.05. The negative value of the coefficient indicates that an increase in the start time of activity B is associated with a decrease in the maximum negative cumulative balance. Activities B, A, and H have the highest impact on the maximum negative cumulative balance and activities N, G, E, and D have the lowest impact.

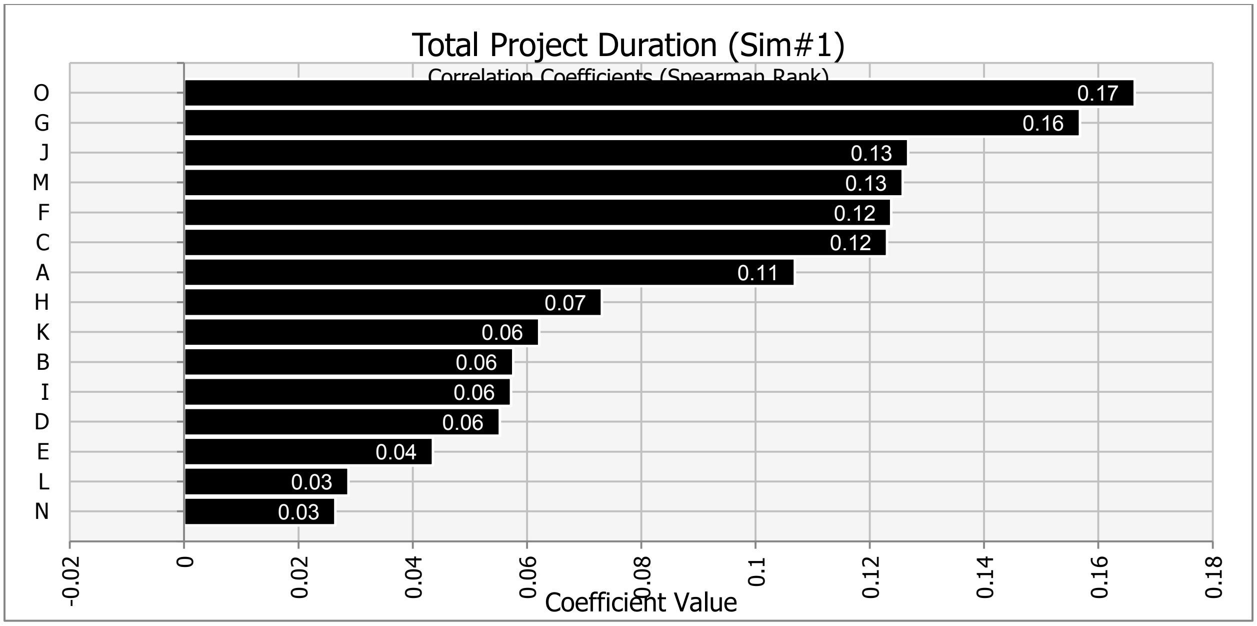

Figure 4-1: Activities' start times' impact on the project duration with an extension increment of 5 days in scenario I

Table 4-5: Impact of activities' start times on the financing cost with an extension increment of 5 days in scenario I

Regression and Rank Information for Financing Cost			
Rank	**Name**	**Regression Coefficient**	**Correlation Coefficient**
1	Interest	0.994	0.994
2	B	0.070	0.097
3	A	0.033	0.027
4	C	0.032	0.035
5	N	-0.020	-0.025
6	F	0.015	0.020
7	D	0.011	-0.059
8	E	0.011	0.022
9	I	0.007	-0.041
10	L	-0.007	0.017
11	M	-0.005	0.065
12	G	0.000	0.019
13	H	0.000	0.017
14	J	0.000	0.016

Table 4-6: Impact of activities' start times on the profit with an extension increment of 5 days in scenario I

Regression and Rank Information for Net Profit			
Rank	**Name**	**Regression Coefficient**	**Correlation Coefficient**
1	Interest	-0.994	-0.994
2	B	-0.070	-0.097
3	A	-0.033	-0.027
4	C	-0.032	-0.035
5	N	0.020	0.025
6	F	-0.015	-0.020
7	D	-0.011	0.059
8	E	-0.011	-0.022
9	I	-0.007	0.041
10	L	0.007	-0.017
11	M	0.005	-0.065
12	G	0.000	-0.019
13	H	0.000	-0.017
14	J	0.000	-0.016

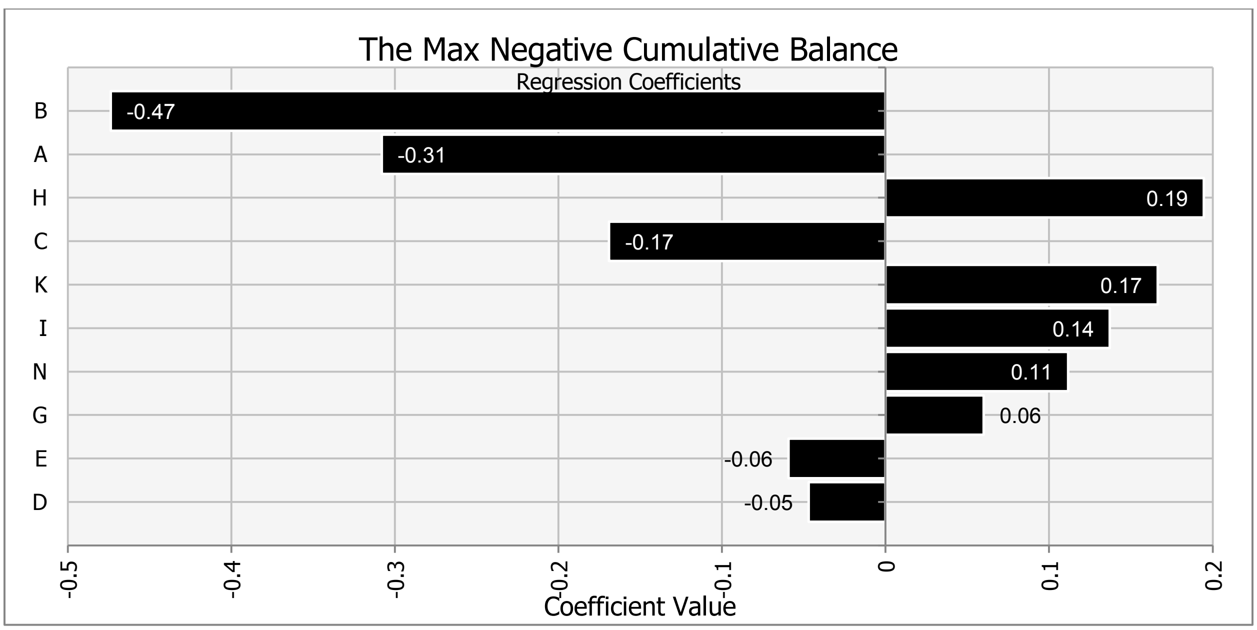

Figure 4-2: Impact of activities' start times on the maximum negative cumulative balance, with an extension increment of 5 days in scenario I

As illustrated in Table 4-7, Table 4-8 and Table 4-9, the impact of the activities on the cash flow parameters are presented by the regression coefficient of each activity. The high value of the regression coefficient of an activity in relation to an output indicates the degree of impact that activity has on this output. The positive value of the regression coefficient indicates a directly proportional relationship between the activity and the output. Table 4-7, Table 4-8 and Table 4-9 present the results of the three extension increments in scenarios I, II and III, respectively.

Table 4-7 presents the regression coefficients of all the activities in scenario I with an extension increment of five days. Activities B, A and C have the highest regression coefficients to the financing cost and the project profit. The regression coefficient values of activities B, A and C in relation to the financing cost are 0.07, 0.033 and 0.032, respectively. The regression coefficients values of activities B, A and C in relation to the project profit are 0.07, -0.033 and -0.032, respectively. Activities B, A and H have the highest regression coefficient values in relation to the maximum negative cumulative balance. The regression coefficient values of activities B, A and H are -0.47, -0.31 and 0.19, respectively. At 0.17, activity O has the highest correlation coefficient value to the project duration. When scenario I is implemented with an extension increment of 10 days, activities B, C and A have the highest regression coefficients to the financing cost and the project profit. The regression coefficients values of activities B, C and A to the financing cost and the project profit are -0.112, -0.05 and -0.043, respectively. Activities A and B have the highest regression coefficient values to the maximum negative cumulative balance. The regression coefficient values of activities A and B are -0.459 and -0.309, respectively. Activities A, I and C have the highest regression coefficient values in respect to the project duration. The regression coefficient values of activities A, I and C are 0.12, 0.12 and 0.115, respectively.

When scenario I is implemented with a 15-day extension increment, activities B and O have the highest regression coefficients to the financing cost. The regression coefficient values of activities B and O are 0.141 and 0.167, respectively. Activity B has the highest regression coefficient value to the project profit. Activities B and A have the highest regression coefficient values to the maximum negative cumulative balance. The regression coefficient values of activities B and A are -0.413 and -0.265, respectively. Activities C and B have the highest regression coefficient value to the project duration. The regression coefficient value of activities C and B are 0.181 and 0.166, respectively.

Table 4-8 presents the regression coefficients of the activities in scenario II. With an extension increment of five days, activity B has the highest regression coefficients to the financing cost and to the project profit. The regression coefficient values of activity B to the financing cost and project profit are 0.059 and -0.059, respectively. Activities B and A have the highest regression coefficient value to the maximum negative cumulative balance. The regression coefficient values of activities B and A are -0.407 and -0.38. Activity G has the highest regression coefficient value to the project duration. The regression coefficient value of activity G is 0.133.

