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Article information:

To cite this document:
Tarek Zayed Yaqiong Liu , (2014),"Cash flow modeling for construction projects", Engineering, Construction and Architectural Management, Vol. 21 Iss 2 pp. 170 - 189
Permanent link to this document:
http://dx.doi.org/10.1108/ECAM-08-2012-0082

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Cash flow modeling for construction projects

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Abstract

Purpose – Construction projects are well known for their complexity and ambiguity. These projects carry out higher risk than traditional ones because they entail high capital outlays and intricate site conditions. Poor financial management of these projects may lead to bankruptcy; therefore, effective cash flow management is essential. Although the peculiar characteristics of construction projects, the accuracy of cash flow forecasting has been a long lasting problem. The paper aims to discuss these issues.

Design/methodology/approach – Many unforeseen factors affect the cash flow forecasting of construction projects. Therefore, the objective of the presented research in this paper is to examine the impact of these factors on contractor's cash flow. A model has been established by integrating analytic hierarchy process and simulation to examine the impact of various factors on cash flow. Data on the selected factors have been collected through questionnaires from various agencies in North America and China.

Findings – Results show that the most significant factors are: change of progress payment, payment duration, financial position of the contractor, project delays, and poor planning. It also shows that the effect of cash inflow factors varied approximately from 9.7 to 16.3 percent with a mean value of 12.4 percent.

Research limitations/implications – The implementation of the developed models are limited to few case study projects in testing the models. However, the developed models and framework are sound for future improvement. They are considered as a major step toward a broader cash flow planning.

Practical implications – The developed methodology and models play essential roles in decision-making process.

Originality/value – The developed model is expected to help contractors realistically forecast project cash flow under uncertainty. This may lead to more dependable and professional cash flow management, which might substantially reduce failures in construction business.

Keywords Modelling, Simulation, Construction projects, Cash flow forecast, Analytic hierarchy process (AHP)

Paper type Research paper

Introduction

Construction projects, i.e., buildings, highways, bridges, underground utilities and drainage facilities, industrial projects, etc., are known for their high risk and uncertainty, particularly, at the cost estimate phase of such projects where the amount of project's information is very limited. Contractors cannot survive in the competitive construction industry without effective cash flow management. Cash flow is the balance of received and spent cash on a project over a specific duration. Studies and investigations have shown that lack of liquidity is a major problem causing failure of construction projects (Al-Issa and Zayed, 2007). According to US census report, construction companies have a higher failure rate than most companies (14 percent). Only 26 percent of companies started in 1976 were still in business in 1988 (Bashford, 1996). According to 2005 BizMiner industry reports, out of the 853,372 construction specialty trade contractors, operating in 2002, only 610,357 were still in business in 2004, with a 28.5 percent failure

Engineering, Construction and Architectural Management
Vol. 21 No. 2, 2014
pp. 170-189
© Emerald Group Publishing Limited
0969-9988
DOI 10.1108/ECAM-08-2012-0082

rate (Al-Issa and Zayed, 2007). Companies may be able to maintain their business for a period of time without showing any profit, or even with a temporary loss; however, they may fail due to lack of liquidity during construction, even if they have a good financial statement. Poor financial position has led to 26.71 percent of the construction industry failures during the past decade (Arditi and Chotibhongs, 2005). Therefore, in order for a contractor to become successful in the construction competition, a healthy cash flow is an essential parameter.

Cash flow control, i.e., cash in/out and forecasting, in construction contracts is very essential to contractors. Financial management has long been recognized as an important management tool (Davis and Carr, 1992). If there are any huge discrepancies between actual and forecasted cash flow values, the contractors need to update the project plan to match the estimated situation immediately. The most important tool, which is available for contractors in order to control the financial aspects of their business, is cash flow diagrams. By diagnosing these diagrams, the engineers can determine whether this project is over/below budget or the process is ahead/behind schedule. With good knowledge of cash flow forecasting, the contractor could efficiently and accurately manage cash flow during construction to prevent extra expenses and avoid project collapse.

Many methodologies have been applied to analyze cash flow forecasting (Blyth and Kaka, 2006). The nonmathematical approaches, mostly referred to as project-oriented forecasting models, were greatly used in traditional research (Khosrowshahi and Kaka, 2007). These forecasting models, which were established based on historical project data, were used to monitor and modify project process. The models were used to forecast cost flow in construction projects and offered a "clear explanation as to the origin and nature of the resulting forecast" (Khosrowshahi and Kaka, 2007; Khosrowshahi, 1991, 1996, 1998). Since construction projects are usually uncertain, complex and unique, mathematical models, conversely, provide much simpler and cheaper approaches. Qualitative and quantitative techniques have been used to study the relationship between a set of independent and dependent variables in cash flow forecasting. A visual model for cash flow forecast was developed using deterministic approach (Khosrowshahi, 1998; Khosrowshahi and Kaka, 2007). The model has been established using the mathematical components of several key factors that can be negotiated to generate priorities. It also generates a forecast by combining the outcome of data analysis with the experience and knowledge of the forecaster.

In forecasting cash flow, there are many factors that should be considered to be fairly concrete, or certain, and others which are more difficult to estimate. Several factors impacting cash flow have been identified and studied and sorted into seven categories: financial, supplier, subcontractor, factors prior to/during project, and communication throughout the whole project (Al-Issa and Zayed, 2007). Based on literature, many models were developed to forecast cash flow before execution phase. However, very few studies have involved the impact of these factors and the uncertainty on cash flow performance of construction projects.

Therefore, the objectives of the research presented in this paper are to:

(1) identify and study the factors that affect cash flow of construction projects;

(2) study and analyze the impact of these factors on cash flow;

(3) design a cash flow forecast model considering uncertainty; and

(4) develop an automated tool to forecast cash flow considering the identified factors.

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Factors affecting cash flow of construction projects

There is large number of factors that affect construction project's cash flow. Based upon literature review and experts opinions, 43 factors are selected and grouped into seven main categories (Al-Issa and Zayed, 2007). Table I shows these factors in which they are clustered under the following categories: financial management, subcontractors, suppliers, communications skills; factors occur prior to and/or during construction; and others. The factors are also categorized based on their effect on cash in (I), cash out (O), and both (I&O). Several factors are discussed and highlighted in the following paragraphs.

Cash retention has been recognized as an important factor that affects project cash inflow (Al-Issa and Zayed, 2007). The purpose of this retention is to supply fund to the owner in the event that the contractor fails to carry out the project and to encourage the contractor to bring to an end any minor outstanding items. The retention is a loss to the contractor, which is equivalent to the sacrifice of interest on the amount of withheld money (Hughes *et al.*, 1998, 2000; Tianji and Robert, 2001).

In construction, more than 50 percent of project expenses are spent on materials, particularly for construction projects (Stukhart, 1995). With such an important proportion, it makes project cash outflow very sensitive to material cost fluctuation (Bernold and Treseler, 1991). The sensitivity of internal rate of return (IRR) to material cost fluctuation is also studied in which it shows high sensitivity (Hwee and Tiong, 2002; Stukhart and Bell, 1987; Proctor, 1996). It is reported that the usual delay of receiving payments is (30-45) days, which will greatly affect contractor's cash outflow (Arditi and Chotibhongs, 2005).

The IRR is sensitive to over/under measurement risks. Project duration is another factor that affects contractor's cash in/out-flow. Small projects might not be affected by duration changes but medium and large projects are more sensitive to duration changes (Hwee and Tiong, 2002). Change orders are also important to contractor's cash in/out-flow because when they are large in value, their impact on IRR is significant. While executing the project, rework might be requested due to mistakes. Rework has a negative impact on project cash in/out-flow; therefore, constructing the work appropriately from the first time saves time and money, which enhances project cash flow (Jacobsen, 1998). In addition, contract terms have a fundamental effect on project cash in/out-flow. It is difficult to manage cash flow and liquidity when payments submitted are tied to main contractor ability to collect because of the "pay-when-paid" or "pay-if-paid" clauses in many contracts (Baumgartner, 2003).

