Cash Flow Forecasting Model for General Contractors Using Moving Weights of Cost Categories

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Abstract: This research introduces the development of a project-level cash flow forecasting model from a general contractor's viewpoint. While most previous models have been proposed to assist contractors in forecasting cash flow in the early stage of pretendering or the planning phase, this paper aims to provide a tool that can be applicable during the construction phase based on the planned earned value and the actual incurred cost on a jobsite level. The critical key to cash flow forecasting at this level lies in how to build a realistic cash-out model. Toward the end, this paper adopts moving weights of cost categories in a budget that are variable depending on the progress of construction works. In addition, it addresses time lags in accordance with the contractual payment conditions and credit times given by suppliers or vendors. As for the cash-in model, net planned monthly earned values are simply transferred to the cash-in forecast with a consideration of billing time and retention money. Validation of the proposed model involves applying realistic data from four ongoing projects. Based on the results of comparative analyses, the writers conclude that the proposed model is more accurate and reliable, yet simpler to field engineers who are generally not familiar with certain intricate financial knowledge.

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Introduction

Background

Cash is the most important of a construction company's resources. More construction companies fail due to a lack of liquidity for supporting their daily activities than because of inadequate management of other resources (Singh and Lakanathan 1992; Navon 1994). Russell (1991) pointed out that more than 60% of construction contractor failures are due mainly to economic factors. In an attempt to analyze the real business environment in the construction industry, various forecasting methods have been applied to cash flow management.

Numerous techniques for cash flow forecasting and management differ in their levels of accuracy and detail, the degree of automation in compiling them, and the method to integrate the time and money elements. Some of the techniques are probabilistic, but most of them are deterministic (Navon 1995). Reinschmidt and Frank (1976) proposed a model for cash flow forecasting in the early planning stage of a project. This model integrated schedule and cost items using a simulation model applied to the stochastic duration of the activities. However, it does not consider the time lag's impact on costs, which is essential in cash flow forecasting. The technique proposed by Sears (1981) is viewed accurately by manually integrating the schedule and cost items, but it requires considerable work and further, it does not consider the time lag between the expenditure and payment of a related cost item. Navon's model (1995, 1997) automatically integrates the bill of quantity (BOQ), cost estimate, and the schedule associated with a lower level of resources. However, if either the BOQ or the schedule is altered due to various changes, integration is likely to be more complicated and time consuming. Moreover, the main obstacle to automating the integration process is compatibility between cost items of the BOQ and activity elements of schedule.

In an attempt to improve the accuracy of a model for forecasting cash flow, Ashley and Teicholz (1977) suggested a cash flow forecast based on detailed methods of cost flow. They classified the direct cost by a number of cost categories such as labor, materials, and equipment which are specified as percentages of total cost. This approach is very realistic because it considers the nature of the budget and cost. However, each of these cost elements is assumed to be a fixed percentage of total cost over the project's duration. Moreover, this model does not consider the effect of time lags on the costs. Also, Gates and Scarpa (1979) and Peer (1982) developed cash flow models in the conceptual and planning stages using algebraic formulations and polynomial regressions. However, none of these models considered time lags to the costs and earned values.

In reality, many factors exist during construction that may affect the cash flow including time delays, cost overruns, unconfirmed earned values, change orders, and changes of cost plan elements (Bennett and Ormerod 1984). The key points of cash flow forecasts lie in how accurate, flexible, and comprehensive they are to be calculated and how effectively they consider uncer-

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tain factors such as time delay, cost overrun, variation of cost, and earned value between plan and actual. Of course, it is impossible to ensure that a project will definitely be as successful as initially planned. Even though construction is in progress, cash flow forecasts cannot be determined precisely. As a result, most models and techniques aforementioned are found to have the following problems: (1) they are not based on the construction stage, but rather only on the planning or preliminary stages in the project delivery process; (2) they do not consider time lags for the costs and earned values in forecasting cash flow; and (3) with regard to integration of cost items and activities, they are not compatible with each item and are rather complicated depending on when change factors occur in the subsequent construction stage.

Because cash flow is a reality, a cash flow forecast on a job site should be more precise than those during the preconstruction phases by addressing the uncertainties of the construction business and jobsite procedures. The main objectives of this paper are: (1) to quantitatively study construction project cash flows; (2) to propose a forecasting cash flow model for construction projects with a consideration of both variable cost weights and a time lag; and (3) to validate the proposed model and suggest guidelines for implementing this cash flow forecasting system. In addition, this paper provides implications to management by focusing more on how project managers or field engineers can benefit by using the presented model.

Research Scope and Methodology

Among a variety of types of construction projects, this research is focused on bid projects. The proposed model is intended to be applicable to the construction stage in the project delivery process from a general contractor's viewpoint. Accordingly, the research scope does not include investment projects such as Build–Operate–Transfer or Build–Operate–Own. Moreover, this research is relevant to the viewpoint of cash flow management at the project level, and subsequently project evaluation is performed by allowing contractors to reflect the capital cost (or so-called, interest cost) whenever negative cash flows occur.

To achieve its end, methodology should possess several necessary steps. As an initial step to meet the objectives, previous research papers that deal with cash flow management are reviewed to investigate problems with existing cash flow forecasting models. It should then suggest a new model of cash flow forecasting for a jobsite using a new algorithm. A numerical example is prepared to demonstrate and verify the computational aspects of the model. The next step is to perform a simulation using experimental data and to compare the model results to existing models proposed by other researcher. The last step of this research is to validate the model. Although the model is developed to offer a practical guideline to improve forecasting quality in evaluating the cash flow on a job site, objectively assessing the validity of the model in a real business scheme is quite difficult. Accordingly, a comparative case study methodology is chosen as a proper validation approach to the research features. Four projects in progress, including one building project and three civil projects, with data compiled over a duration of 12 months are identified as the case study materials. Based on the results of comparative analyses, we measure to see if the proposed model can be more accurate, flexible, and simpler to typical field engineers on a job site.