In scenario II and with an extension increment of 10 days, activities B and O have the highest regression coefficients to the financing cost. The regression coefficient values of activities B and O are -0.097 and 0.1, respectively. Activity B has the highest regression coefficient value to the project profit and the maximum negative cumulative balance. The regression coefficient values of activity B to the project profit and to the maximum negative cumulative balance are 0.097 and -0.437, respectively. Activities O, L and F have the highest regression coefficient value to the project duration. The regression coefficient value of activities O, L and F are 0.132, 0.116 and 0.111, respectively.

In scenario II and an extension increment of 15 days, activities B and O have the highest regression coefficients to the financing cost. The regression coefficient values of activities B and O to the financing cost are 0.118 and 0.12, respectively. Activity B has the highest regression coefficient values to the project profit. Activities B and C have the highest regression coefficient values to the maximum negative cumulative balance. The regression coefficient values of activities B and C are -0.398 and -0.208, respectively. Activities O and J have the highest regression coefficient value to the project duration. The regression coefficient values of activity O and J are 0.185 and 0.195, respectively.

Table 4-9 presents the regression coefficients of the activities in scenario III. With an extension increment of five days, activity B has the highest regression coefficients to the financing cost and to the project profit. The regression coefficient values of activity B to the financing cost and to project profit are 0.03 and -0.03, respectively. Activities A and B have the highest regression coefficient values, -0.26 and -0.247, to the maximum negative cumulative balance Activities C, O and M have the highest regression coefficient value to the project duration. The regression coefficient values of activities C, O and M are 0.124, 0.111 and 0.108, respectively.

In scenario III, with an extension increment of 10 days, activities B and O have the highest regression coefficients to the financing cost. The regression coefficient values of activities B and O are -0.117 and 0.1, respectively. Activity B has the highest regression coefficient to the project profit. No activities are influencing the maximum negative cumulative balance. Activities A, C and J have the highest regression coefficient value to the project duration. The regression coefficient values of activities A, C and J are 0.158, 0.155 and 0.151, respectively.

In scenario III, with a 15-day extension increment, activities B and O have the highest regression coefficients to the financing cost at 0.076 and 0.09, respectively. Activity B has the highest regression coefficient value to the project profit. Activities B and C have the highest regression coefficient value to the maximum negative cumulative balance. The regression coefficient values of activities B and C are -0.373 and -0.254, respectively. Activities L, I, C and M have the highest regression coefficient value to the project duration. The regression coefficient values of activities L, I, C and M are 0.202, 0.146, 0.138 and 0.138, respectively.

Table 4-7: The regression coefficients of the activities in scenario I

Scenarios	**Scenario I**											
Extension Increment	**5 days**				**10 days**				**15 days**			
Cash Flow parameters / **Activities**	$\hat{I}_t$	$\hat{F}_t$	$\hat{N}_t$	**D**	$\hat{I}_t$	$\hat{F}_t$	$\hat{N}_t$	**D**	$\hat{I}_t$	$\hat{F}_t$	$\hat{N}_t$	**D**
A	0.033	-0.31	-0.033	0.11	-0.043	-0.309	-0.04	0.12	0.056	-0.265	-0.056	0.101
B	0.07	-0.47	-0.07	0.06	-0.112	-0.459	-0.11	0	0.141	-0.413	-0.141	0.166
C	0.032	-0.17	-0.032	0.12	-0.05	-0.236	-0.05	0.115	0.066	-0.209	-0.066	0.181
D	0.011	-0.05	-0.011	0.06	-0.01	-0.127	-0.01	0	0.013	-0.091	-0.013	0.096
E	0.011	-0.06	-0.011	0.04	-0.015	0	-0.02	0.094	0.01	0.07	-0.01	0.132
F	0.015	0	-0.015	0.12	-0.02	-0.105	-0.02	0.083	0.031	-0.131	-0.031	0.12
G	0	0.06	0	0.16	0	0	0	0.097	0	0.108	0	0.128
H	0	0.19	0	0.07	0	0.127	0	0.099	0	0.136	0	0
I	0.007	0.14	-0.007	0.06	0	0	0	0.12	0	0	0	0.136
J	0	0	0	0.13	0	0	0	0.097	0	0	0	0.087
K	-	0.17	-	0.06	0.011	0.14	0.011	0.1	-0.011	0.257	0.011	0.099
L	-0.007	0	0.007	0.03	0.012	0	0.012	0	-0.016	0	0.016	0.138
M	-0.005	-	0.005	0.13	-	-	-	0	-	-	-	0.115
N	-0.02	0.11	0.02	0.03	0.033	0.174	0.033	-	-0.043	0.138	0.043	-
O	-	-	-	0.17	0.15	-	-	0.12	0.167	-	-	0.11

Table 4-8: The regression coefficients of the activities in scenario II

Scenarios	**Scenario II**											
Extension Increment	**5 days**				**10 days**				**15 days**			
Cash Flow parameters / **Activities**	$\hat{I}_t$	$\hat{F}_t$	$\hat{N}_t$	**D**	$\hat{I}_t$	$\hat{F}_t$	$\hat{N}_t$	**D**	$\hat{I}_t$	$\hat{F}_t$	$\hat{N}_t$	**D**
A	0.023	-0.38	-0.023	0.099	-0.034	-0.238	0.034	0	0.044	-0.24	-0.044	0.121
B	0.059	-0.407	-0.059	0	-0.097	-0.437	0.097	0.101	0.118	-0.398	-0.118	0.156
C	0.022	-0.155	-0.022	0	-0.041	-0.239	0.041	0.085	0.054	-0.208	-0.054	0.138
D	-	-0.06	-	0	-	-0.11	-	0	-	-0.103	-	0
E	-	-	-	0.106	-	0.079	-	0.086	0.021	0.089	-0.021	0.088
F	-	-	-	0.093	-	-0.108	-	0.111	0.022	-0.16	-0.022	0.147
G	-	0.082	-	0.133	-	-	-	0.094	-	-	-	-
H	-	0.216	-	0.128	-	0.14	-	0	-	0.097	-	0.089
I	-	0.126	-	0	-	-	-	0.108	-	-	-	0.106
J	-	-	-	0	-	-	-	0.085	-	-	-	0.195
K	-	0.171	-	0.116	-	0.169	-	0.103	-	0.157	-	0.149
L	-	-	-	0.078	-	-	-	0.116	-	-	-	0.087
M	-	-	-	0.14	-	-	-	0.104	-	-	-	0.096
N	-	0.159	-	-	-	0.116	-	-	-0.029	0.143	0.029	0.077
O	-	-	-	0.081	0.1	-0.063	-	0.132	0.12	-	-	0.185

Table 4-9: The regression coefficients of the activities in scenario III

Scenarios	Scenario III											
Extension increment	5 days				10 days				15 days			
Cash Flow parameters / Activities	$\hat{I}_t$	$\hat{F}_t$	$\hat{N}_t$	D	$\hat{I}_t$	$\hat{F}_t$	$\hat{N}_t$	D	$\hat{I}_t$	$\hat{F}_t$	$\hat{N}_t$	D
A	-	-0.26	-	0	-	-	-	0.158	0.029	-0.182	-0.029	0.081
B	-0.03	-0.247	0.03	0	-0.117	-	0.117	0.1	0.076	-0.373	-0.076	0.113
C	-	-0.184	-	0.124	-	-	-	0.155	-	-0.254	-	0.138
D	-	-0.163	-	0	-	-	-	0.103	-	-0.098	-	0.126
E	-	-	-	0	-	-	-	0.119	-	-	-	0.09
F	-	-	-	0	-	-	-	0	-	-0.211	-	0.08
G	-	-	-	0.095	-	-	-	0.18	-	-	-	0.119
H	-	-	-	0	-	-	-	0.148	-	0.155	-	0.087
I	-	-	-	0.088	-	-	-	0	-	-	-	0.146
J	-	-	-	0.1	-	-	-	0.151	-	-	-	0.105
K	-	0.235	-	0	-	-	-	-	-	0.188	-	-
L	-	-	-	-	-	-	-	0.124	-	-	-	0.202
M	-	-	-	0.108	-	-	-	0.077	-	-	-	0.138
N	-	0.142	-	0.091	-	-	-	0.089	-	0.185	-	0.112
O	-	-	-	0.111	0.1	-	-	0.091	0.09	-	-	0.132

4.4.1. ACTIVITIES OF THE HIGHEST IMPACT

Table 4-10 presents the top three activities that have the most impact on the total project duration, financing cost, the net project profit and the maximum negative cumulative balance for the three scenarios I, II and III with the three extension increments of 5, 10 and 15 days. The activities are ranked according to the correlation and regression coefficient values. These values measure the strength of the relationship between the activities' start times and the cash flow parameters.