Research methodology

The methodology of this research passes through various steps, i.e., reviewing literature on cash flow factors and analysis, establishing a new forecasting model, and predicting cash flow based on the newly developed model. Figure 1 demonstrates the steps of this methodology, which are briefly discussed below.

(1) *Literature review*: it comprises several elements:

- study previous cash flow forecasting models to find their advantages and limitations;
- identify and collect the uncertainty factors and categorize them; and
- acquire a comprehensive knowledge of research techniques.

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Table I. Factors that affect cash flow of construction projects

Category	Factors	
Financial management	F_1: change of progress payment duration (I)	F_7: loan repayment (O)
	F_2: change of progress payment condition (I)	F_8: payments of material (before/after arrival) (O)
	F_3: receiving front payment (I)	F_9: over work measurement (I&O)
	F_4: large retention percent (I)	F_{10}: under work measurement(I&O)
	F_5: delay in releasing retention (I)	F_{11}: change of labor and staff wages (O)
	F_6: financial position (O)	F_{12}: bank interest (O)
Sub-contractor	Sub_1: decision to sub-contract (O)	Sub_3: failure of sub-contractor (I&O)
	Sub_2: over/under measurement (O)	Sub_4: renting vs buying equipment (O)
Suppliers	Sup_1: delay of making payments (O)	Sup_3: delay in delivery (I&O)
	Sup_2: Procurement problems (O)	Sup_4: price change (O)
Prior to construction	P_1: poor design (O)	P_4: cash flow forecasting (O)
	P_2: inaccurate bid items (I&O)	P_5: competitors (I)
	P_3: estimating strategies (O)	
During construction	D_1: mistakes in executing the work (I&O)	D_5: small project's duration-increase/decrease (I&O)
	D_2: lack of adequate insurance (O)	D_6: project delayed (I&O)
	D_3: replacement of defective work (I&O)	D_7: material and equipment shortages (O)
	D_4: large project's duration-increase/decrease (I&O)	D_8: lack of skilled labor (O)
		D_9: improper planning and management (I&O)
Communication skills	C_1: contractor/owner disputes (I&O)	C_3: relation with owner (I&O)
	C_2: poor communication – contractor staff (I&O)	C_4: relation with consultant team (O)
Others	O_1: weather condition (I&O)	O_3: negative change orders-omit work (I&O)
	O_2: positive change orders-additional work (I&O)	O_4: inability to manage change orders (I&O)
		O_5: number of claims (I&O)

Notes: I, affect cash-in; O, affect cash-out; I&O, affect cash-in and -out

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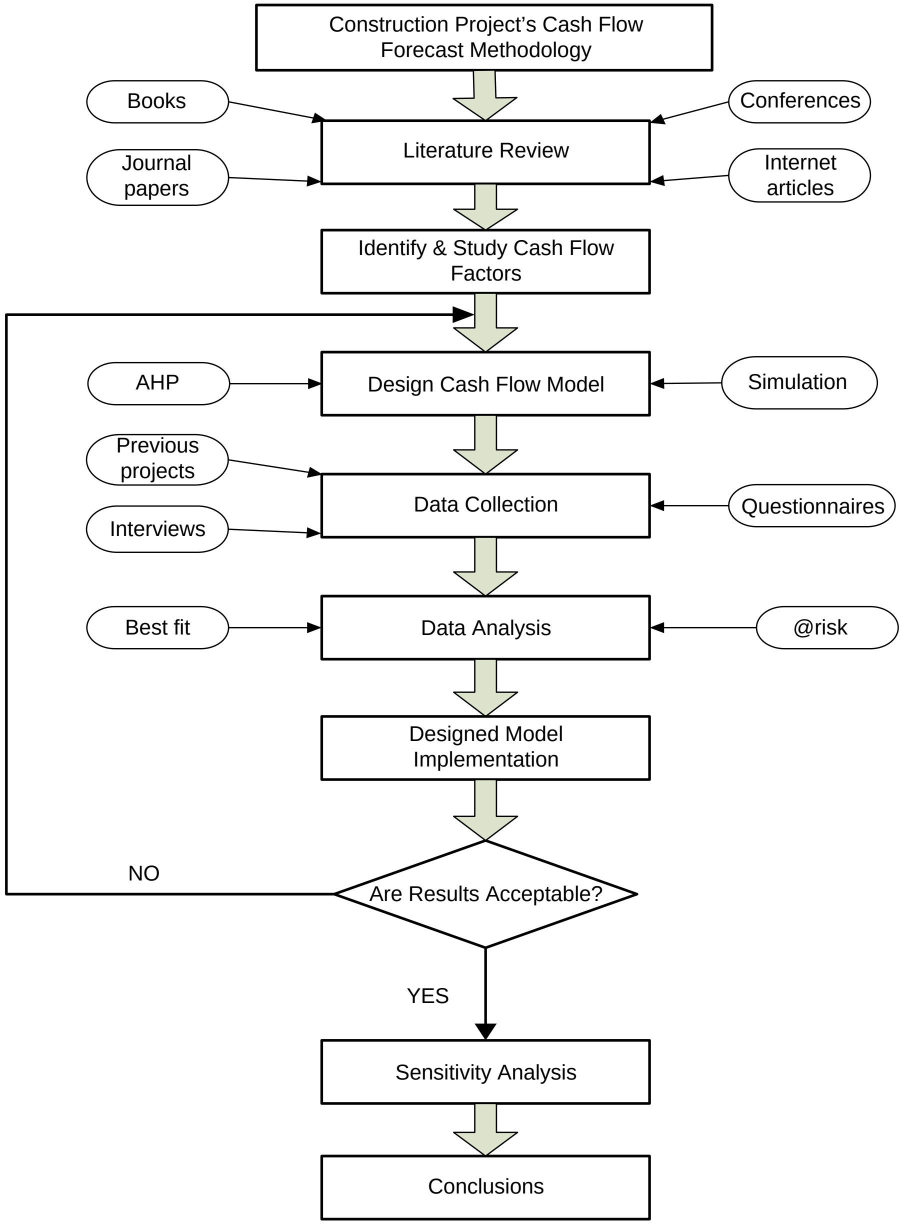

Figure 1.
Methodology of cash flow forecast model

Model development: develop a cash flow forecast model using integrated analytic hierarchy process (AHP) and simulation techniques. The weight and effect of every factor on cash flow forecast is determined using the AHP technique (Saaty, 1980, 1994). Then, a simulation model is developed, using the AHP analysis, to forecast cash flow and draw the overdraft.

(2) *Data collection*: a questionnaire is designed to investigate the factors' impact on cash flow from construction management experts. Questionnaires are sent to construction companies in North America and China.

(3) *Data analysis and model implementation*: data collected from questionnaires are analyzed and probability distributions are constructed for the factor's weights using @ RISK and best fit analyses. The AHP technique is used to calculate factors' weight. The developed cash flow models are then simulated in order to forecast the effect of cash flow factors and analyze cash flow.

(4) *Model verification*: real world case studies are used to verify the forecast model robustness.

(5) *Sensitivity analysis*: it is conducted to determine the importance of the selected cash flow factors.

(6) *Conclusions*: research outcomes are summarized and limitations are briefly discussed.