Cash Flow to General Contractor

Typical Project Cash Flow

Most construction projects are individual profit centers, each with its own cash cycle based on the costs of activities related to the project and on payments from a client, both of which are prescribed by a contract. Typical cash flow on a construction project consists of: (1) cash out such as bid costs, preconstruction costs (engineering, design, mobilization, etc.), materials and supplies, equipment and equipment rentals, payments of subcontracts, labor and overhead; and (2) cash in such as billings (less retentions), retentions, claims and change orders. The factors that affect cash flows are the duration of the project, the retention conditions, the times for receiving payments from the client, credit arrangement with suppliers or vendors, equipment rentals, and times of payments to subcontractors, etc.

Cash flow at the project level consists of a complete history of all cash disbursement and all earnings received as a result of project execution. Many construction projects have negative net cash flows until the very end of construction when the final payment is received or advanced payment is received before starting the project. This is a typical situation when the final payment consists of retention money and the retention percentage is greater than the profit percentage of the project.

Structure of Construction Budget

A budget structure in construction projects is constituted of cost accounts such as bills, sections, items, and resources. A budget is a plan for allocating resources (Meredith and Mantel 1995). Hendrickson and Au (1989) identified the fact that allocation of a cost to the budget may be used to develop the cost function of an operation. The basic idea in this method is that each expenditure item can be assigned to particular categories of operation. Ideally, the allocation item of joint costs should be causally related to the category of basic costs in an allocation process. Generally, a budget structure in construction projects is set up into labor, material, equipment, subcontract, and indirect expenses. If a general contractor performs all the areas of job management on site, expenses for management and overhead cost become a higher burden to the general contractor. To mitigate these costs, general contractors prefer to distribute a role of management to other participants. As an example, if a portion of a subcontract is increased, the general contractor is able to decrease the indirect expenses used for hiring project personnel: the workers, supervisory personnel, and engineers associated with the project. From the general contractor's viewpoint, labor and equipment costs are uncertain because productivity is extremely volatile and hard to measure. For this reason, general contractors attempt to hire subcontractors to reduce job-management costs and to maximize their profit opportunity by concentrating their control ability on variable costs, uncertain time, and strict quality. Typically, the portions of subcontract cost range from 50 to 70%. Material, labor, equipment, and indirect cost are arrayed between 25 and 35%, 5 and 15%, 10 and 25%, and 5 and 15%, respectively (Oberlender 2000).

Jobsite Cash Flow Forecast Model

Cash-Out Model

Time Lag

The critical key to cash flow forecasting at the project level is how to build a cash-out model. All resources to be incurred to costs in a budget have different time lags. They are subject to contracting procedures and a corporation's payment policy to other organizations. Accordingly, cash-out forecasts set the tone for time lags. Cost categories are classified in order to compile construction resources with similar time lags. Time lag, as used here, is based on contracting payment conditions and credit times given by suppliers or vendors.

Ahuja and Walsh (1983) also insist that there are delays between the dates of costs incurred and the dates of payment due. These delays will vary depending on resource types and credit arrangements as negotiated with subcontractors and suppliers. This approach is maintained by a number of previous researchers (Peterman 1973; Ashley and Teicholz 1977; McCaffer 1979; Trimble 1982; Kenley and Wilson 1989; Navon 1995; Kaka 1996).

Different cost categories are defined for materials, labor, equipment, subcontractors, indirect expenses (site overhead), and depreciation items since these cost categories generally have different time lags. If additional cost categories are needed, they can be classified. As mentioned before, since payment conditions of subcontracts are controlled by general contractor policy, it can be noted that the general contractors entail 50–70% certainty in cash flow forecasting regarding time lags. The only remaining problems are how to determine time lags of other cost categories and how to plan a budget for each period.

Jepson (1969) suggested that net cash flow for individual projects must be derived from "component" curves of inflow and outflow profiles. Fondahl and Bacarreza (1972) claimed that total costs can be broken down as to category since different cost resources may have different cost curves or different time lags related to their payment.

Moving Weights of Cost Categories

Ashley and Teicholz (1977) developed five cost curves for cost categories in their highway construction project. Fondahl and Bacarreza (1972) also applied three cost curves to their school project (Curves 1, 2, and 3). Curve 1 is based on the assumption that the rate of expenditure will be uniform over the project duration. Curve 2 assumes that only 25% of the total cost is incurred during the first half of the project duration and the remaining 75% in the second half. Curve 3 assumes that 75% of the total cost is incurred in the first half of project duration. In their research, only field overhead and home office overhead costs were analogous to Curve 1, which implies that only these costs were assumed to be incurred at a uniform rate over the project duration.

In other words, all cost categories except field overhead and home office overhead were not incurred at a uniform rate over the project lifetime. Unless the curves of all cost categories are uniform, the relative weights of the different cost categories should be changed whenever costs are incurred over the project duration. If weights of cost categories are uniform over the project duration, curves of all categories should represent straight lines. The concepts of the moving weights method and fixed weights method are illustrated in Fig. 1.