Table 4-10: The critical activities of scenarios I, II and III

Scenarios	Financial Parameters	Extension Increment				Critical Activities
		Rank	5days	10 days	15 days	
Scenario I	$\hat{I}_t$ (Financing cost)	Rank1	Activity B	Activity O	Activity O	O
		Rank2	Activity A	Activity B	Activity B	B
		Rank3	Activity C	Activity C	Activity C	C
	$\hat{F}_t$ (Max negative Balance)	Rank1	Activity B	Activity B	Activity B	B
		Rank2	Activity A	Activity A	Activity A	A
		Rank3	Activity H	Activity C	Activity K	-
	D (Final Project Duration)	Rank1	Activity O	Activity O	Activity C	O
		Rank2	Activity G	Activity I	Activity B	-
		Rank3	Activity J	Activity A	Activity L	-
	$\hat{N}_t$ (Net Project Profit)	Rank1	Activity B	Activity B	Activity B	B
		Rank2	Activity A	Activity C	Activity C	C
		Rank3	Activity C	Activity A	Activity A	A
Scenario II	$\hat{I}_t$ (Financing cost)	Rank1	Activity B	Activity O	Activity O	O
		Rank2	Activity A	Activity B	Activity B	B
		Rank3	Activity C	Activity C	Activity C	C
	$\hat{F}_t$ (Max negative Balance)	Rank1	Activity B	Activity B	Activity B	B
		Rank2	Activity A	Activity C	Activity A	A
		Rank3	Activity H	Activity A	Activity C	C
	D (Final Project Duration)	Rank1	ActivityM	Activity O	Activity J	O
		Rank2	Activity G	Activity L	Activity O	-
		Rank3	Activity H	Activity F	Activity B	-
	$\hat{N}_t$ (Net Project Profit)	Rank1	Activity B	Activity B	Activity B	B
		Rank2	Activity A	Activity C	Activity C	C
		Rank3	Activity C	Activity A	Activity A	A
Scenario III	$\hat{I}_t$ (Financing cost)	Rank1	Activity B	Activity B	Activity O	B
		Rank 2	-	Activity O	Activity B	O
		Rank3	-	-	Activity A	-
	$\hat{F}_t$ (Max negative Balance)	Rank 1	Activity A	-	Activity B	B
		Rank 2	Activity B	-	Activity C	-
		Rank 3	Activity K	-	Activity F	-
	D (Final Project Duration)	Rank 1	Activity C	Activity A	Activity I	-
		Rank 2	Activity O	Activity C	Activity C	C
		Rank 3	ActivityM	Activity G	Activity M	M
	$\hat{N}_t$ (Net Project Profit)	Rank 1	Activity B	Activity B	Activity B	B
		Rank 2	-	-	Activity A	-

4.4.1.1. Scenario I

As presented in Table 4-10, for the Financing Cost, activities B and C are repeated as the highest impact activities for the extension increments of 5, 10 and 15 days. Activity O has repeatedly had the highest impact on the financing cost for extensions of 10 and 15 days. For the maximum negative cumulative balance, it can be seen that activities B and A are most-often the activities with the highest impact for the extension increments of 5, 10 and 15 days. For the project duration, it can be observed that activity O is repeated as the highest-impact activity on the project duration when there are extension increments of 5 and 10 days. For the net project profit, activities B, C and A are repeatedly indicated as having the highest impact for extension increments of 5, 10 and 15 days. According to scenario I, activities B, C and O are the critical activities for the financing cost. Activities B and A are the critical activities for the maximum negative cumulative balance. Activities B, C and A are the critical activities for the project profit.

4.4.1.2. Scenario II

As presented in Table 4-10, activities B and C are repeated as being the highest impact activities for the financing cost for extension increments of 5, 10 and 15 days. Activity O has also repeated as having the highest impact activity to the financing cost for extensions of 10 and 15 days. For the maximum negative cumulative balance, we note that activities B and A are repeated as the highest impact activities for extension increments of 5, 10 and 15 days. Meanwhile, activity C is presented as one of the highest impact activities to the maximum negative cumulative balance for extension increments of 10 and 15 days. For the project duration activity O is repeated as one of the highest impact activities for extension increments of 10 and 15 days. For the project profit, activities B, C and A are repeated as the highest impact activities for the 5, 10 and 15-day extensions. According to scenario II, activities B, C and O are the activities that are critical to the financing cost. Activities B, C and A are the critical activities for the maximum negative cumulative balance. Activity O is the critical activity for the project duration, and activities B, C and A are the critical activities for the project profit.

4.4.1.3. Scenario III

As presented in Table 4-10, for the financing cost, activity B is repeated as having the highest impact for extension increments of 5, 10 and 15 days. Activity O is repeated as the highest impact activity to the financing cost for extensions of 10 and 15 days. For the maximum negative cumulative balance, it is noticed that activity B is repeated as being the highest-impact activity on the maximum negative cumulative balance for extensions of 5 and 15 days. For the project duration, activity C repeatedly shows that it is one of the activities with the highest impact on the project duration with extension increments of 5, 10 and 15 days. Activity M is repeated as being the highest-impact activity for extensions of 5 and 15 days. For the project profit, it is noticed that activity B is repeated as having the highest impact activity for the 5, 10 and 15-day extensions.

Scenario III also shows that activities B and O are critical activities for the financing cost. Activities A and C are the critical activities for the maximum negative cumulative balance. Activities C and M are the critical activities to the project duration. Activity B is the critical activity to the project profit. Moreover, we can observe from all three scenarios that activities B and O are the highest impact activities on the financing cost. Activity C is presented as the highest impact activity to the financing cost for scenarios I and II. Activity A is presented as the highest impact activity to the maximum negative cumulative balance for scenarios I, II and III.

Activity B is presented as the highest impact activity to the maximum negative cumulative balance in scenario I. Activity C is presented as the highest impact activity to the maximum negative cumulative balance for scenarios II and III. Activity O appears to be the highest impact activity for the project duration for scenario II. Activities C and M are presented as the highest impact activities to the project duration in scenario III. Activities C and A are presented as the highest impact activities to the project profit in scenarios I and II. Activity B appears as one of the highest impact activity to the project profit for scenario I, scenario II and scenario III.

According to the results of Scenarios I, II and III in this case study, we can determine the criticality of the activities, or those activities that have the highest regression and correlation coefficients and consequently have the highest impact on the cash flow parameters. It was observed that these same activities were repeatedly the highest impact activities for the scenarios I, II and III. As discussed above, activities' criticality to cash-flow parameters, which is an indication of the number of times a given activity determined a particular cash-flow parameter over the number of runs, can be assessed in detail. The critical activities to the financing cost are activities **B, C and O**. The critical activities to the maximum negative cumulative balance are activities **B, A and C**. The critical activities to project duration are activities **G, J, C, O, and M**, and the critical activities to project profit are activities **B, C and A**. Therefore, the critical activities to the cash flow parameters are activities **A, B, C and O**, activities **C** and **B** have total float equal to zero, however the total float of activities **A** and **B** are not equal to zero. According to the results of three scenarios, the critical activities to the total project duration are the activities that have total float equal to zero. However, the critical activities to the cash flow parameters are the activities that have repeated and presented as one of the highest impact activities, which have the highest correlation or regression coefficients values to the cash flow parameters **and/or** the activities that have total float equal to zero.

4.4.2. DETAILED ANALYSIS

In this section a detailed analysis is conducted on the critical activities to cash flow parameters, as identified in the previous section. The values of the critical activities' start times are changed in specific ranges where the effect of these changes to the cash flow parameters are evaluated and measured. In this step, we will measure the criticality of these activities to cash flow parameters. Studying the impact of changing activities' start times in a specific range on the outputs will lead to an assessing the activities' criticality to cash flow parameters. The analysis in this section is done for scenario III with an extension of 5 days.

4.4.2.1. Activities` Criticality to the Financing Cost

The start times of activities B, C and O are varied by decrementing and incrementing their values from the respective mean value across the range from -30 % to +30%. The change of the start times' values of activities B, C and O changes the mean values of the financing cost from $430.3 to $434.67, from $430 to $432.5, and from $432.3 to $420, respectively. The result shows that activity O is the activity that is most critical to the financing cost, as shown in Figure 4-3.

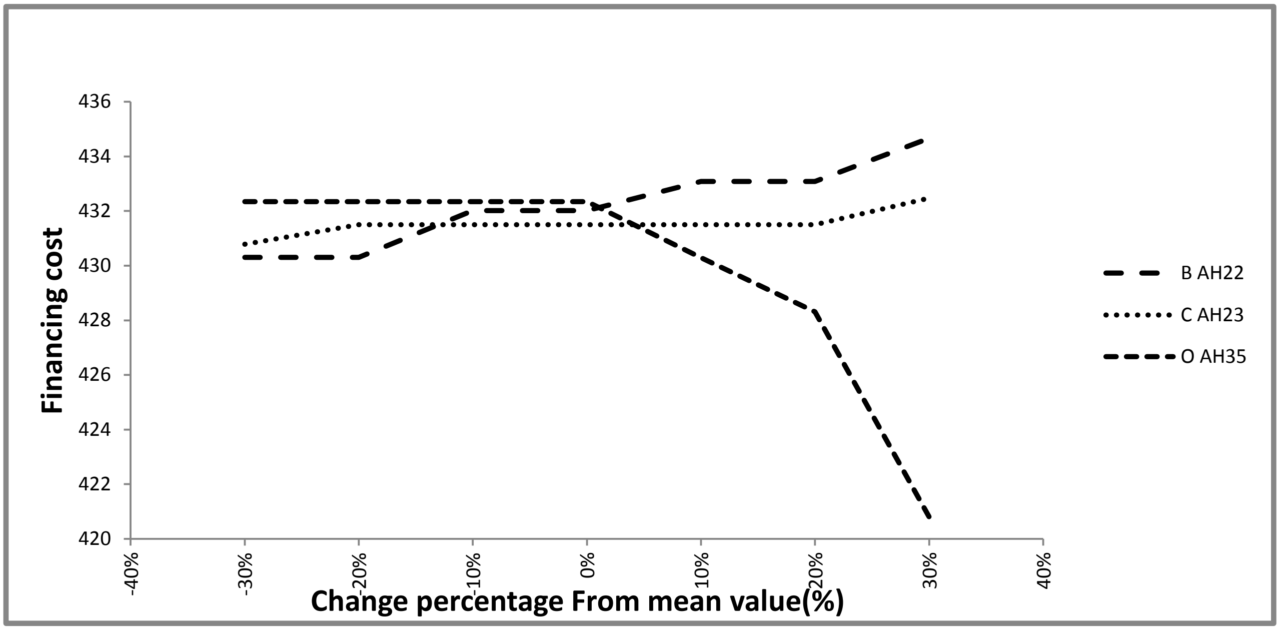

Figure 4-3: Mean of the financing cost versus the percentage change of activities B, C and O's start times

4.4.2.2. Activities' Criticality to the Maximum Negative Cumulative Balance

The analysis focuses on the inputs, which are the start times of activities A, B and C that are critical to the maximum negative cumulative balance. As shown in Figure 4-4, the start times of activities A, B and C vary by incrementing and decrementing their values from their respective mean values across the range from +30% to -30%. Changing the start time values changes the mean values of the maximum negative cumulative balance from $48,681.7 to $47,459, from $48,664.3 to $47,232.5 and from $48,435.6 to $47,459.8, for activities A, B and C, respectively. The results show that activities A, B and C are the critical activities to the maximum negative cumulative balance.