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Development of cash flow forecast model

The developed cash flow model considers three parameters: cash inflow, cash outflow, and overdraft in the sequence of calculation that is shown in Figure 2. As discussed earlier in the paper that there are many factors that affect the cash flow forecast in construction projects. This study identified 43 of them under seven main categories as shown in Table I. Several of these factors are subjective in nature, i.e., poor design; however, the rest are objectives. Therefore, it was necessary to sort and allocate the 43 cash flow factors into the following groups: factors affecting cash inflow, outflow and both (Table I). Typically, contractors receive their payments from owners on a weekly or monthly basis or based on billing terms. Payments from the owner are always planned monthly in which it is the basis for estimating cash inflow values. Sometimes, several unforeseen events might occur; e.g., contractor might not receive the exact amount on the contract date because of owner's poor financial position. If a payment is delayed, the billing time of cash inflow should be adjusted in the cash-in model. In order to consider the impact of cash inflow and outflow subjective and objective factors in the mathematical cash flow models, a quantification methodology should be utilized. In the present research, the quantification effect is performed utilizing three main criteria, i.e., weight (W), effect (E), and percent of cash affected (P). This effect is integrated in the cash-in and cash-out mathematical models as shown in Equations (1)-(3):

$$Cash\text{-}in_m = \left[1 - \left(\sum_{l=1}^{n} W_l \cdot E_l \cdot P\right)\right] \cdot C_{in-m} \tag{1}$$

$$Cash\text{-}out_m = \left[1 + \left(\sum_{k=1}^{r} W_k \cdot E_k \cdot P\right)\right] \cdot (1+i) \cdot C_{out-m} \tag{2}$$

$$Overdraft_m = Cash\text{-}in_m - Cash\text{-}out_m \tag{3}$$

where, W_l and W_k are weights of factors l and k, respectively; E_l and E_k are the effectiveness indexes of factors l and k, respectively; P is the percent of cash that

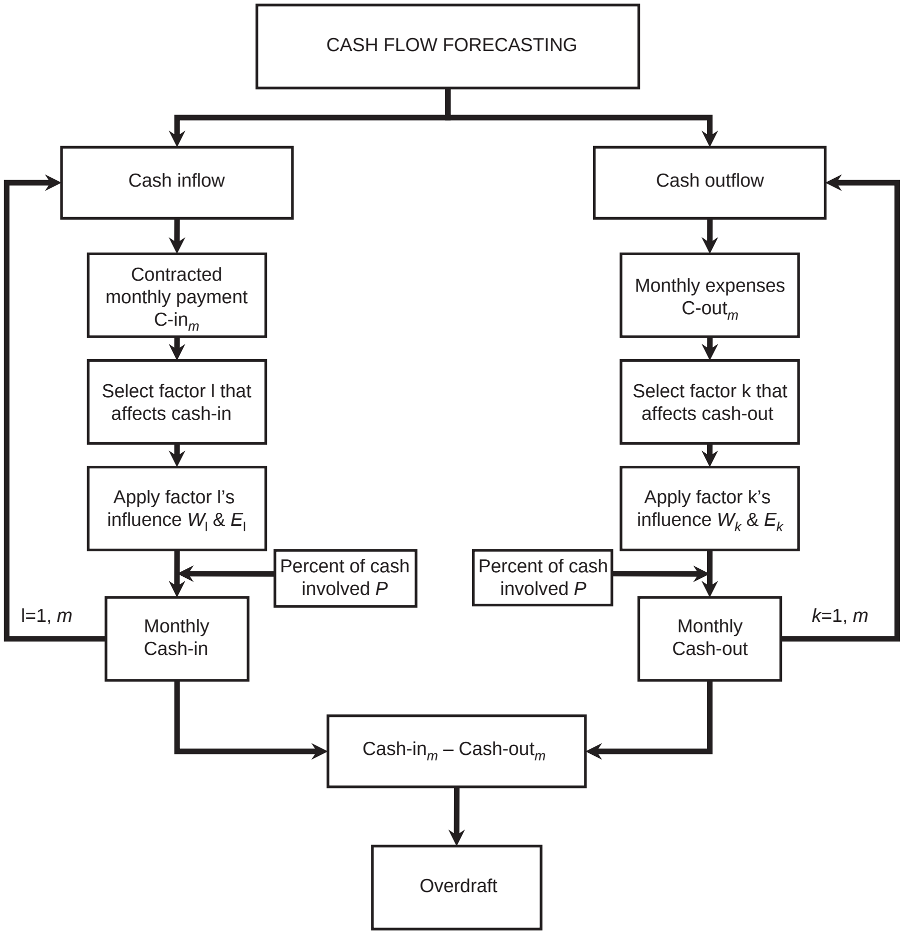

Figure 2.
Cash flow forecast model development

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represents the factors' effect (will be discussed later in the paper); C_{out-m} is the estimated expense (cash outflow) of the project at a specific time m; "i" is the current local interest rate; and C_{in-m} is the income (cash inflow) of the project at a specific time m. The value of n and r represent the number of factors that affect cash inflow and outflow, respectively.

As mentioned earlier, the terminologies weight (W), effect (E), and percent of cash affected (P) are added to the cash flow models to represent the effect of the 43 factors on cash flow models. The weights (W) of these factors are determined based upon the opinion of construction experts. The AHP technique is utilized to assess the value of W for each factor as explained earlier in this paper. The effect value (E) is collected from experts through a questionnaire. It reflects the type of project, i.e., project specific. Thus, the value of W is representing a general impact of a particular factor; however, the value of E is representing specific impact of such factor in a given project type. This impact is calculated by the multiplication of $W \times E$ as shown in Equations (1) and (2).

If the models in Equations (1) and (2) are left without the introduction of the term P, hence, the summation of $W_l \times E_l$ might add to 100 percent in the worst case scenario

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where all the factors occur. This might lead to the increase of cash outflow and the reduction of cash inflow by 100 percent, which is illogical. Therefore, the concept of P is added to the developed models in order to restrict the effect of factors to a certain percent that might not be exceeded. In other words, the effect of factors on cash inflow and outflow is limited or capped to $\pm P$ percent. The value of P has a maximum amount of effect on cash inflow and outflow in case of all factors occur. The present research assumes that the effect of factors when they occur is negative. Cash outflow is negatively affected by increasing expenses; however, cash inflow is affected by reducing the incoming funds. For example, suppose that in the worst case scenario where all the factors occur or exist, they will affect the cash inflow and outflow with a certain percent ($P = 40$ percent). It means that if all factors occur and affect the project, the cash inflow will only be reduced by a value capped to 40 percent and/or the cash outflow will be increased to a cap of 40 percent. The reduction and increase in both types of cash are represented by ± 40 percent. This concept was introduced to experts in the construction industry through site interviews where they showed positive feedback toward this cap. They also estimated the value of P to follow a triangular distribution of 0 percent lower limit, 30 percent mean value, and upper limit of 50 percent. Therefore, the maximum value or effect limit of factors is ± 50 percent with a mean value of ± 30 percent. In other words, the maximum effect is $+50$ percent on cash outflow with a mean value of $+30$ and -50 percent on cash inflow with a mean value of -30 percent. However, the best scenario occurs when the value of P is 0 percent, which means the effect of factors is almost null. In reality, the value of P lies in between the best and mean scenarios. This is why the concept of P is introduced to the above equations. Thus, the value of P has a plus sign in Equation (2) and a negative sign in Equation (1).