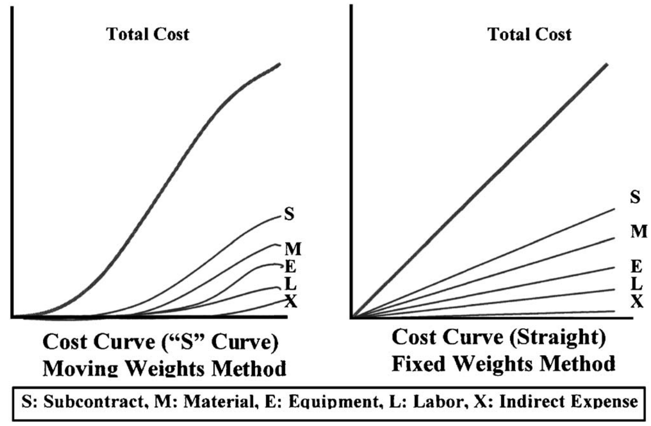

Fig. 1. Comparison of weights of costs during construction period

For that reason, whenever costs are incurred in a periodic month, weights of cost categories relative to the remaining budget are changed, even though neither the overall budget (the forecast total cost) nor the planning for execution is changed. Moreover, if a change of project amount or project duration occurred due to a change order or a change of contract conditions, weights of cost categories should also be adjusted (Park 2001).

Consequently, this implies that the next weight of a cost category to be applied will be set in accordance with the cumulative actual cost and the remaining budget. Thus, "the moving weights method" continuously changes over the project duration to pertain to the remaining budget. Applying moving weights of cost categories to the remaining budget in a month (time series) reduces the uncertainty of forecasting cash out for the remaining duration of the project. This characteristic of a budget during the construction period is illustrated in Fig. 2.

Cash-In Model

Billing Time

Generally, earned values will be received on a monthly basis or based on billing terms, but planning of earned values on a jobsite is established by a monthly amount. Earned value planning is the basis for estimated cash-in values in actual cash flow analysis. Net planned monthly earned values are simply transferred to the cash-in forecast, to be applied there with appropriate time lags. The billing period, the time between the dates of bill submittal and the progress payment receipt, is stipulated in the contract. If a payment delay occurs due to the owner's circumstances, the billing time of cash in can be adjusted in this model. In practice, billing terms in the contract should provide for a billing schedule for owner and contractor, but those terms can be applied variously depending on the owner's financing situation.

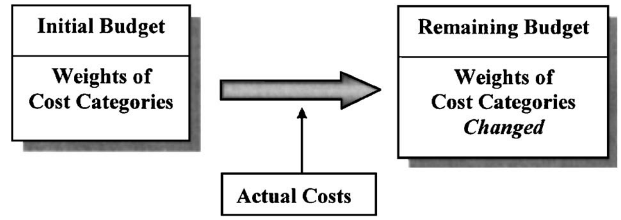

Fig. 2. Characteristic of budget during construction period

Retention Money

Cash-in planning should consider the effects of retention money and the billing period on earned values. Retention money is based on a percentage of retention stipulated in the contract. A cumulative cash-in curve is obtained from the cumulative earned value curve by applying a retention rate and billing period. Generally, contractors can improve cash flow by providing percent retention schedules in contracts with subcontractors. Then, the retention money is released when construction is completed and accepted. If cash in is properly planned and manipulated by a model, it will supply the funds necessary to meet the cash requirements of the project without borrowing from other organizations.

Mathematical Algorithm of Model

Cash Out

The model algorithm for cash out can be represented by equations. In cash out, the cost categories in an initial budget can be classified depending on the time lags of all resources in the budget. After that, the following equation is applied:

$$\text{initial weight } (w_i) = C_i \div \text{TB} \tag{1}$$

where i=cost categories; C_i=budget of individual cost categories; and TB=initial total budget (total costs).

Whenever deviation between actual and planned data occurs, an adjustment of weight is calculated and applied to the next cash planning. Since actual cost in accordance with initial weight of each cost category in each month is not incurred, actual cost and actual earned value should be reflected in the next weights of individual categories. The weight is called the "moving weight" in this research. Therefore, the next moving weight to be applied is

$$\text{moving weight } (\tau w_i) = \tau C_i \div \tau\text{TB} \tag{2}$$

where τC_i=remaining budget of individual cost category and τTB=remaining total budget.

From Eqs. (1) and (2), the constraints on weights of the individual cost categories can be represented by the following equations:

$$\Sigma w_i = 1 \tag{3}$$

or

$$\Sigma \tau w_i = 1 \tag{4}$$

where i=individual cost categories.

As a result, equations for the moving weights cash-out model are as follows. In terms of this model, the algorithm can be continuously updated to the weight to be applied in each month over the project duration

$$F_{t+1,i} = w_{t+1,i} \times C_{t+1} \tag{5}$$

$$w_{t+1,i} = \frac{C_{t,i} - \text{AC}_{t,i}}{\text{TB}_t - \text{TC}_t} \tag{6}$$

$$\sum \text{AC}_i = \sum \sum \text{FC}_{t+1,i} \tag{7}$$

where $F_{t+1,i}$=forecast of individual cost categories of time series in period $t+1$; C_{t+1}=planned costs of time series in period $t+1$; $w_{t+1,i}$=weights of cost categories of time series in period $t+1$; $\text{AC}_{,i}$=actual cumulative cost of individual cost categories; TC_t=actual cumulative total cost; and $\text{FC}_{t+1,i}$=actual cash-out flow.