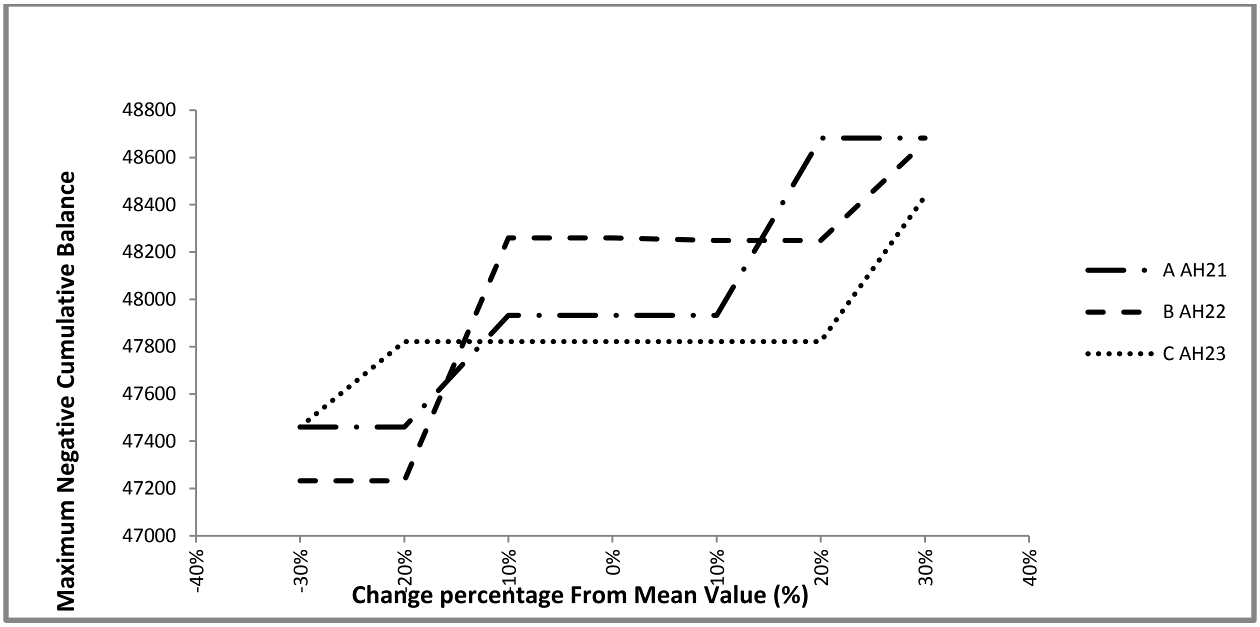

Figure 4-4: Mean of the maximum negative cumulative balance versus the percentage change of activities A, B and C start times

4.4.2.3. Activities' Criticality to the Project Total Duration

The start times of activities G, J, C, O, and M are varied by decrementing and incrementing their values from their respective mean values across the range from -30 % to +30%. Changing the start times of activities G, J, O, and M changes the mean values of the total project duration from 42 to 45 days, from 43 to 49 days, from 45 to 53 days and from 43 to 51 days, respectively, as shown in Figure 4-5. The results show that activities O and M are the ones most critical to the project duration.

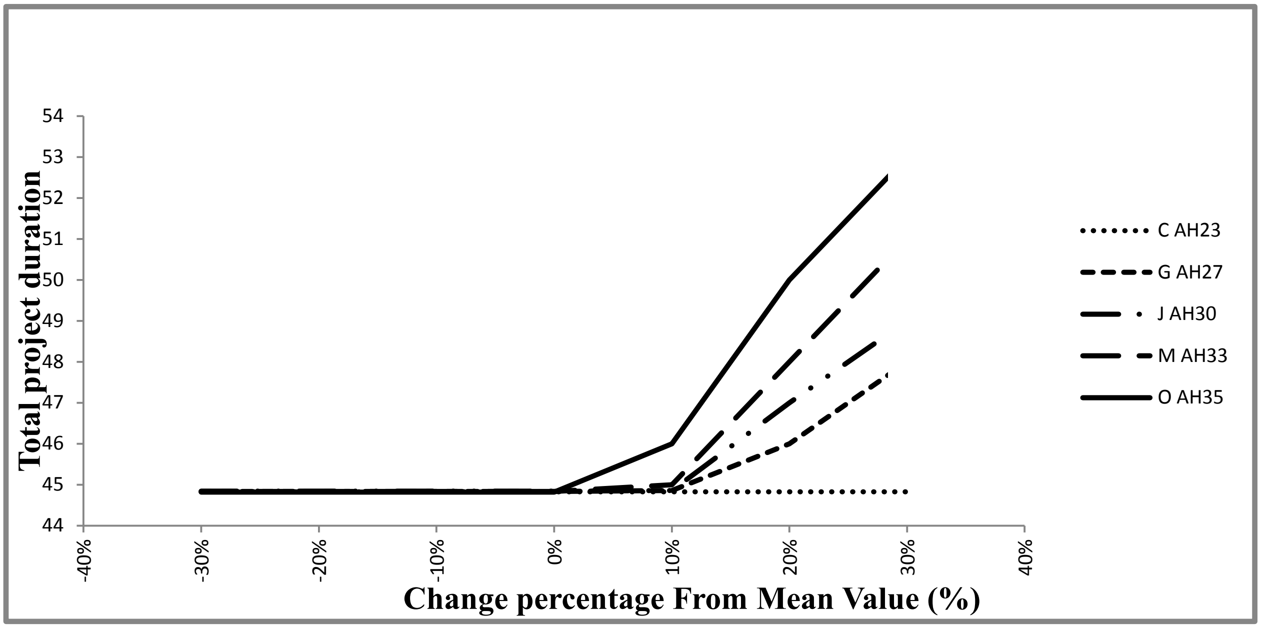

Figure 4-5: Mean of total project duration versus the percentage change of activities' start times

4.4.2.4. Activities' Criticality to the Project Profit

The start times of activities A, B and C are varied by decrementing and incrementing their values from the respective mean value across the range from -30% to +30%. Changing the start times of activities A, B and C changes the mean values of the project profit from $23,228.9 to $23,227.4, from $23,230 to $23,227.8, and from $23,229.5 to $23,227.8, respectively. As shown in Figure 4-6, activity B is the activity which is most critical to the project profit.

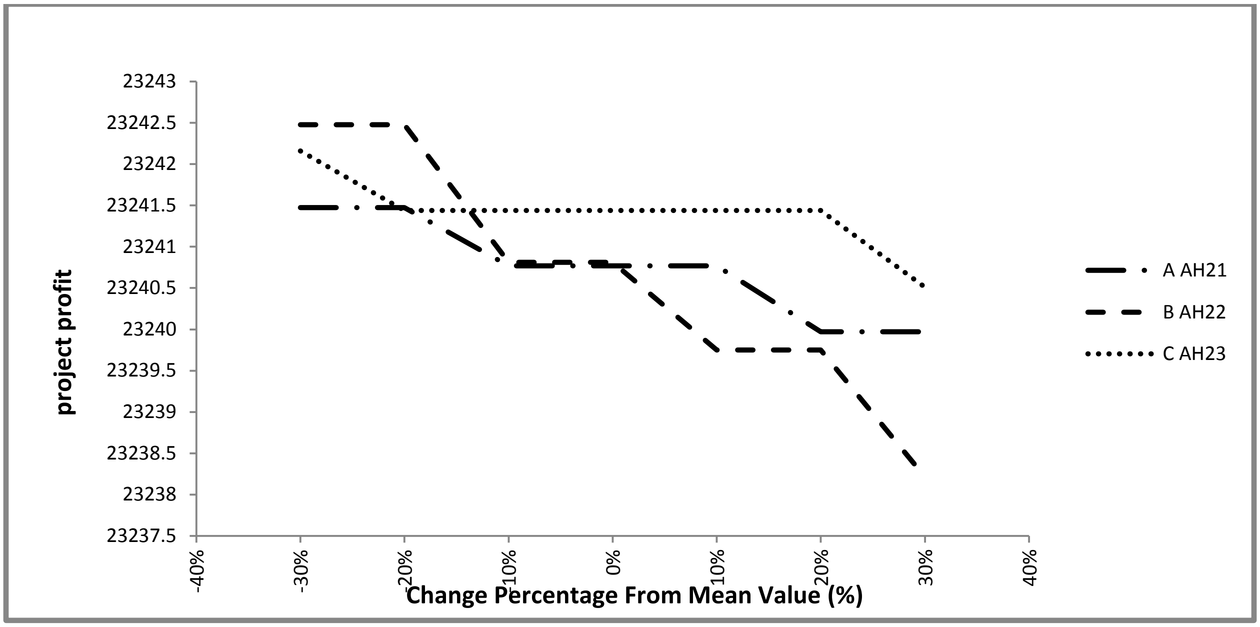

Figure 4-6: Mean of project profit versus percentage change of activities' start times