In this research and as depicted by Figure 2, the impact of each factor is represented by factor's weight and effect. The value of weights, W_k or W_l, and effectiveness, E_k or E_l, are normalized between 0 and 1. When multiplying W and E by P, it restricts their effect to a specific value as discussed earlier. Hence, if we multiply $W \times E \times P$, it produces the increased value of cash out or decreased value of cash in due to the effect of factors. Therefore, this value has to be subtracted from 1 in order to calculate the percentages of unaffected cash in and added to 1 for the unaffected cash out as shown in Equations (1) and (2). For example, if the weight of F5 (delay in releasing retention) is 0.1, the effect is 0.5, and the value of P is 0.3, then, $W \times E \times P = 0.1 \times 0.5 \times 0.3 = 0.015$. This factor is affecting cash inflow, hence, Equation (1) will be utilized where the multiplication of $W \times E \times P$ will be subtracted from 1 to produce the effect on cash inflow as follows: $1 - W \times E \times P = 1 - 0.015 = 0.985$. Then, if the cash inflow at this month is \$100,000, then, the expected decrease in the cash inflow due to the effect of F5 (delay in releasing retention) equals to \$100,000−\$98,500 = \$1,500. Similarly, all the other factors will be treated where the summation of $W \times E \times P$ for the factors that impact cash inflow will be determined and added to 1 in order to consider the effect of these factors. Then, the resulted value will be multiplied by the value of cash inflow and interest rate. It is assumed that interest would only be applied to the negative cash flow because positive cash flow intervals are typically small where the contractor uses this positive cash within project activities.

The overdraft at a specific time m could be either positive or negative. It is noted that cash flow forecasting has been defined by parameters W, P, and E. An effectiveness index is generated in order to normalize the values collected from experts. The value 9 is the maximum effect that a single factor can have on cash flow. For example, if a factor

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is rated as 9, its effectiveness is corresponding to the normalized peak value of 1. The above-mentioned parameters are all derived based on engineers' or experts' opinions and judgment. They are all embedded into the model as random variables. The parameters can define the specific characteristics of cash flow shape. By manipulating the three parameters, i.e., *W*, *P*, and *E*, the profile geometry of cash flow can be identified. The original input values of cash inflow and outflow have been used to obtain the base or reference cash flow curves. Using the above-mentioned three equations, the qualitative factors' impact is considered in forecasting cash flow of a specific project.

In order to consider the uncertainty in the collected data, in the evaluation of various factors and in cash flow parameters, Monte Carlo simulation is used to experiment with the developed models in Equations (1)-(3) using the developed probability distribution of each factor. Simulation-based analysis and modeling is used to analyze the properties of the collected data from questionnaires and determine the relative weights of various factors. This type of analysis considers the variability and uncertainty in the collected data and the nature of cash flow problem. Accordingly, the present research is considering the integrated AHP and simulation techniques to perform this analysis and develop a simulation-based model(s), which forecast project's cash flow considering Equations (1)-(3) as shown in the following steps:

(1) Fit a probability distribution for the various variables of Equations (1)-(3), i.e., *W*, *E*, *P*, and *i*. These distributions are based on the collected data from experts and construction case study projects. The AHP technique is utilized to determine the weights (*W*) for the various factors. Details will be discussed later in the paper.

(2) The Monte Carlo simulation algorithm is implemented to assess the values of cash-in, cash-out, and overdraft using the abovementioned three Equations (1)-(3).

(3) Simulate Equations (1)-(3) using Matlab software for large number of trials, which results in probability distributions for cash-in, cash-out, and overdraft.

(4) Steps 1, 2, and 3 will be repeated for every week or month of the project and recoded to draw the overdraft profile of the project after simulating the cash flow along the entire project duration.

(5) Draw the cash flow profile of the project using the mean values in order to demonstrate the models' outcomes.

Data collection

A data collection plan is developed in order to obtain the required information for the developed research. After a comprehensive literature review and several interviews with construction engineers/experts, 43 factors are identified as sensitive to cash flow in construction projects. These factors are categorized to facilitate modeling their effect on cash flow and forecast this impact. To this end, data are collected from experts and engineers through a questionnaire and on-site interviews. A questionnaire is designed to obtain each factor's effect on cash flow and to calculate its weight. Experts/engineers are interviewed to identify problems and to obtain realistic knowledge on management of cash flow variables. They are asked to rate the importance of various factors on a scale of 1-9, where 1 signifies that factors are "equally important." The other numbers signify the relative importance of two factors in a pair-wise comparison matrix. In all, 233 questionnaires are sent to 200 construction companies in North America and China through e-mail, fax, and interviews. A 100 responses are received for a return rate of 43 percent (100/233). In addition, information on several case study projects and financial figures are collected from specialized contractors.

Data are also collected from a heavy (highway) construction project located in Tianjian, China. The estimated cost was 13,019,990 Yuan (CAD $2,456,601 as of March 12, 2009). The project lasted seven months started in April 2006 and ends in September 2006. Monthly interest of 0.5 percent was applied to only negative cash flow. Front-end loading was not allowed in this project. The main construction activities of this project include mobilization, earth work-excavation, earth work subgrade compact and leveling, drainage structure, sub-base gravel, base course aggregate, side walk and stone curb, hot mix asphalt concrete, quality control, and side slope of road. The total planned duration of this project was 170 days. According to the project manager, the factors that affected this project were: F_1, F_8, F_9, Sp_1, Sp_2, D_3, D_4, D_7, D_9, C_1, and O_1 (refer to Table I for abbreviation clarifications). More case study projects' data are sought to validate the developed methodology and models and prove the concept of this research.

Data analysis and preparation for model implementation

The collected data are used to generate probability distributions for the effect (E) and weight (W) of each category and its factors. The @ RISK software has been used to generate these distributions and their test statistics information. The AHP technique is used to generate the weight (W) of each category and their factors. The weights of each factor are calculated through three steps: weight of categories; weight of factors; and decomposed weight. The decomposed weight (W) of a factor is calculated by multiplying the weight of its associated category by the weight of this factor within the category. For example, the category of "subcontractor" has a weight of 0.0890 and the factor "Sub_1" has a weight of 0.2434 within the "subcontractor" category. Then, the decomposed weight of the factor "Sub_1" equals to $0.0890 \times 0.2434 = 0.0217$. Similarly, the decomposed weights of all factors are calculated for each questionnaire's response. Therefore, 100 decomposed weights are generated for each of the 43 factors. The @ RISK software has also been used to generate probability distributions and their test statistics information for the weights of all factors. These distributions represent the weights, W_k or W_l, in the implementation of Equations (1)-(3) within the simulation processes. It is worthy to mention here that the AHP method implementation requires to test the consistency of pair-wise comparison matrices. The consistency of the collected matrices were checked, which showed robust results. Few matrices were inconsistent in which the researchers went back to the reviewers to fix them and rechecked again. Due to paper size limitations, this part of the analysis is not presented.

Table II shows the test statistics information for the weight of main categories. The results of probability fitting process show that all categories follow "Normal" distribution with mean (μ) and standard deviation (σ) as shown in Table II. Statistical tests are implemented to choose the best fit probability distribution for each factor. The χ^2-statistic and A-D statistical tests are used to check the soundness of fitted probability distributions. The p-value of a test should be close to 1 in order for a factor to follow the appropriate distribution. The results of χ^2-test indicate that normal distribution is the best fit for main categories' weight. The critical values at significant level $\alpha = 0.25$ have been chosen to compare with the χ^2-test results. Since the significant level value is higher than the χ^2-statistical results, the normal distribution

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Table II.
Statistical analyses of weights of main categories "normal distribution"

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
χ^2	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

cannot be rejected as the best-fit for this data set at $\alpha = 0.25$ significant level. For instance, based on Table II, if the χ^2-test result is 27.01 for Finance (F) category, and the critical value at $\alpha = 0.25$ significant level is 32.62, then, normal distribution is a highly qualified fit for the data. Similarly, the rest of probability distributions of other categories and their factors are constructed. In addition, 95 percent confidence intervals are constructed as shown in Table II as well. This table shows that the categories of "financial management (F)" and "during construction (D)" have the highest weights of mean equals to 0.285 and 0.209, respectively. They follow normal distribution with SD of 0.024 and 0.021, respectively. However, "communication skills (C)" category has the lowest weight of 0.079 and follows normal distribution with standard deviation of 0.012. Similarly, the effect (E) is analyzed and probability distributions are generated for all factors as shown in Table III. Almost all factors follow normal distribution at $\alpha = 0.25$ significant level.