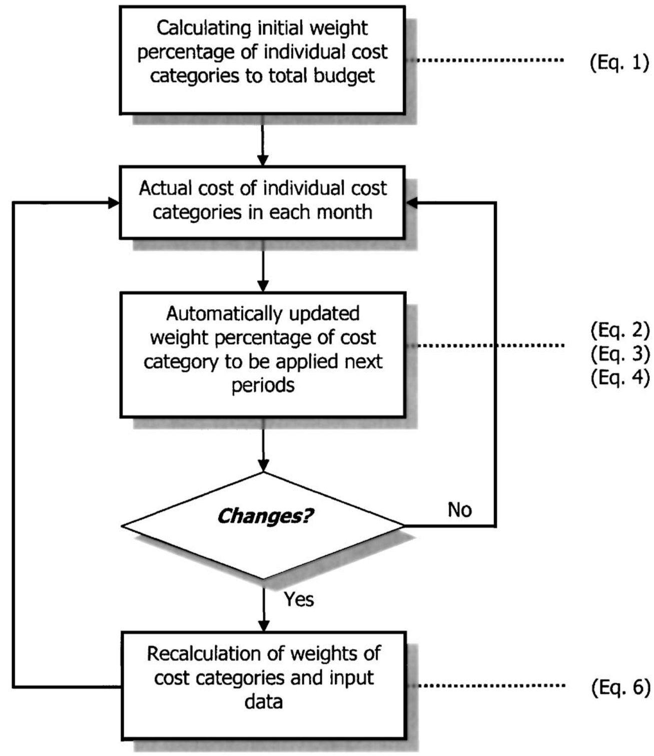

Fig. 3. Process of model

Cash In

Earned value is converted to cash in by deducting retention and applying billing time. This model considers that most contractors withhold retention from subcontractors at the same rate they are withheld by the owner. Therefore cash in should consider two kinds of retention money: contractors' retention and subcontractors' retention. Hence, the cash in is calculated as follows:

$$\text{CI}_t = V_t \times (1 - r_c) + r_s \times S_t \tag{8}$$

where CI_t=cash in at the time t; V_t=earned value at the time t; r_c=contractual retention rate; r_s=subcontractual retention rate; and S_t=subcontract cost at the time t.

Depending on the contractual agreement, release of retention is prescribed in two ways: first at the completion of the contract and second, at the end of the maintenance period. The model is simulated by entering the figures of release of retention by contractors whenever the subcontract ends.

Model Process

Fig. 3 illustrates an integrated process of model to cash flow forecasting. It consists of three steps designed for general contractors on a job site level to evaluate cash flow. The first step requires input data for evaluating each individual project, such as planned earned values and budget (cost) to each month, cost categories, weights, and time lags. If more cost categories due to different time lags are required, the users can classify separate cost categories.

The second step updates new weights to cost categories reflected on actual cost. Also, forecast cash flow such as cash in, cash out, cumulative cash flow, and capital cost are automatically

Table 1. Example of Cash Forecasting at Start of Project[a]

Time period (days)	Planed earned value	Planned budget	Actual value	Actual cost	Cash in	Cash out	Balance	Cumulative balance	Interest (10%)	Depreciation
0							0.00		0.00	
30	1,097	1,072	—	—	—	83.08	**−132.39**	−132.39	−1.09	49.31
61	1,159	1,130	—	—	—	87.58	**−139.56**	−271.95	−2.24	51.98
91	1,104	1,095	—	—	—	84.86	**−135.23**	−407.18	−3.35	50.37
122	1,106	1,084	—	—	—	84.01	**−133.87**	−541.05	−4.45	49.86
152	982	975	—	—	5,448.00	75.56	**5,327.59**	4,786.53	39.34	44.85
183	627	620	—	—	—	987.66	**−1,016.18**	3,770.36	30.99	28.52
213	716	709	—	—	—	1,045.39	**−1,078.01**	2,692.35	22.13	32.61
244	997	972	—	—	—	1,035.10	**−1,079.81**	1,612.54	13.25	44.71
274	1,183	1,176	—	—	3,523.00	1,041.27	**2,427.64**	4,040.18	33.21	54.10
305	1,302	1,288	—	—	—	954.41	**−1,013.66**	3,026.52	24.88	59.25
335	1,173	1,152	—	—	—	632.71	**−685.70**	2,340.82	19.24	52.99
365	1,083	1,059	—	—	—	703.51	**−752.23**	1,588.60	13.06	48.71
396	—	—	—	—	—	851.96	**−851.96**	736.64	6.05	—
426	—	—	—	—	—	1,030.76	**−1,030.76**	−294.13	−2.42	—
457	—	—	—	—	—	1,128.93	**−1,128.93**	−1,423.06	−11.70	—
487	—	—	—	—	—	1,009.73	**−1,009.73**	−2,432.79	−20.00	—
518	—	—	—	—	—	928.21	**−928.21**	−3,361.00	−27.62	—
Sum	12,529	12,332	—	—	8,971.00	11,764.73	**−3,361.00**	—	129.30	567.27
	Material	Labor	Depreciation	Equipment	Main materials	Sub-Con	Expense	Sum	Billing time	Retainage
Time lag (days)	150	0	0	0	0	150	0		120	0
Planned budget	4,033.80	456.28	567.27	27.13	0	6,775.20	472.32	12,332		
Initial weight (%)	**32.71%**	**3.70%**	**4.60%**	**0.22%**	**0.00%**	**54.94%**	**3.83%**	**100.00%**		**0%**

[a]Unit=1,000 US dollars.

calculated. This stage is based on moving weights of each classified cost category in each month. Moving weight is that weight to be applied to the next month that is adjusted and calculated by deducting the actual cost from the initial budget to the individual classified cost category in each month. Therefore, a weight of each budget of each individual cost category to the remaining budget is to be changed every month.

The final step provides feedback to estimate the new planned earned values and budget for each month. Whenever deviations between planned and actual costs and earned values occur, they are automatically distributed over the remaining duration if needed. If deviations between them are considerably more or less than expected, the project manager must modify the initial planning to forecast cash flow.