The impacts of the variation of the start times of the critical activities to the maximum negative cumulative balance, financing cost, and project profit are presented in Table 4-11, Table 4-12, and Table 4-13 respectively. Table 4-11 shows the incrementing and decrementing values of the critical activities' start times' values and their effect on the maximum negative cumulative balance. Increasing the start time of activity A from day 2.8 to day 5.2 can increase the minimum value of the negative cumulative balance from $37,055.5 to $37,372. Increasing the start time of activity A causes an increase in the maximum value of the cumulative negative balance from $57,674 to $58,842. Increasing the start time of activity B from day 3.5 to day 6.5 causes an increase in the minimum value of the negative cumulative balance from $39,821.3 to $40,711.5. Increasing the start time of activity B causes a decrease in the maximum value of the cumulative negative balance from $58,851.5 to $57,591.6. Increasing the start time of activity C from day

1.4 to day 2.6 causes an increase in the minimum value of the negative cumulative balance from $38,488.7 to $38,528.8. Increasing the start time of activity C causes an increase in the maximum value of the cumulative negative balance from $57,868 to $57,997.

Table 4-12 shows the incrementing and decrementing values of the critical activities' start times' values to the financing cost. Increasing the start time of activity B from a value of 3.5 to 6.5 days can increase the minimum value of the financing cost from $288.2 to $290.7. Increasing the start time of activity B causes an increase in the maximum value of the financing cost from $596.9 to $601. Increasing the start time of activity C from day 1.4 to day 2.6 days causes an increase in the minimum value of the financing cost from $283.6 to $286.5. Increasing the start time of activity C causes an increase in the maximum value of the financing cost from $593 to $595. Increasing the start time of activity O from 26.6 days to 49.4 days causes a decrease in the minimum value of the financing cost from $286.5 to $277.6. Increasing the start time of activity O causes a decrease in the maximum value of the financing cost from $600 to $581.

Table 4-13 shows the incrementing and decrementing values of the critical activities' start times' values to the project's profit. Increasing the start time of activity A from the value of 2.8 days to 5.2 days can decrease the minimum value of the project's profit from $20,548 to $20,544.8. Increasing the start time of activity B causes a decrease in the maximum value of the project's profit from $26,565 to $26,560.8. Increasing the start time of activity B from 3.5 to 6.5 days causes an increase in the minimum value of the project's profit from $20,547 to $20,548. Increasing the start time of activity B causes a decrease in the maximum value of the project's profit from $26,568.8 to $26,567. Increasing the start time of activity C from the value of 1.4 days to 2.6 days causes a decrease in the minimum value of the project's profit from $20,549 to

$20,548. Increasing the start time of activity O causes a decrease in the maximum value of the project's profit from $26,568.8 to $26,567.6.

Table 4-11 : The impact of changing the critical activities' start times to the maximum negative cumulative balance

Activity Name	Start time Value Range	F^ Mean value Range ($)	F^ Minimum value Range ($)	F^ Maximum value Range($)
A	2.8- 5.2	47459- 48681.7	37055.5 - 37372	57674 - 58842
B	3.5 - 6.5	47232.5 – 48664.3	39821.3-40711.5	58851.5- 57591.6
C	1.4 – 2.6	47459.8 - 48435.6	38488.7- 38528.8	57868 - 57997

Table 4-12: The impact of changing the critical activities' start times to the financing cost

Activity Name	Start time Value Range	I^ Mean Value Range ($)	I^ Minimum Value Range ($)	I^ Maximum Value Range ($)
B	3.5 – 6.5	430.4 - 434.7	288.2 – 290.7	596.9 - 601
C	1.4 – 2.6	430.7 – 432.4	283.6- 286.5	593- 595
O	26.6 – 49.9	432.34 – 420.8	286.5 – 277.6	600- 581

Table 4-13: The impact of changing the critical activities' start times to the project profit

Activity Name	Start Time Value Range	N^ Mean Value Range($)	N^ Minimum Value Range ($)	N^ Maximum Value Range ($)
A	2.8 – 5.2	23228.9 – 23227.4	20548- 20544.8	26565 – 26560.8
B	3.5 – 6.5	23230 – 23225.8	20547 – 20548.	26568.8 - 26567
C	1.4 – 2.6	23229.5 – 23227.8	20549 - 20548.	26568.8 – 26567.6

CHAPTER 5
CONCLUSION

5.1. CONCLUSION

The purpose of this research is to study the impact of activities' start times on cash flow parameters considering the stochastic cash inflow and cash outflow transactions. A careful evaluation of the interaction between the project cash flow and the project schedule was carried out to assess the impact of the stochastic start times of activities on the cash flow parameters.

A comprehensive literature review was undertaken. Based on this literature review, the researcher efforts were concentrated in three categories: the existing cash flow forecasting models, the existing scheduling problems with cash flow models, and the applications of Monte Carlo simulation. The literature review confirmed that incorporating those factors that influence the cash inflow and outflow improves the forecasting accuracy of cash flow parameters. The probability distributions of the weights and the effects of the qualitative factors were obtained from an earlier study. Overall, cash outflow qualitative factors increase cash outflow transactions by approximately 10.6%, while cash inflow transactions decrease cash inflow transaction by 9%.

The research methodology was designed to assess the criticality of activities' start times to cash flow parameters. The Monte Carlo simulation technique was used to generate random values for the start times of activities. The simulation outputs include the probability distributions for the project duration, financing cost, maximum negative cumulative balance, and project profit. The Monte Carlo Simulation was used to generate stochastic schedules such that the start times of the activities are selected within a range denoted by the early start times to the late start times plus the specified extension increment, with the fulfillment of the dependencies between the activities. The @RISK commercial simulation software was used to implement the simulation to assess the criticality of activities' start times to cash flow parameters while considering the stochastic nature of the cash inflow and cash outflow.

Three scenarios were defined, based on the number of qualitative factors that impact the project cash inflow and cash outflow transactions that they incorporate. These scenarios were established so that scenario I incorporates zero qualitative factors, scenario II incorporates six factors that impact cash inflow transactions and nine that impact cash outflow transactions, and scenario III incorporates all of the qualitative factors that impact cash inflow and cash outflow transactions. Moreover, three extension increments of 5, 10, and 15 days were used for each scenario. The results of the influence of the activities' start times on the cash flow parameters, including the project duration, the maximum negative cumulative balance, the project profit and the financing cost were analyzed for each scenario. 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 III 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 II is considered to be the best schedule. This generated schedule indicates a 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.

A detailed sensitivity analysis was carried out to assess and measure the criticality of activities to the project duration, maximum negative cumulative balance, financing cost, and project profit. The criticality of activities is an indication of the number of times an activity determines the outputs over the number of the simulation runs. The activities that are most critical to the cash flow parameters exhibit the highest regression coefficient values. The results indicated that activities A, B and C are the activities that are the most critical to the maximum negative cumulative balance and to the project profit, activities C, B and O are the ones most critical to the financing cost, and activities O, M, G, J and C are the activities that are most critical for the project total duration. Assessing activities' criticality helps managers focus on and prioritize the activities that should be completed on time.

5.2. CONTRIBUTIONS

This research helps to assess the impact of activities' start times on the cash flow parameters while incorporating the qualitative factors on the project cash inflow and outflow transactions. Monte Carlo simulation was used to generate random variables for the start times of the activities, which resulted in stochastic schedules while maintaining the dependencies between activities. The Model's outputs include the total project duration, the project profit, the maximum negative cumulative balance and the financing cost. The major contribution of this research can be summarized as follows:

1- The uncertainty of cash inflow and outflow are considered by incorporating the qualitative factors' effects that have been studied and defined in an earlier research. Moreover, Conducts a survey and design a questionnaire to obtain an accurate value of p, which is the range of percentage of cash that is affected by the qualitative factors.

2- Integrates an Excel-based CPM model with the cash flow model such that the dependencies between activities are maintained and extension increments are supplemented to assess the impact of stochastic activities' start times on cash flow parameters using Monte Carlo simulation technique.

5.3. LIMITATIONS

This research generates stochastic schedules by using the Monte Carlo simulation technique to generate random variables for the start time of activities. The start times of activities are defined in the range from the early start time to the late start time plus the specified extension increment. The start times are defined in a discrete uniform probability distribution. The illustrated methodology is used to assess the criticality of activities' start times on cash flow parameters. However, it has the limitation that it does not consider the duration of each activity as a random variable. Moreover, the direct costs of activities are based on only one construction method. The accuracy of the weekly disbursements depends on the accuracy of the estimation of the activities' direct cost.

5.4. FUTURE WORK

It is recommended in the future to modify the illustrated methodology as follows:

1-Generate alternative schedules from the original schedule using stochastic extension increments

The extension increment is the time space within which the activities can be shifted without affecting the extended total duration. In this research, the extension increments are deterministic values; future work could make use of stochastic extension increments to improve the accuracy of the range from the early start times to the late start times plus the extension increment. Moreover, the impact of activities' start times could then be determined accurately, as the possible alternative schedules will be determined from stochastic extension increments in addition to the activities' stochastic start times.