The interest rate data are collected from Bank of Canada and China for the last two decades. Probability distributions are constructed for the interest rate of both countries to be used for Canadian and Chinese projects. The @ RISK software has also been used to generate probability distributions and their test statistics information for the interest rate as shown in Figures 3(a) and (b). Figure 3(a) shows the Canadian interest rate fitted distribution: triangular (1.54, 6.00, 7.94); however, Figure 3(b) shows the Chinese interest rate distribution: logistic (6.09, 0.60).

Different scenarios have been studied for the factors' impact and the inclusion of qualitative factors in the developed models. The best case scenario transpires when none of these factors occurs. Then, no modifications are warranted to the original forecast. The worst case scenario occurs when all the factors exist and arise for a particular project. The other, intermediate cases occur when several factors exist while others do not. Simulation results indicate that if all of the cash inflow factors occur, the cash inflow will decrease by 9.7-16.3 percent, with an average of 12.4 percent of cash inflow value. On the other hand, if all of the cash outflow factors occur, the cash outflow will increase by 12.9-20.4 percent, with an average of 16.7 percent of cash outflow value.

Differences between China and North America in the analysis

As mentioned earlier in the paper, data are collected from North America and China. In all, 100 questionnaires have been received from construction experts with different

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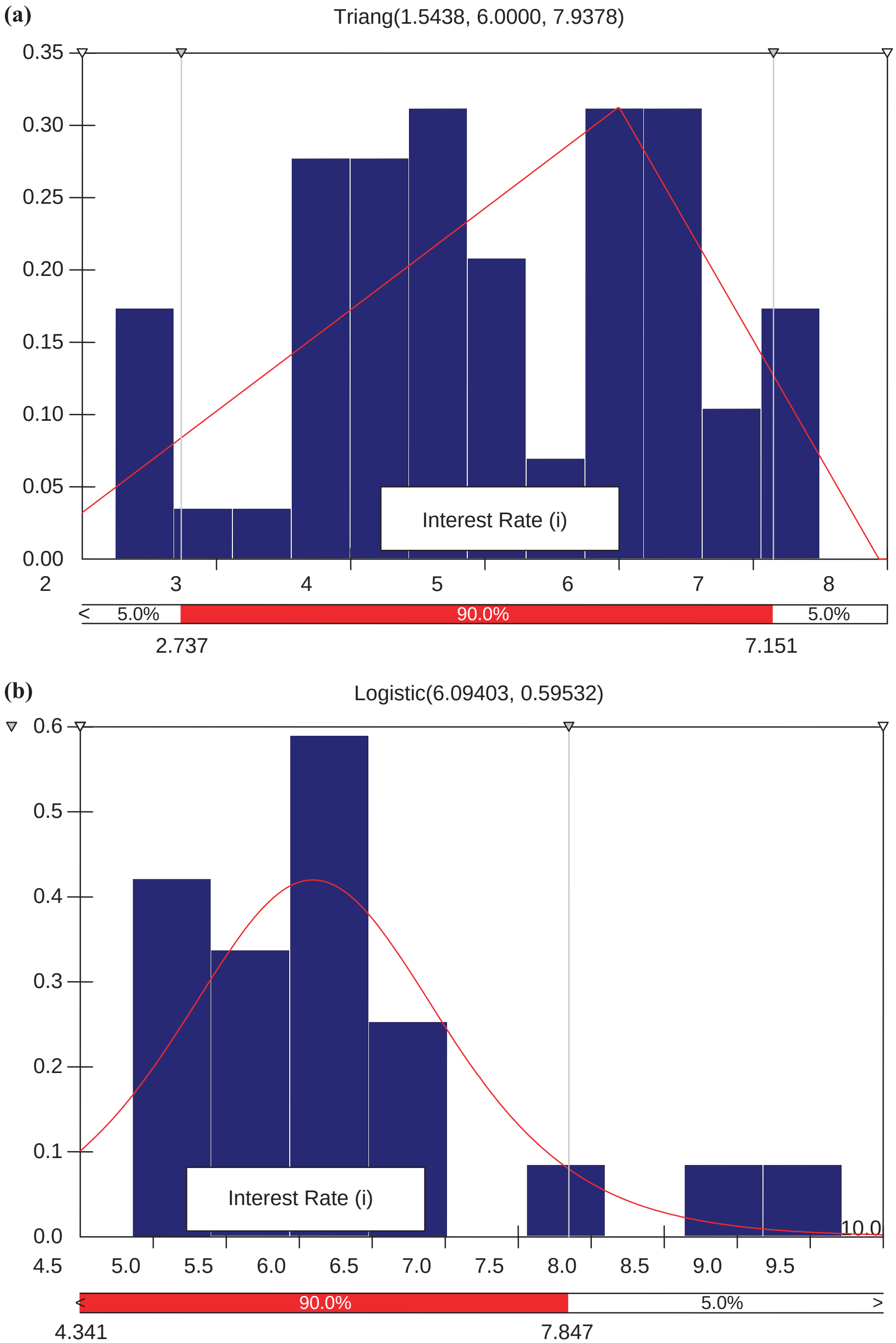
Table III. Statistical analysis of factors' effect "normal distribution"