As a basis for applying the proposed model, this paper sets up basic assumptions: (1) in the initial time period, the planned earned value to the contract amount and planned cost to the budget are not automatically generated each month. Instead they are made independently by engineers on the jobsite by their own method of planning. (2) Time lags of cost categories are based on corporate historical data and company policy. (3) Cost categories classified at the start of a project have to continuously be used in order to maintain the degree of accuracy in moving weight over the project duration. (4) This model is used to forecast cash flow values at the close of each month (last day of the month). (5) Depreciation of company owned equipment is included in actual cash transfer incurred cost in order to show cash flow at the project level. (6) Home office overhead is not considered in this model since that is not generally considered as a job or project cost. That is incurred at the company level and accordingly may be billed directly on a jobsite.

Illustrative Example

To illustrate the new methodology proposed, we have conducted a simple case study. The illustrative case is composed with the following figures: project duration is 12 months, contract amount is US$12,529,000, and budget is US$12,332,000. Input variables for the case are: (1) planned earned values (PE), planned budget (PB), actual earned value (AE), and actual cost (AC) at each month; (2) cost categories classified based on contract procedure; (3) weight percentage and credit time of each cost category; (4) billing time and percentage of retention to be stipulated in contract; and (5) percentage of interest to be applied by corporate policy or decision. According to investigations by Singh and Lakanathan (1992), the application of "S curves" for cash flow projections can achieve an accuracy of approximately 88–97%. Subsequently, input data at each month are based on S curves.

The basic assumptions applied to the case study are: (1) changes of AC and AE against PE and PB at each month are addressed, but overrun of budget and delay of duration are not considered; (2) cost categories depending on time lags are simply classified as labor (0 days), materials (150 days), rent equipment (0 days), depreciation of owned equipment (0 days), subcontract (150 days), and field expense (0 days); (3) billing time to earned value is 120 days and percent of retainage is 0% of earned value

Table 2. Example of Updated Cash Forecasting after "1" Month[a]

Time period (days)	Planed value	Planned budget	Actual value	Actual cost	Cash in	Cash out	Balance	Cumulative balance	Interest (10%)	Depreciation
0							0		0.00	
30	1,097	1,072	1,090	729	—	87.48	**−121.01**	−121.01	−0.99	33.53
61	1,159	1,130	—	—	—	84.56	**−136.54**	−257.55	−2.12	51.98
91	1,104	1,095	—	—	—	81.94	**−132.31**	−389.86	−3.20	50.37
122	1,106	1,084	—	—	—	81.12	**−130.98**	−520.84	−4.28	49.86
152	982	975	—	—	5,441.00	72.96	**5,323.19**	4,802.35	39.47	44.85
183	627	620	—	—	—	654.38	**−682.90**	4,119.45	33.86	28.52
213	716	709	—	—	—	1,046.52	**−1,079.13**	3,040.32	24.99	32.61
244	997	972	—	—	—	1,035.43	**−1,080.14**	1,960.18	16.11	44.71
274	1,183	1,176	—	—	3,523.00	1,041.02	**2,427.88**	4,388.07	36.07	54.10
305	1,302	1,288	—	—	—	953.57	**−1,012.82**	3,375.25	27.74	59.25
335	1,173	1,152	—	—	—	631.29	**−684.28**	2,690.96	22.12	52.99
365	1,083	1,059	—	—	—	702.58	**−751.29**	1,939.67	15.94	48.71
396	—	—	—	—	—	854.55	**−854.55**	1,085.12	8.92	—
426	—	—	—	—	—	1,033.90	**−1,033.90**	51.22	0.42	—
457	—	—	—	—	—	1,132.37	**−1,132.37**	−1,081.15	−8.89	—
487	—	—	—	—	—	1,012.80	**−1,012.80**	−2,093.96	−17.21	—
518	—	—	—	—	—	931.04	**−931.04**	−3,025.00	−24.86	—
Sum	12,529	12,332	1,090	729	8,964.00	11,437.51	**−3,025.00**	—	164.08	551.49
	Material	Labor	Depreciation	Equipment	Main materials	Sub-Con	Expense	Sum		Retainage
Planned budget	4,033.80	456.28	567.27	27.13	0	6,775.20	472.32	12,332		0%
Actual cost after 1 month	**72.97**	**8.97**	**33.53**	**1.60**	**0**	**535.01**	**76.91**	**729**		
Actual weight (%)	10.01	1.23	4.60	0.22	0.00	73.39	10.55	100.00		
Remaining budget	3,960.82	447.32	533.74	25.53	0	6,240.19	395.41	11,603		
New moving weight (%)	**34.14**	**3.86**	**4.60**	**0.22**	**0.00**	**53.78**	**3.41**	100.00		

[a]Unit=1,000 US dollars.

each time; (4) in consideration of different time lags of cost categories, cash flow is calculated each 30 days; and (5) whenever negative cumulative cash flow occurs, internal interest (10%) is charged.

Table 1 represents the example of cash forecasting at the beginning of project ("0" month) made in accordance with the basic conditions and aforementioned algorithm with considerations of time lags and moving weights. As an example, in time period of 30 days, cash out (US$83.03) is gaged only considering cost categories that have no time lags [planned budget (US$1,072) × sum of initial weights of labor, equipment, and expenses (7.75%)]. It expects that the final cash balance at completion will be negative—around US$3,316,000. As the first month passes and actual cost (US$729) is incurred, we can update new weights to cost categories. The proposed model employs weights that are updated based on weight percentage of cost categories to the remaining budget each month over the duration, while the traditional approach is designed based only on weights to the initial total budget. For example, new moving weight of the material cost category (34.14%) can be updated by dividing the remaining budget of material (US$3,960.82) to the remaining total budget (US$11,603). Table 2 shows an example of the updated cash balance (negative US$3,025,000) in accordance with these revised moving weights.