2-Make activities' durations stochastic instead of deterministic

In this research, the durations of activities are deterministic. However, future work could consider the uncertainty in the duration of activities, which would make the alternative generated schedules more accurate. Moreover, this would help in studying the impact of activity durations on the project cash flow. In addition, it could be a very useful way to measure the activities' criticality.

3-Consider the effects of alternative construction methods on activities` direct cost.

In this research, the weekly cash outflow is calculated based on the activities' direct cost of five working days plus overhead, while the weekly cash inflow is calculated based on the weekly cash outflow plus the mark up. The direct cost of activities is determined based on a single construction method and consequently the calculation of the weekly cash inflow and cash outflow are determined based on this same construction method. Future work could incorporate the possibility of using different construction methods and evaluate their effect on the direct cost of activities. Such a modification would make the calculation of cash inflow, cash outflow and the outputs' results much more realistic.

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APPENDIX A

Table A-1: The cash flow parameters for scenario I with extension increment of 10 days

The cash flow parameters	WEEKS										
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11
E(0)	E(1)	E(2)	E(3)	E(4)	E(5)	E(6)	E(7)	E(8)	E(9)	E(10)	E(11)
0	0.00	-10925.00	-14566.67	-18093.33	-11516.43	-20223.57	-16598.33	-7551.67	-8625.00	0.00	0.00
P(0)	P(1)	P(2)	P(3)	P(4)	P(5)	P(6)	P(7)	P(8)	P(9)	P(10)	P(11)
0	0	0	0.00	13110.00	17480.00	21712.00	13819.71	24268.29	19918.00	9062.00	10350.00
F(0)	F(1)	F(2)	F(3)	F(4)	F(5)	F(6)	F(7)	F(8)	F(9)	F(10)	F(11)
0	0.00	-10925.00	-25491.67	-43585.00	-41991.43	-44735.00	-39621.33	-33353.29	-17710.00	2208.00	11270.00
N(0)	N(1)	N(2)	N(3)	N(4)	N(5)	N(6)	N(7)	N(8)	N(9)	N(10)	N(11)
0	0.00	-10925.00	-25491.67	-30475.00	-24511.43	-23023.00	-25801.62	-9085.00	2208.00	11270.00	21620.00
I(0)	I(1)	I(2)	I(3)	I(4)	I(5)	I(6)	I(7)	I(8)	I(9)	I(10)	I(11)
0	0.00	-10.24	-34.14	-64.76	-67.94	-64.92	-58.73	-55.46	-25.12	0.00	0.00
I'(0)	I'(1)	I'(2)	I'(3)	I'(4)	I'(5)	I'(6)	I'(7)	I'(8)	I'(9)	I'(10)	I'(11)
0	0.00	-10.242	0.000	-109.245	-177.387	-242.638	-301.822	-357.846	-383.637	-384.356	-385.077
F'(0)	F'(1)	F'(2)	F'(3)	F'(4)	F'(5)	F'(6)	F'(7)	F'(8)	F'(9)	F'(10)	F'(11)
0	0.00	-10935.24	0.00	-43694.24	-42168.82	-44977.64	-39923.16	-33711.13	-18093.64	1823.64	10884.92
N'(0)	N'(1)	N'(2)	N'(3)	N'(4)	N'(5)	N'(6)	N'(7)	N'(8)	N'(9)	N'(10)	N'(11)
0.00	0.00	-10935.24	-10935.24	-30584.24	-24688.82	-23265.64	-26103.44	-9442.85	1824.36	10885.64	21234.92

Table A-2: The cash flow parameters for scenario I with extension increment of 15 days

The cash flow Parameters	**WEEKS**										
	Week 2	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**	**Week 9**	**Week 10**	**Week 11**	**Week 12**
E(0)	E(2)	E(3)	E(4)	E(5)	E(6)	E(7)	E(8)	E(9)	E(10)	E(11)	E(12)
0	-2300.00	-15333.33	-15342.92	-16071.25	-15270.36	-19325.48	-13148.33	-7283.33	-4025.00	0.00	0.00
P(0)	P(2)	P(3)	P(4)	P(5)	P(6)	P(7)	P(8)	P(9)	P(10)	P(11)	P(12)
0	0	0.00	2760.00	18400.00	18411.50	19285.50	18324.43	23190.57	15778.00	8740.00	4830.00
F(0)	F(2)	F(3)	F(4)	F(5)	F(6)	F(7)	F(8)	F(9)	F(10)	F(11)	F(12)
0	-2300.00	-17633.33	-32976.25	-46287.50	-43157.86	-44071.83	-37934.67	-26893.57	-7728.00	8050.00	16790.00
N(0)	N(2)	N(3)	N(4)	N(5)	N(6)	N(7)	N(8)	N(9)	N(10)	N(11)	N(12)
0	-2300.00	-17633.33	-30216.25	-27887.50	-24746.36	-24786.33	-19610.24	-3703.00	8050.00	16790.00	21620.00
I(0)	I(2)	I(3)	I(4)	I(5)	I(6)	I(7)	I(8)	I(9)	I(10)	I(11)	I(12)
0	-2.16	-18.69	-47.45	-71.72	-66.61	-64.52	-58.80	-43.60	-10.72	0.00	0.00
I'(0)	I'(2)	I'(3)	I'(4)	I'(5)	I'(6)	I'(7)	I'(8)	I'(9)	I'(10)	I'(11)	I'(12)
0	-2.156	0.000	-68.333	-140.184	-207.052	-271.957	-331.268	-375.486	-386.907	-387.632	-388.359
F'(0)	F'(2)	F'(3)	F'(4)	F'(5)	F'(6)	F'(7)	F'(8)	F'(9)	F'(10)	F'(11)	F'(12)
0	-2302.16	0.00	-33044.58	-46427.68	-43364.91	-44343.79	-38265.93	-27269.06	-8114.91	7662.37	16401.64
N'(0)	N'(2)	N'(3)	N'(4)	N'(5)	N'(6)	N'(7)	N'(8)	N'(9)	N'(10)	N'(11)	N'(12)
0.00	-2302.16	-2302.16	-30284.58	-28027.68	-24953.41	-25058.29	-19941.51	-4078.49	7663.09	16402.37	21231.64

Table A-3: The cash flow parameters for scenario II with extension increment of 5 days

Cash flow Parameters	WEEKS											
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12
E(0)	**E(1)**	**E(2)**	**E(3)**	**E(4)**	**E(5)**	**E(6)**	**E(7)**	**E(8)**	**E(9)**	**E(10)**	**E(11)**	**E(12)**
0	-2383.94	-15892.95	-15902.89	-16657.80	-15827.68	-20030.80	-13628.21	-7549.15	-4171.90	0.00	0.00	
P(0)	**P(1)**	**P(2)**	**P(3)**	**P(4)**	**P(5)**	**P(6)**	**P(7)**	**P(8)**	**P(9)**	**P(10)**	**P(11)**	**P(12)**
0	0	0	2782.56	18628.58	19083.14	19964.6	19020.4	23899.14	16563.79	9258.32	5117.02	136.8
F(0)	**F(1)**	**F(2)**	**F(3)**	**F(4)**	**F(5)**	**F(6)**	**F(7)**	**F(8)**	**F(9)**	**F(10)**	**F(11)**	**F(12)**
0	-2383.94	-18276.90	-34179.78	-48055.02	-45254.12	-46201.78	-39865.38	-28394.10	-8666.86	7896.93	17155.25	22272.27
N(0)	**N(1)**	**N(2)**	**N(3)**	**N(4)**	**N(5)**	**N(6)**	**N(7)**	**N(8)**	**N(9)**	**N(10)**	**N(11)**	**N(12)**
0	-2383.94	-18276.90	-31397.22	-29426.44	-26170.98	-26237.17	-20844.95	-4494.96	7896.93	17155.25	22272.27	22409.06
I(0)	**I(1)**	**I(2)**	**I(3)**	**I(4)**	**I(5)**	**I(6)**	**I(7)**	**I(8)**	**I(9)**	**I(10)**	**I(11)**	**I(12)**
0	-2.23	-19.37	-49.18	-74.49	-70.16	-67.85	-61.97	-46.16	-12.34	0.00	0.00	0.00
I'(0)	**I'(1)**	**I'(2)**	**I'(3)**	**I'(4)**	**I'(5)**	**I'(6)**	**I'(7)**	**I'(8)**	**I'(9)**	**I'(10)**	**I'(11)**	**I'(12)**
0	-2.23	-21.609	-70.827	-145.447	-215.879	-283.88	-346.49	-393.3	-406.38	-407.14	-407.14	-408.7
F'(0)	**F'(1)**	**F'(2)**	**F'(3)**	**F'(4)**	**F'(5)**	**F'(6)**	**F'(7)**	**F'(8)**	**F'(9)**	**F'(10)**	**F'(11)**	**F'(12)**
0	-2386.18	-18298.50	-34250.61	-48200.47	-45469.85	-46485.77	-40211.87	-28787.40	-9073.24	7489.8	16747.34	21863.6
N'(0)	**N'(1)**	**N'(2)**	**N'(3)**	**N'(4)**	**N'(5)**	**N'(6)**	**N'(7)**	**N'(8)**	**N'(9)**	**N'(10)**	**N'(11)**	**N'(12)**
0.00	-2386.18	-18298.50	-31468.05	-29571.89	-26386.72	-26521.16	-21191.43	-4888.26	7490.55	16748.11	21864.36	22000.40