Factors	μ	σ	95% confidence Upper limit	95% confidence Lower limit	χ^2 Test value	χ^2 p-value	A-D test Test value	A-D test p-value
F_1	0.819	0.173	0.801	0.836	20.280	0.854	0.296	>0.25
F_2	0.713	0.167	0.696	0.730	11.760	0.301	0.440	>0.25
F_3	0.758	0.140	0.744	0.772	7.360	0.691	0.390	>0.25
F_4	0.704	0.160	0.688	0.720	15.500	0.115	0.580	$\leqslant 0.15$
F_5	0.626	0.181	0.608	0.644	6.260	0.793	0.316	>0.25
F_6	0.796	0.124	0.784	0.809	6.040	0.812	0.309	>0.25
F_7	0.659	0.189	0.640	0.678	6.040	0.812	0.495	$\leqslant 0.25$
F_8	0.729	0.067	0.722	0.735	4.060	0.945	0.192	>0.25
F_9	0.666	0.222	0.644	0.688	4.280	0.934	0.320	>0.25
F_{10}	0.664	0.215	0.642	0.685	18.140	0.053	0.784	$\leqslant 0.25$
F_{11}	0.605	0.120	0.593	0.617	6.260	0.793	0.273	>0.25
F_{12}	0.611	0.174	0.594	0.629	12.200	0.272	0.480	$\leqslant 0.25$
Sub_1	0.624	0.163	0.608	0.640	5.820	0.830	0.710	$\leqslant 0.1$
Sub_2	0.658	0.190	0.639	0.677	4.940	0.895	0.303	>0.25
Sub_3	0.695	0.184	0.677	0.714	12.420	0.258	0.385	>0.25
Sub_4	0.582	0.223	0.560	0.605	5.380	0.864	0.175	>0.25
Sup_1	0.652	0.188	0.633	0.671	4.500	0.922	0.254	>0.25
Sup_2	0.627	0.174	0.610	0.645	3.620	0.963	0.175	>0.25
Sup_3	0.719	0.204	0.698	0.739	7.580	0.670	0.434	>0.25
Sup_4	0.555	0.219	0.533	0.577	5.380	0.864	0.414	>0.25
D_1	0.708	0.230	0.685	0.731	5.600	0.848	0.338	>0.25
D_2	0.532	0.237	0.508	0.555	13.080	0.219	0.491	$\leqslant 0.25$
D_3	0.525	0.190	0.506	0.544	5.820	0.830	0.252	>0.25
D_4	0.715	0.177	0.697	0.733	13.520	0.196	0.502	$\leqslant 0.25$
D_5	0.635	0.206	0.615	0.656	6.260	0.793	0.285	>0.25
D_6	0.813	0.139	0.799	0.827	3.840	0.954	0.118	>0.25
D_7	0.739	0.224	0.717	0.762	10.440	0.403	0.296	>0.25
D_8	0.652	0.216	0.630	0.673	5.380	0.864	0.253	>0.25
D_9	0.856	0.106	0.845	0.867	18.360	0.049	0.628	$\leqslant 0.1$
P_1	0.734	0.198	0.714	0.754	7.140	0.712	0.282	>0.25
P_2	0.572	0.214	0.551	0.594	9.120	0.521	0.356	>0.25
P_3	0.658	0.170	0.641	0.675	6.920	0.733	0.325	>0.25
P_4	0.747	0.194	0.728	0.767	4.060	0.945	0.256	>0.25
P_5	0.613	0.233	0.590	0.636	5.160	0.880	0.272	>0.25
C_1	0.689	0.156	0.674	0.705	2.520	0.991	0.079	>0.25
C_2	0.645	0.196	0.626	0.665	4.720	0.909	0.165	>0.25
C_3	0.738	0.187	0.719	0.757	7.140	0.712	0.458	>0.25
C_4	0.554	0.180	0.536	0.572	8.240	0.605	0.435	>0.25
O_1	0.633	0.188	0.614	0.652	4.060	0.945	0.192	>0.25
O_2	0.610	0.178	0.592	0.627	10.880	0.367	0.260	>0.25
O_3	0.511	0.183	0.493	0.530	8.240	0.605	0.265	>0.25
O_4	0.719	0.193	0.700	0.739	3.620	0.963	0.335	>0.25
O_5	0.686	0.241	0.661	0.710	10.440	0.403	0.332	>0.25

experience and specialties. They rated the impact of each factor on construction cash flow based on their judgment, experience, and construction industry features in their region. Among the 100 questionnaires, 33 questionnaires are collected from North America (i.e. USA and Canada) and 67 from China. Data are clustered into these two sets or groups, i.e., North America and China, in order to study the differences between them and consider location in the analysis. The analysis is performed using a



Notes: (a) Canadian interest rate; (b) Chinese interest rate

Figure 3.
Interest rates for Canada and China (last two decades)

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combination of @ RISK and SPSS software. Results from SPSS software can be used to analyze whether factors from both categories have similar impact on construction project cash flow. Table IV presents the summary of questionnaire results for each category.

The similarities and differences of factors impact on cash flow forecasting are evaluated considering location parameter, i.e., North America and China. Two important tests are conducted using SPSS, namely normality and homogeneity tests. In the SPSS, two well-known tests of normality are used Kolmogorov-Smirnov and Shapiro-Wilk tests.

Factor	China			North America		
	Mean	SD	Variance	Mean	SD	Variance
F_1	7.5373	1.4702	2.1292	7.3030	1.6102	2.5142
F_2	6.5522	1.5104	2.2473	6.9394	1.5600	2.3600
F_3	7.0746	1.4493	2.0691	6.6970	1.6102	2.5142
F_4	6.4179	1.2810	1.6164	6.5758	1.3470	1.7594
F_5	5.5672	1.8441	3.3500	5.0606	1.7489	2.9660
F_6	7.4478	1.2826	1.6204	6.7273	1.0975	1.1680
F_7	6.3134	1.9401	3.7077	6.3030	2.0076	3.9082
F_8	6.5224	1.3524	1.8017	6.5455	1.3250	1.7025
F_9	6.4776	2.1487	4.5480	5.5152	1.9704	3.7649
F_{10}	6.2239	2.0436	4.1141	5.6061	1.9193	3.5721
F_{11}	4.9552	1.9418	3.7144	5.6364	2.3825	5.5041
F_{12}	5.1791	2.0665	4.2067	5.1212	2.1177	4.3489
Sub_1	5.9701	1.8584	3.4021	5.6667	1.7970	3.1313
Sub_2	5.4627	1.7695	3.0844	5.9697	1.8955	3.4839
Sub_3	6.5224	1.6455	2.6674	5.6970	1.8453	3.3021
Sub_4	5.7463	1.9644	3.8013	5.1818	2.2144	4.7548
Sup_1	6.2836	1.6588	2.7106	5.3333	1.2910	1.6162
Sup_2	6.0448	1.6736	2.7592	5.5152	1.7342	2.9164
Sup_3	6.8507	1.8444	3.3509	6.0606	1.8361	3.2691
Sup_4	5.6418	1.9046	3.5732	4.8485	1.9384	3.6437
D_1	6.4627	1.8856	3.5023	6.8182	1.9114	3.5427
D_2	4.7313	2.1361	4.4950	5.2424	2.1364	4.4261
D_3	4.9701	1.6327	2.6260	5.0909	1.6272	2.5675
D_4	6.7612	1.7241	2.9280	6.5152	1.5835	2.4316
D_5	5.5224	1.8121	3.2346	5.5455	2.1079	4.3085
D_6	7.2388	1.4469	2.0624	7.4242	1.1734	1.3352
D_7	6.6269	1.8735	3.4578	6.4848	1.7875	3.0983
D_8	5.5672	1.9865	3.8873	6.3030	1.6102	2.5142
D_9	7.6716	1.0644	1.1161	7.3939	1.0589	1.0872
P_1	6.8060	1.8111	3.2310	6.3939	1.6759	2.7236
P_2	5.5075	1.8288	3.2947	5.1818	2.0380	4.0275
P_3	5.9552	1.6462	2.6696	5.7879	1.3171	1.6823
P_4	6.7910	1.7280	2.9414	6.7879	1.5362	2.2883
P_5	5.2985	1.8750	3.4631	5.3636	2.1624	4.5344
C_1	6.5075	1.4707	2.1305	6.1515	1.3947	1.8861
C_2	5.9701	1.8502	3.3722	5.3939	1.4348	1.9963
C_3	7.0299	1.8338	3.3125	5.7576	1.4584	2.0624
C_4	5.3284	1.8039	3.2056	4.5152	1.6031	2.4922
O_1	5.7164	1.7304	2.9494	5.2727	1.7189	2.8650
O_2	5.6866	1.5395	2.3346	5.4848	1.6031	2.4922
O_3	4.3731	1.9136	3.6070	4.4848	1.7342	2.9164
O_4	6.0149	1.8215	3.2684	6.1818	1.8617	3.3609
O_5	6.2537	2.1836	4.6968	6.0000	2.1651	4.5455

Table IV. Summary of collected scores

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However, the Shapiro-Wilk test is adopted in this research to assess the normality because it is more appropriate for the collected sample size. If the *p*-value of the Shapiro-Wilk test is >0.05 (i.e. significant level), then, the population of corresponding data is normally distributed and vice verse. The homogeneity test is used to test the differences between two means of the same variable in both categories. If data are normally distributed, then, a *t*-test for independent groups is used to acquire the difference between groups since the samples come from different individuals who are independent. Mann-Whitney *U*-test, as nonparametric test, is introduced as it does not require the assumption of normality. It compares medians rather than means to reduce the influence of outliers. Among the 100 data points for each factor, two distributions are derived based on the two groups using @ RISK software. The abovementioned tests are discussed to show the differences and similarities of the collected data from North America and China.