Table 3. Project Overview

Project name	Project overview
Project A: apartment	• 8–25 story (seven building apartment)
	• 490 unit
	• Area: 279 ha
Project B: industrial complex	• Width: 20 M (four lane)
	• Earth work: 19 million m^3
	• Joint venture project
Project C: railway	• Total length: 11.432 km
	• Bridge: 12 (4,867 m)
	• Tunnel: 1 (545 m)
	• Stations: three stop
	• Joint venture project
Project D: sewage treatment	• Treatment capacity: 80,830 t/day

Validation of Model

Model validation includes measuring the accuracy of a model in describing the actual conditions of a problem to solve and in

Table 4. Project Basic Data[a]

Items	Project A	Project B	Project C	Project D
Contract amount	46,648	94,465	79,632	51,257
Duration (months)	33	49.3	96	63
Total budget (dollars)	36,486	82,946	72,989	42,221
Labor (%)	1.31	8.95	2.20	4.21
Material (%)	33.73	21.28	15.30	3.08
Equipment (%)	0.22	1.33	5.40	0
Subcontract (%)	49.14	63.47	61.70	83.58
Depreciation (%)	4.6	0.36	0	0
Expense (%)	11.0	4.61	15.40	9.13

[a]Unit=1,000 US dollars.

Table 5. Time Lags for Each Cost Category[a]

	Project A	Project B	Project C	Project D
Labor	0[b]	0[b]	0[b]	0[b]
Material	150	120	90	120
Equipment[c]	0[b]	0[b]	0[b]	0[b]
Subcontract	150	120	90	90
Depreciation	0[b]	0[b]	—	—
Expense	0[b]	0[b]	0[b]	0[b]

[a]Unit=days.

[b]The last day of the month when cost is incurred.

[c]Equipment cost is charged to expense of cash out in accounting perspective.

Table 6. Billing Time and Delay in Payment for Each Project[a]

	Project A	Project B	Project C	Project D
Billing time	120	30	90	60
Delay in payment[b]	0	0	150	30

[a]Unit=days.

[b]Delay payment is total delay time from the client.

evaluating the usefulness of the model in terms of its objectives to a larger case with similar problem contexts. Stated earlier, a comparative case study methodology was used to validate whether the model meets its development objective.

Validation Procedures

To verify the model, we performed simulation using empirical data from actual projects in progress. Simulation results based on the proposed model and existing model are compared. A simulation template is implemented in a common spreadsheet package—*Microsoft Excel*™—for the simulation experiments. Considering different time lags of cost categories, cash flow is calculated in monthly increments. The fixed weights method (FWM)—the current approach—applies fixed weights to cost categories over project duration, whereas the moving weights method (MWM)—the new proposed model—applies different weights each month using a new algorithm. The results of these two models were then compared to show the accuracy and consistency of the model. The stepwise procedures for the validation of the proposed model are as follows:

1. Four actual projects in progress including one building and three civil infrastructure projects, with data compiled over a duration of 12 months (see Tables 3 and 4);
2. To obtain forecast cash flow data, MWM and FWM are applied to actual data through the simulation; and
3. To compare the accuracy of MWM to FWM, the results of the simulation are analyzed.

To simulate the dynamic cash flow forecasting, simulation experiments were conducted 12 times from the first to the twelfth month by each method for individual projects and compared by the two methods: MWM and FWM. In addition, 2 types of simulations are performed on each project in order to compare the accuracy of forecasting models. Subsequently, 48 simulations per each project and a total of 192 simulations were performed for four projects. In the comparative analysis the results of forecasting are applied to cash flow each month instead of the cumulative cash flow forecasting applied previously in experiments since previous cash flow affects subsequent cash flow.

To compare the accuracy of two models, MWM and FWM, the simulation is performed in accordance with the following two types: (1) Type 1—planned data and actual data are identical to each other. This type is used to determine the reliability of the model and compare the two methods under ideal conditions since planned data are one of the most critical variables in this forecasting cash flow model, and (2) Type 2—planned data and actual data are different as reported by the jobsite for 12 months. In this case, the uncertainty of the construction job site is involved and the effect of planned data on the forecasting cash flow is considered. Finally, the following data are required for comparative analysis of the four projects in progress:

1. Time lags of billing time and individual cost categories (see Tables 5 and 6);
2. Total contract amount and total budget reflect contract amount and budget changed during the construction stage;
3. Monthly cost planning data and earned value planning data;
4. Weights of cost categories in the budget;
5. Retention rate and capital cost rate; and
6. Actual cash flow such as cash in and cash out for each month.

Validation Results

Measurement of Accuracy

Mean absolute deviation (MAD) was used to measure the error for each month's forecasted cash flow by means of the two models: MWM and FWM. The MAD is a commonly used measure

Table 7. Example of Comparative Analysis for Project A[a]

Time period (days)	Actual cash flow			Forecasting cash flow		Mean absolute deviation	
	Cash in	Cash out	Cash flow	MWM	FWM	MWM	FWM
183	—	736.003	−736.003	−678.018	−707.169	57.985	28.834
213	—	900.032	−900.032	−875.830	−879.505	24.202	20.527
244	—	1,160.845	−1,160.845	−1,107.974	−1,112.959	52.871	47.886
274	4,357.000	733.015	3,623.985	3,567.408	3,523.455	56.577	100.530
305	—	810.016	−810.016	−919.695	−943.710	109.678	133.694
335	—	632.069	−632.069	−662.458	−697.197	30.388	65.128
365	—	909.009	−909.009	−1,041.238	−1,083.378	132.229	174.369
Average						66.276	81.567

MWM=moving weights method; and FWM=fixed weights method.

[a]Simulation 1—after 1 month, Type 1.