Table A-4: The cash flow parameters for scenario II with extension increment of 10 days

Cash flow Parameters	**WEEKS**											
	Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**	**Week 9**	**Week 10**	**Week 11**	**Week 11**
E(0)	**E(1)**	**E(2)**	**E(3)**	**E(4)**	**E(5)**	**E(6)**	**E(7)**	**E(8)**	**E(9)**	**E(10)**	**E(11)**	**E(12)**
0	0.00	-11323.73	-15098.31	-18753.68	-11936.74	-20961.67	-17204.12	-7827.28	-8939.79	0.00	0.00	0.00
P(0)	**P(1)**	**P(2)**	**P(3)**	**P(4)**	**P(5)**	**P(6)**	**P(7)**	**P(8)**	**P(9)**	**P(10)**	**P(11)**	**P(12)**
0	0	0	0.00	13217.17	176994.20	22384.56	14547.62	24858.07	20768.16	9700.20	10691.26	293.14
F(0)	**F(1)**	**F(2)**	**F(3)**	**F(4)**	**F(5)**	**F(6)**	**F(7)**	**F(8)**	**F(9)**	**F(10)**	**F(11)**	**F(12)**
0	0.00	-11323.73	-26422.03	-45175.72	-43895.30	-46862.77	-41682.33	-34961.99	-19043.70	1724.46	11424.66	22115.93
N(0)	**N(1)**	**N(2)**	**N(3)**	**N(4)**	**N(5)**	**N(6)**	**N(7)**	**N(8)**	**N(9)**	**N(10)**	**N(11)**	**N(12)**
0	0.00	-11323.73	-26422.03	-31958.55	-25901.10	-24478.21	-27134.71	-10103.91	1724.46	11424.66	22115.93	22409.06
I(0)	**I(1)**	**I(2)**	**I(3)**	**I(4)**	**I(5)**	**I(6)**	**I(7)**	**I(8)**	**I(9)**	**I(10)**	**I(11)**	**I(12)**
0	0.00	-10.62	-35.39	-67.12	-71.11	-68.91	-62.03	-58.22	-27.33	0.00	0.00	0.00
I'(0)	**I'(1)**	**I'(2)**	**I'(3)**	**I'(4)**	**I'(5)**	**I'(6)**	**I'(7)**	**I'(8)**	**I'(9)**	**I'(10)**	**I'(11)**	**I'(12)**
0	0.00	-10.616	0.000	-113.232	-184.557	-253.119	-315.619	-374.427	-402.455	-403.209	-403.96	-404.723
F'(0)	**F'(1)**	**F'(2)**	**F'(3)**	**F'(4)**	**F'(5)**	**F'(6)**	**F'(7)**	**F'(8)**	**F'(9)**	**F'(10)**	**F'(11)**	**F'(12)**
0	0.00	-11334.35	0.00	-45288.95	-44079.85	-47115.89	-41997.95	-35336.41	-19446.15	1321.25	11020.70	21711.20
N'(0)	**N'(1)**	**N'(2)**	**N'(3)**	**N'(4)**	**N'(5)**	**N'(6)**	**N'(7)**	**N'(8)**	**N'(9)**	**N'(10)**	**N'(11)**	**N'(12)**
0.00	0.00	-11334.35	-11334.35	-32071.78	-26085.65	-24731.33	-27450.33	-10478.34	1322.00	11021.45	21711.96	22004.34

Table A-5: The cash flow parameters for scenario II with extension increment of 15 days

Cash flow Parameters	**WEEKS**												
	Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**	**Week 9**	**Week 10**	**Week 11**	**Week 12**	**Week 13**
E(0)	**E(1)**	**E(2)**	**E(3)**	**E(4)**	**E(5)**	**E(6)**	**E(7)**	**E(8)**	**E(9)**	**E(10)**	**E(11)**	**E(12)**	**E(13)**
0	0.00	-2383.94	-15892.95	-15902.89	-16657.80	-15827.68	-20030.8	-13628.21	-7549.15	-4171.90	0.00	0.00	0.00
P(0)	**P(1)**	**P(2)**	**P(3)**	**P(4)**	**P(5)**	**P(6)**	**P(7)**	**P(8)**	**P(9)**	**P(10)**	**P(11)**	**P(12)**	**P(13)**
0	0	0	0.00	2782.56	18628.58	19083.14	19964.61	19020.43	23899.14	16563.79	9258.32	5117.02	136.80
F(0)	**F(1)**	**F(2)**	**F(3)**	**F(4)**	**F(5)**	**F(6)**	**F(7)**	**F(8)**	**F(9)**	**F(10)**	**F(11)**	**F(12)**	**F(13)**
0	0.00	-2383.94	-18276.90	-34179.78	-48055.02	-45254.12	-46201.8	-39865.38	-28394.10	-8666.86	7896.93	17155.25	22272.27
N(0)	**N(1)**	**N(2)**	**N(3)**	**N(4)**	**N(5)**	**N(6)**	**N(7)**	**N(8)**	**N(9)**	**N(10)**	**N(11)**	**N(12)**	**N(13)**
0	0.00	-2383.94	-18276.90	-31397.22	-29426.44	-26170.98	-26237.2	-20844.95	-4494.96	7896.93	17155.25	22272.27	22409.06
I(0)	**I(1)**	**I(2)**	**I(3)**	**I(4)**	**I(5)**	**I(6)**	**I(7)**	**I(8)**	**I(9)**	**I(10)**	**I(11)**	**I(12)**	**I(13)**
0	0.00	-2.23	-19.37	-49.18	-74.49	-70.16	-67.85	-61.97	-46.16	-12.34	0.00	0.00	0.00
I’(0)	**I’(1)**	**I’(2)**	**I’(3)**	**I’(4)**	**I’(5)**	**I’(6)**	**I’(7)**	**I’(8)**	**I’(9)**	**I’(10)**	**I’(11)**	**I’ (12)**	**I’ (13)**
0	0.00	-2.235	0.000	-70.827	-145.447	-215.879	-283.986	-346.490	-393.301	-406.378	-407.140	-407.903	-408.67
F’(0)	**F’(1)**	**F’(2)**	**F’(3)**	**F’(4)**	**F’(5)**	**F’(6)**	**F’(7)**	**F’(8)**	**F’(9)**	**F’(10)**	**F’(11)**	**F’ (12)**	**F’ (13)**
0	0.00	-2386.18	0.00	-34250.61	-48200.47	-45469.85	-46485.8	-40211.87	-28787.40	-9073.24	7489.79	16747.34	21863.60
N’(0)	**N’(1)**	**N’(2)**	**N’(3)**	**N’(4)**	**N’(5)**	**N’(6)**	**N’(7)**	**N’(8)**	**N’(9)**	**N’(10)**	**N’(11)**	**N’ (12)**	**N’ (13)**
0.00	0.00	-2386.18	-2386.18	-31468.05	-29571.89	-26386.72	-26521.2	-21191.43	-4888.26	7490.55	16748.11	21864.36	22000.40

Table A-6: The cash flow parameters for scenario III with extension increment of 5 days

Cash Flow Parameters	WEEKS												
	Week0	Week 1	Week2	Week3	Week4	Week5	Week6	Week7	Week8	Week9	Week10	Week11	Week12
E	**E(0)**	**E(1)**	**E(2)**	**E(3)**	**E(4)**	**E(5)**	**E(6)**	**E(7)**	**E(8)**	**E(9)**	**E(10)**	**E(11)**	**E(12)**
	0	-2544.63	-16964.22	-16974.82	-17780.62	-16894.54	-21380.97	-14546.82	-8058.00	-4453.11	0.00	0.00	0.00
P	**P(0)**	**P(1)**	**P(2)**	**P(3)**	**P(4)**	**P(5)**	**P(6)**	**P(7)**	**P(8)**	**P(9)**	**P(10)**	**P(11)**	**P(12)**
	0	0	0	2781.61	18816.03	20368.65	21250.63	20368.15	25177.70	18186.55	10363.07	5728.99	475.91
F	**F(0)**	**F(1)**	**F(2)**	**F(3)**	**F(4)**	**F(5)**	**F(6)**	**F(7)**	**F(8)**	**F(9)**	**F(10)**	**F(11)**	**F(12)**
	0	-2544.63	-19508.85	-36483.67	-51482.67	-49833.14	-50573.51	-43869.70	-31559.56	-10834.97	7351.58	17714.65	23443.64
N	**N(0)**	**N(1)**	**N(2)**	**N(3)**	**N(4)**	**N(5)**	**N(6)**	**N(7)**	**N(8)**	**N(9)**	**N(10)**	**N(11)**	**N(11)**
	0	-2544.63	-19508.85	-33702.06	-32666.65	-29192.54	-29322.89	-23501.56	-6381.86	7351.58	17714.65	23443.64	23919.54
I	**I(0)**	**I(1)**	**I(2)**	**I(3)**	**I(4)**	**I(5)**	**I(6)**	**I(7)**	**I(8)**	**I(9)**	**I(10)**	**I(11)**	**I(12)**
	0	-2.39	-20.68	-52.49	-79.86	-77.09	-74.78	-68.62	-51.62	-16.14	0.00	0.00	0.00
$\hat{I}_t$	**I'(0)**	**I'(1)**	**I'(2)**	**I'(3)**	**I'(4)**	**I'(5)**	**I'(6)**	**I'(7)**	**I'(8)**	**I'(9)**	**I'(10)**	**I'(11)**	**I'(12)**
	0	-2.39	-23.065	-75.601	-155.604	-232.984	-308.202	-377.398	-429.725	-446.672	-447.509	-448.348	-449.189
$\hat{F}_t$	**F'(0)**	**F'(1)**	**F'(2)**	**F'(3)**	**F'(4)**	**F'(5)**	**F'(6)**	**F'(7)**	**F'(8)**	**F'(9)**	**F'(10)**	**F'(11)**	**F'(12)**
	0	-2547.02	-19531.91	-36559.27	-51638.28	-49794.17	-50881.71	-44247.10	-31989.28	-11281.64	6904.07	17266.30	22994.45
$\hat{N}_t$	**N'(0)**	**N'(1)**	**N'(2)**	**N'(3)**	**N'(4)**	**N'(5)**	**N'(6)**	**N'(7)**	**N'(8)**	**N'(9)**	**N'(10)**	**N'(11)**	**N'(12)**
	0.00	-2547.02	-19531.91	-33777.66	-32822.25	-29425.53	-29631.09	-23878.95	-6811.59	6904.91	17267.14	22995.29	23470.36