For instance, using Shapiro-Wilk test, the significance value of China group is 0.03 for factor F_1, which is below the significant level 0.05, then, data do not follow normal distribution. The values of China and North America groups for O_3 factor are 0.997-0.737, respectively. They are greater than the significant level of 0.05, which shows that data are considered to be normally distributed. Similar analysis is performed for the rest of factors although it is not presented in this paper because of paper size limitations.

Homogeneity test

Homogeneity tests are performed to check whether the collected data in both groups, i.e., China and North America, are different or not. Three tests are conducted as shown in Table V: Mann-Whitney *U*-test, *t*-test for independent groups, and Tukey box plot. Results show that only seven influencing factors out of 43 had significant differences between the Chinese and North American groups, i.e., C_3 "Contractor personal relation with owner," C_4 "Contractor personal relation with consultant team," D_8 "Lack of skilled labor," F_1 "Change of progress payment duration," F_{11} "Change of labor and staff wages," Sup_1 "Delay of making payments to suppliers," and O_5 "Number of claims." If these factors are not expected to occur in a project or few of them exist, then, both group data can be considered as one data set. For simplicity, the entire data set will be utilized in the analysis of this paper except for the case study that is collected from China in which Chinese group data set is used. Due to paper size limitations, the analysis of these differences is not discussed in details.

Cash flow analyzer (CFA)

The CFA is an application programmed to execute the developed methodology using the designed models in present research. It allows the users to select anticipated factors that may affect their projects, to enter the project financial data, and to generate the expected cash flow analysis and diagrams. This application is based on MATLAB software language 7.6.0, 2008b version. Graphical user interface technique has been implemented into the program to provide a friendly and easy environment for users. The contractors could adopt this product (i.e. CFA) with a pre-defined list of expected factors that affect project cash flow and pre-estimate cost to predict the cash flow performance before and during construction.

The main screens of the developed are shown in Figures 4(a) and (b). Figure 4(a) shows the input screen that requires the user(s) to enter cash in and out-flow values and select the expected list of factors that might affect the project. The sensitivity analysis range of each factor is required as well. In Figure 4(b), cash flow and overdraft

Factor	Normal	M-W *U*-test and *t*-test	Homogeneity
F_1	No	0.026	No
F_2	Yes	0.168	Yes
F_3	No	0.005	Yes
F_4	Yes	0.345	Yes
F_5	Yes	0.2	Yes
F_6	No	0.057	Yes
F_7	Yes	0.663	Yes
F_8	Yes	0.663	Yes
F_9	No	0.663	Yes
F_{10}	Yes	0.663	Yes
F_{11}	Yes	0.663	No
F_{12}	Yes	0.663	Yes
Sub_1	Yes	0.663	Yes
Sub_2	Yes	0.2	Yes
Sub_3	Yes	0.196	Yes
Sub_4	Yes	0.576	Yes
Sup_1	Yes	0.08	No
Sup_2	Yes	0.511	Yes
Sup_3	No	0.353	Yes
Sup_4	Yes	0.061	Yes
D_1	Yes	0.046	Yes
D_2	No	0.125	Yes
D_3	Yes	0.675	Yes
D_4	No	0.403	Yes
D_5	Yes	0.68	Yes
D_6	No	0.065	Yes
D_7	Yes	0.794	Yes
D_8	Yes	0.026	No
D_9	Yes	0.718	Yes
C_1	Yes	0.444	Yes
C_2	Yes	0.349	Yes
C_3	No	0.003	No
C_4	Yes	0.032	No
O_1	No	0.342	Yes
O_2	No	0.05	No
O_3	Yes	0.278	Yes
O_4	Yes	0.223	Yes
O_5	No	0.034	No

Table V. Summary of normality and homogeneity tests

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profiles are shown in addition to sensitivity analysis results. This program applies the developed methodology and models using the integrated AHP and simulation techniques. The user applies the following steps in order to use the CFA:

(1) input several parameters, which have been defined in the contract, such as the amount of pre-estimated cost/income per month, interest, up-front payment, etc.

(2) identify and select the factors that might affect this particular project;

(3) apply the developed simulation methodology using the selected factors' effect and the developed model; and

(4) synthesize the series of cash inflow, outflow and overdraft, as well as the most likely cash flow profile.

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(a)