Table 8. Comparison of Mean Absolute Deviation (MAD) in Moving Weight Method (MWM) and Fixed Weights Method (FWM) (Type 1)[a]

	MAD			
	MWM (A)	FWM (B)	$B-A$	MAPE
Project A	41.207[b]	68.010	26.803	65.04%[c]
Project B	62.395	93.356	30.962	49.62%
Project C	24.106	24.173	0.067	0.28%
Project D	27.781	31.739	3.957	14.24%
Average				32.30%

[a]Unit=1,000 US dollars.

[b]It is calculated by Eq. (9) through the 12 times of simulations from the 1st month to the 12th month (refer to Table 7 for the case of simulation 1).

[c]MAPE=26.803÷41.207=65.04%.

that forecasts accuracy as the degree of variation by the following equation. This measure is simply the measure of the absolute deviations for all forecasts

$$\text{MAD} = \frac{1}{n}\left|\text{Acf}_{ti} - \text{Fcf}_{ti}\right| \quad (9)$$

where Acf_{ti}=actual value of cash flow, Fcf_{ti}=forecasting value of cash flow at t month by the ith simulations, respectively; $t=1-12$; $i=1-12$; and n=number of observations.

In comparative analysis, the mean absolute percent error (MAPE) method was estimated for comparing errors. It can be achieved by dividing the difference between MAD of MWM and FWM by MAD of MWM. This fraction represents how large the error of FWM is as compared to MWM. All absolute deviation data between MWM and FWM are summed and divided by the number of observations, by the following equations:

$$\text{average MAPE} = \frac{1}{n}\sum_{t=1}^{t=12}\sum_{i=1}^{i=12}\frac{\text{mMAD}_{ti} - \text{fMAD}_{ii}}{\text{mMAD}_{ti}}100(\%) \quad (10)$$

where mMAD_{ti}=MAD value of MWM at t month by ith simulation; fMAD_{ti}=MAD value of FWM at t month by ith simulation; and n=number of observations.

The cash flow data consisted of four detailed real projects in progress, together with their associated estimated monthly values. The data were obtained from "D" Construction and Engineering Company in Korea. During the data collecting, adjustment of budget and contract amount including inflation was applied to specific projects. Table 7 shows the actual data to achieve the MAD for the specific case of simulation 1, which are estimated by Eq. (9) after the first month passes from the start of the project.

Table 9. Comparison of Mean Absolute Deviation (MAD) in Moving Weight Method (MWM) and Fixed Weights Method (FWM) (Type 2)

	MAD			
	MWM (A)	FWM (B)	$B-A$	Mean absolute percent error (%)
Project A	153.910	157.198	3.287	2.14
Project B	867.361	873.238	5.877	0.68
Project C	37.960	38.395	0.430	1.14
Project D	222.364	232.462	10.099	4.54
Average	—	—	—	2.13

Table 10. Reliability of Moving Weights Method (Type 1)[a]

Project	Mean absolute deviation (A)	Contract amount (B)[b]	$(A/B)\times 100$ (%)
A	41.207	13,489	0.31
B	62.395	27,464	0.23
C	27.094	4,539	0.60
D	27.781	7,310	0.38
Average			0.38

[a]Unit=1,000 US dollars.

[b]Contract amount means total earned values for 12 months.

In the same way, the average MAD can be calculated through the 12 times of simulations from the first month to the twelfth month. Based on the results of MAD for simulations, MWM is more accurate than FWM. In the Type 1 simulation, the accuracy is 0.28–65.04%, with an average of 32.30% higher than FWM in the ideal condition, where planning is well established as reflected on the construction jobsite, and continuously updated (see Table 8). In the case of Type 2, the accuracy is 1.14–4.54%, an average of 2.13% higher (see Table 9). As a result, the degree of accuracy of MWM is an average of 17.21% higher than FWM.

Reliability

Kenley and Wilson (1986) and Kaka and Price (1991) suggested that the error range of forecasting in the construction industry is within ±3% of the contract amount. This is considered an acceptable limit and demonstrates the reliability of the proposed model. The error range of the forecasting is 0.23–0.6%, with an average of 0.38% for four projects in Type 1, and 0.82–2.78%, with an average of 1.79% for four projects in Type 2 (see Tables 10 and 11). Despite unavoidable errors in the planning data, the result is thought of as being reasonably attained by applying the model for forecasting. Consequently, the reliability of the MWM model is acceptable and well demonstrated based on simulation.

Practical Implications to Industry

Financial management has long been recognized as an important management tool. A company can survive a transitional period without a profit, or even with a loss; however, it may fail due to lack of cash during the operation even if it has a good financial statement. In the viewpoint of corporate, cash flow forecasts should be made at all stages of the project from the planning stage to the operation and maintenance stage of a project. However, cash flow forecasting and management are a dynamic process. Deviations of all projects at the corporate level may significantly affect the firm's financial status. Moreover, inadequate cash flow forecasts to a certain project may drive a corporate into a crisis of financial situations.

Table 11. Reliability of Moving Weights Method (Type 2)[a]

Project	Mean absolute deviation (A)	Contract amount (B)[b]	$(A/B)\times 100$ (%)
A	153.910	12,529	1.23
B	867.361	31,158	2.78
C	37.045	4,516	0.82
D	222.364	9,500	2.34
Average			1.79

[a]Unit =1,000 US dollars.

[b]Contract amount means total earned values for 12 months.

Considering the real business world in construction industry, various forecasting methods may be applied to cash flow. Some judgment on a jobsite is needed in the case of forecasting cash flow with respect to complexity and unexpected situations in construction industry. However, if jobsite engineers or project managers rely only on judgment based on their experience without the use of any mathematical forecasting techniques, they may not make a good decision to forecast cash flow. Essentially, a good forecasting technique needs to include both a historical trend-based data supported method and competent judgments based on construction experience and knowledge.