Table A-7: The cash flow parameters for scenario III with extension increment of 10 days

Cash flow parameters	**Weeks**											
	Week1	**Week2**	**Week3**	**Week4**	**Week5**	**Week6**	**Week7**	**Week8**	**Week9**	**Week10**	**Week11**	**Week11**
E(0)	**E(1)**	**E(2)**	**E(3)**	**E(4)**	**E(5)**	**E(6)**	**E(7)**	**E(8)**	**E(9)**	**E(10)**	**E(11)**	**E(12)**
0	0.00	-12087.00	-16116.01	-20017.77	-12741.34	-22374.59	-18363.76	-8354.88	-9542.37	0.00	0.00	0.00
P(0)	**P(1)**	**P(2)**	**P(3)**	**P(4)**	**P(5)**	**P(6)**	**P(7)**	**P(8)**	**P(9)**	**P(10)**	**P(11)**	**P(12)**
0	0	0	0.00	13207.50	18906.90	23602.68	16070.35	25815.88	22466.87	11099.78	11323.43	1023.87
F(0)	**F(1)**	**F(2)**	**F(3)**	**F(4)**	**F(5)**	**F(6)**	**F(7)**	**F(8)**	**F(9)**	**F(10)**	**F(11)**	**F(12)**
0	0.00	-12087.00	-28203.01	-48220.78	-47754.62	-51222.31	-45983.39	-38267.92	-21994.41	472.46	11572.24	22895.67
N(0)	**N(1)**	**N(2)**	**N(3)**	**N(4)**	**N(5)**	**N(6)**	**N(7)**	**N(8)**	**N(9)**	**N(10)**	**N(11)**	**N(12)**
0	0.00	-12087.00	-28203.01	-35013.29	-28847.72	-27619.63	-29913.04	-12452.04	472.46	11572.24	22895.67	23919.54
I(0)	**I(1)**	**I(2)**	**I(3)**	**I(4)**	**I(5)**	**I(6)**	**I(7)**	**I(8)**	**I(9)**	**I(10)**	**I(11)**	**I(12)**
0	0.00	-11.33	-37.77	-71.65	-77.59	-75.07	-69.00	-63.92	-32.29	0.00	0.00	0.00
I'(0)	**I'(1)**	**I'(2)**	**I'(3)**	**I'(4)**	**I'(5)**	**I'(6)**	**I'(7)**	**I'(8)**	**I'(9)**	**I'(10)**	**I'(11)**	**I'(12)**
0	0.00	-11.332	0.000	-120.864	-198.676	-274.12	-343.641	-408.205	-441.264	-442.091	-442.92	-443.750
F'(0)	**F'(1)**	**F'(2)**	**F'(3)**	**F'(4)**	**F'(5)**	**F'(6)**	**F'(7)**	**F'(8)**	**F'(9)**	**F'(10)**	**F'(11)**	**F'(12)**
0	0.00	-12098.34	0.00	-48341.65	-47953.31	-51496.43	-46327.03	-38676.12	-22435.67	30.37	11129.32	22451.92
N'(0)	**N'(1)**	**N'(2)**	**N'(3)**	**N'(4)**	**N'(5)**	**N'(6)**	**N'(7)**	**N'(8)**	**N'(9)**	**N'(10)**	**N'(11)**	**N'(12)**
	0.00	-12098.34	-12098.34	-35134.15	-29046.40	-27893.75	-30256.68	-12860.24	31.20	11130.15	22452.75	23475.79

Table A-8: The cash flow parameters for scenario III with extension increment of 15 days

The Cash flow arameters	Weeks												
	Week1	**Week2**	**Week3**	**Week4**	**Week5**	**Week6**	**Week7**	**Week8**	**Week9**	**Week10**	**Week11**	**Week12**	**Week13**
E(0)	**E(1)**	**E(2)**	**E(3)**	**E(4)**	**E(5)**	**E(6)**	**E(7)**	**E(8)**	**E(9)**	**E(10)**	**E(11)**	**E(12)**	**E(13)**
0	0.00	-2544.63	-16964.22	-16974.82	-17780.62	-16894.54	-21380.97	-14546.82	-8058.00	-4453.11	0.00	0.00	0.00
P(0)	**P(1)**	**P(2)**	**P(3)**	**P(4)**	**P(5)**	**P(6)**	**P(7)**	**P(8)**	**P(9)**	**P(10)**	**P(11)**	**P(12)**	**P(13)**
0	0	0	0.00	2780.53	18809.87	20368.64	21250.28	20368.52	25175.78	18189.47	10365.84	5730.52	477.81
F(0)	**F(1)**	**F(2)**	**F(3)**	**F(4)**	**F(5)**	**F(6)**	**F(7)**	**F(8)**	**F(9)**	**F(10)**	**F(11)**	**F(12)**	**F(13)**
0	0.00	-2544.63	-19508.85	-36483.67	-51483.76	-49568.43	-50580.75	-43877.29	-31566.77	-10844.09	-7345.38	17711.21	23441.7
N(0)	**N(1)**	**N(2)**	**N(3)**	**N(4)**	**N(5)**	**N(6)**	**N(7)**	**N(8)**	**N(9)**	**N(10)**	**N(11)**	**N(12)**	**N(13)**
0	0.00	-2544.63	-19508.85	-33703.14	-32673.89	-29199.78	-29330.47	-23508.76	-6390.98	7345.38	17711.21	23441.74	23919.54
I(0)	**I(1)**	**I(2)**	**I(3)**	**I(4)**	**I(5)**	**I(6)**	**I(7)**	**I(8)**	**I(9)**	**I(10)**	**I(11)**	**I(12)**	**I(13)**
0	0.00	-2.39	-20.68	-52.49	-79.86	-77.61	-74.79	-68.63	-51.63	-16.16	0.00	0.00	0.00
I'(0)	**I'(1)**	**I'(2)**	**I'(3)**	**I'(4)**	**I'(5)**	**I'(6)**	**I'(7)**	**I'(8)**	**I'(9)**	**I'(10)**	**I'(11)**	**I'(12)**	**I'(13)**
0	0.00	-2.386	0.000	-75.601	-155.606	-233.512	-308.231	-377.441	-429.782	-446.74	-447.584	-448.423	-449.264
F'(0)	**F'(1)**	**F'(2)**	**F'(3)**	**F'(4)**	**F'(5)**	**F'(6)**	**F'(7)**	**F'(8)**	**F'(9)**	**F'(10)**	**F'(11)**	**F'(12)**	**F'(13)**
0	0.00	-2547.02	0.00	-36559.27	-51639.37	-49801.43	-50888.99	-44254.73	-31996.55	-11290.84	6897.8	17262.79	22992.47
N'(0)	**N'(1)**	**N'(2)**	**N'(3)**	**N'(4)**	**N'(5)**	**N'(6)**	**N'(7)**	**N'(8)**	**N'(9)**	**N'(10)**	**N'(11)**	**N'(12)**	**N'(13)**
	0.00	-2547.02	-2547.02	-33778.74	-32829.49	-29432.78	-29638.70	-23886.20	-6820.77	6898.63	17263.63	22993.31	23470.28

APPENDIX B

Questionnaire

Dear Sir/Madame,

In order to study the impact of the qualitative factors on the project cash flow, a percentage, *P*, has been used to represent the factors effect on the project cash flow. This percentage, *P*, has been defined as the percent of cash that represents the qualitative factors[i] effect, increases the expenses[ii], or decreases the income[iii].

If all the factors effects have been considered, the income will be very low and the expenses will be high according to *P*. (which defined as the worst case from the contractor perspective)

Survey data is being collected from as many participants as possible to help determine the **maximum** and the **minimum** values of *P* that affect the income and the outcome of the construction projects.

Maximum values of p	Minimum value of p

P.S

- (*i*) The qualitative factors are the ones that affecting on the project cash flow:
    1- Financial management
    2- Sub-Contractors
    3- Suppliers
    4- During Construction
    5- Prior Construction
    6- Communication skills
    7- Others
- (*ii*) The expenses are the direct costs of activities + overhead
- *(iii)* Incomes are the expenses + markup

Thank you in advance for your effort and your co-operation

Regards

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i Qualitative factors are the ones that affecting on the project cash flow; such as, financial management, sub-contractor, suppliers, during or prior construction, communication skills, etc.
ii Expenses have been defined as the cash out flow, Direct cost + Overhead and Taxes.
iii Income has been defined as the cash inflow, Expenses + Mark up.