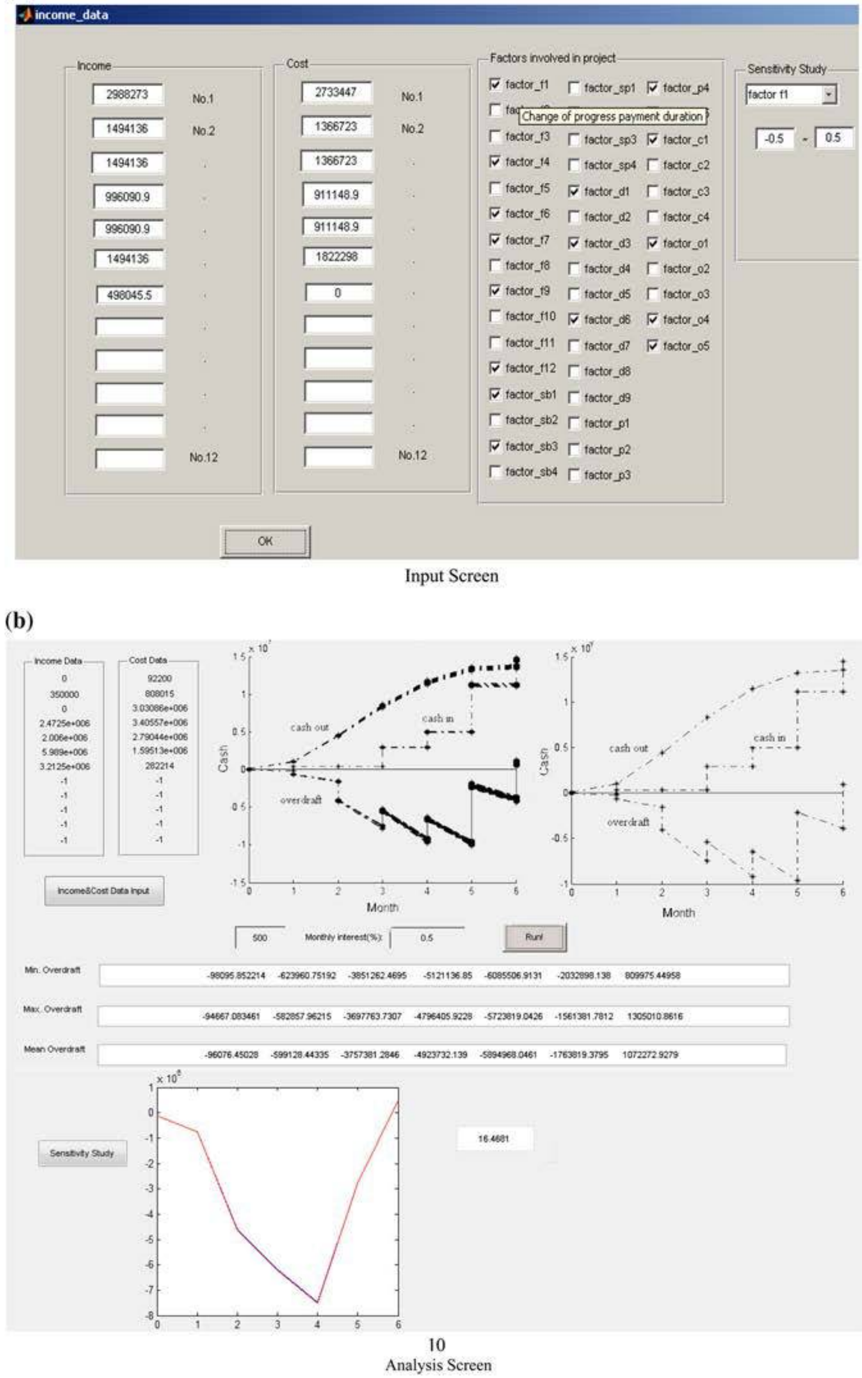

Figure 4.
Main screens of cash flow analyzer (CFA) for case study project

Notes: (a) Input screen; (b) analysis screen

Implementation of cash flow forecast models to case study

The developed methodology and models are implemented to the case study project as depicted in the data collection section of this paper. This implementation is meant to prove the research concept. More data on case studies are sought to validate the developed methodology and models. The factors that affect case study project are specified before conducting any calculations based upon the collected data from project site. Then, the CFA program is used to implement the models and perform the analysis. Instead of a unique profile, a series of cash flow curves are obtained where the cash flow profile values fluctuate around the most likely (mean) value. The peak and mean values are presented in the final result. Monthly cash in and out-flow analysis is used to represent cash activities in the construction project.

The program calculates maximum, minimum, and mean values of each point on the overdraft profile and compares them to actual overdraft (AO) data that are collected from the project. The maximum, minimum, and mean overdraft (MO) values and the list of real cash in/out values, which are collected from the project, are shown in Table VI. Results show that the AO is within the range of the forecasted overdraft in which the difference between AO and MO is minimal. For example, the AO value, i.e., 626,372 Yuan, at the end of month 2 is more than the forecasted NO and less than the XO. The difference between AO and MO is 29,733.7 Yuan, which is a 4.35 percent variance compared to its original value. Similarly, this difference is calculated for all months, which results in an average difference of 4.82 percent. This result shows that the developed models and methodology is robust and sound.

Sensitivity analysis

It is always useful to assess which factor has the highest effect on the results of developed models. Contractors could pay more attention to the factors which likely cause many problems during construction if the model is very sensitive to them. Sensitivity analysis is done by changing the factors' values from −50 to +50 percent with an increment of 10 percent from the base value. One factor is changed while the rest of factors are held constant at average values. Basically, the factor with the largest variance on mean value has the highest sensitivity. For example, factor F_3 "receive front payment" has the highest mean difference of 1.70126×10^{13} within the limits 1.68085×10^{13} at −50 percent and 1.73×10^{13} at +50 percent deviations. Contractors might also be curious to know what will happen if all factors are expected to occur. How much will the percent of effect be? All the cash inflow and outflow factors are treated separately. Figure 5 presents the sensitivity

Table VI. Real overdraft vs forecasted overdraft (¥:Yuan) for the case study project

Time	Estimated cost	Real cost	Payment received	Actual overdraft (AO)	Forecasted overdraft by CFA (the developed models) Maximum (XO)	Minimum (NO)	Mean (MO)	Cost variance 1−AO/MO (%)
Month 1	92,200	100,000	0	−100,000	−94,667	−98,096	−96,077	3.92
Month 2	808,015	876,372	350,000	−626,372	−582,858	−623,961	−599,128	4.35
Month 3	3,030,858	3,287,265	0	−3,913,637	−3,697,764	−3,851,262	−3,757,381	3.99
Month 4	3,405,575	3,693,682	2,472,500	−5,134,819	−4,796,406	−5,121,137	−4,923,732	4.11
Month 5	2,790,440	3,026,508	2,006,000	−6,155,327	−5,723,819	−6,085,507	−5,894,968	4.23
Month 6	1,595,128	1,730,074	5,989,000	−1,896,401	−1,561,382	−2,032,898	−1,763,819	6.99
Month 7	282,214	306,089	3,212,500	1,010,010	1,305,011	809,975	1,072,273	6.16
			Average					4.82

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results of this assumption. Results indicate that the overall cash outflow factors have higher impact than cash inflow factors. It also shows that F_3 has the highest variability, which shows high effect on the results of developed models. On the other hand, D_3 "replacing defective work" has the lowest variability and effect.

Conclusions

The presented research in this paper helps in developing a new methodology and models to forecast cash flow of construction projects before and during construction stages. In all, 43 factors that affect project's cash flow have been identified and studied. Variability and uncertainty in the effect of these factors and data collection are considered using simulation-based analysis. Probability distributions for the effect and weight of these factors are constructed based upon the collected data from questionnaires, interviews and phone calls with practitioners. Cash flow models are designed and implemented using the integration of Monte Carlo simulation and AHP techniques to forecast cash flow and overdraft. CFA program is designed to implement the designed models and methodology. Results show that the categories of "financial management (F)" and "during construction (D)" have the highest weights of mean equals to 0.285 and 0.209, respectively. They follow normal distribution with SD of 0.024 and 0.021, respectively. However, the category of "communication skills (C)" has the lowest weight of mean equals to 0.079 and follows normal distribution with SD of 0.012. This research may serve as an advance warning flag for construction contractors in which mitigation procedures for cash flow problems should be undertaken. Contractors should pay attention to the maximum and minimum overdraft to avoid the worst case scenarios. It is an advantage to have a prior knowledge of cash flow forecasting and understand the impact of various cash flow factors. In conclusion,

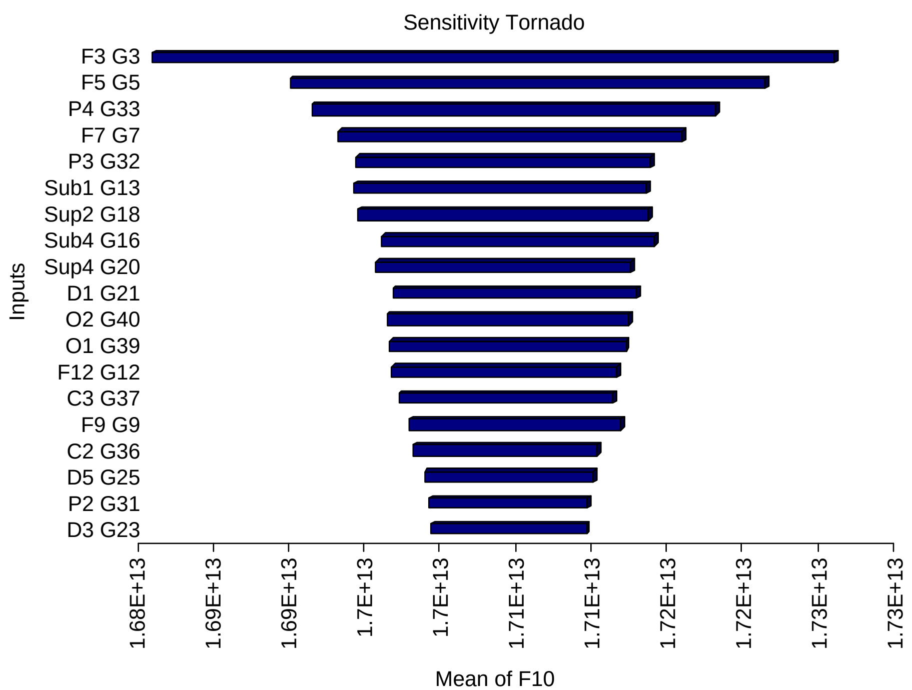

Figure 5.
The sensitivity tornado of case study project

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the developed cash flow models can be of vast benefit to practitioners and academics in forecasting cash flow progress before and during construction.

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