In this respect, the proposed model suggest a practical and easy approach for jobsite engineers and project managers who are generally not familiar with finance knowledge of forecasting cash flow using the regular reports. This model can be applied as part of a project evaluation process and continuously updated to show deviations between plan and actual data through changes or information from the jobsite. In addition, the fast and simple forecasting cash flow allows field engineers or project managers to support and to save time for decision making of strategy of cash management to the corporation and projects.

Conclusions

A simple cash flow forecasting model (MWM) was developed to assist general contractors on jobsites during the construction phase. The model was based on the general procedure of construction jobsites and the nature of a general contractor's budget. The model included new methodology that was not addressed by previous researchers. A comparative case study methodology was chosen as a proper validation approach to evaluate the benefits of the proposed model. Four real projects were identified as the case study materials and the validity of the model was tested by actual data from these projects in progress. The overall validation procedures were derived from a series of simulations by comparing the results of the proposed model with other models suggested by previous researchers. Ultimately, the cash flow forecasting model was demonstrated to be a simple, accurate, and reliable forecasting tool for general contractors at the construction stage in comparison with FWM.

During the case studies, two issues were recognized as requiring more research. The first is that the model is dependent on the planning of cost and earned value. If planning of cost and earned value are not accurate, the forecasted cash flow would not be accurate. The second issue is, similar to the first, how to obtain reliable variables at the jobsite level such as the release of retention money—because it can be applied depending on the duration of a subcontract.

Despite several limitations, the proposed model presents a practical and easy approach for jobsite engineers and project managers who are not familiar with extensive financial knowledge, just using regular reports without separate information at the jobsite. In addition, this model can be applied as part of a project evaluation process considering internal interest (capital cost) at the corporate level. The model can be continuously updated to show deviations between planned and actual data through information changes from the jobsite. Encouraged by the results of current research, future procedural research will concentrate on: (1) analyzing the impact on difference between planned data and actual data; (2) developing cash flow forecasts at the planning stage using the relationship between cumulative earned value and cost categories; and finally (3) implementing a system at the corporate level to monitor cash flow in a proactive and timely manner.

References

Ahuja, H. N., and Walsh, M. A.. (1983). *Successful methods in cost engineering*, Wiley, New York.

Ashley, D. B., and Teicholz, P. M. (1977). "Pre-estimate cash flow analysis." *J. Constr. Div., Am. Soc. Civ. Eng.*, 103(3), 369–379.

Bennett, J., and Ormerod, R. N. (1984). "Simulation applied to construction projects." *Constr. Manage. Econom.*, 2, 225–263.

Fondahl, J. W., and Bacarreza, R. R. (1972). "Construction contract markup related to forecasted cash flow." *Technical Rep. Prepared for Construction Industry Institute*, Stanford Univ., Stanford, Calif.

Gates, M., and Scarpa, A. (1979). "Preliminary cumulative cash flow analysis." *Cost Eng.*, 21(6), 243–249.

Hendrickson, C., and Au, T. (1989). *Project management for construction: Fundamental concepts for owner, engineer, architects, and builders*, Prentice Hall, Englewood Cliffs, N.J.

Jepson, W. B. (1969). "Financial control of construction and reducing the element of risk." *Contact. J.*, April, 862–864.

Kaka, A. P. (1996). "Towards more flexible and accurate cash flow." *Constr. Manage. Econom.*, 14, 35–44.

Kaka, A. P., and Price, A. D. F. (1991). "Net cash flow models: Are they reliable?" *Constr. Manage. Econom.*, 9, 291–308.

Kenley, R., and Wilson, O. D. (1986). "A construction project cash flow model—An idiographic approach." *Constr. Manage. Econom.*, 4, 213–232.

Kenley, R., and Wilson, O. D. (1989). "A construction project net cash flow model." *Constr. Manage. Econom.*, 7, 3–18.

McCaffer, R. (1979). "Cash flow forecasting." *Quantity Surveying*, August, 22–26.

Meredith, J. R., and Mantel, S. J., Jr. (1995). *Project management—A management approach*, 3rd Ed., J Wiley, New York.

Navon, R. (1994). "Company-level cash-flow management." *J. Constr. Eng. Manage.*, 122(1), 22–29.

Navon, R. (1995). "Resource-based model for automatic cash-flow forecasting." *Constr. Manage. Econom.*, 13, 501–510.

Navon, R. (1997). "Cash-flow forecasting and management." *Proc., Construction Congress*, ASCE, New York, 1056–1063.

Oberlender, G. D. (2000). *Project management for engineering and construction*, 2nd Ed., McGraw–Hill, New York.

Park, H. K. (2001). "Cash flow forecasting model using moving weights of cost categories for general contractors on jobsite." PhD dissertation, Univ. of Wisconsin, Madison, Wis.

Peer, S. (1982). "Application of cost-flow forecasting models." *J. Constr. Div., Am. Soc. Civ. Eng.*, 108(2), 226–232.

Peterman, G. G. (1973). "A way to forecast cash flow." *World Constr.*, October, 17–22.

Reinschmidt, K. F., and Frank, W. E. (1976). "Construction cash flow management system." *J. Constr. Div., Am. Soc. Civ. Eng.*, 102(4), 615–627.

Russell, J. S. (1991). "Contractor failure: Analysis." *J. Perform. Constr. Facil.*, 5(2), 163–180.

Sears, G. A. (1981). "CPM/COST: An integrated approach." *J. Constr. Div., Am. Soc. Civ. Eng.*, 107(2), 227–238.

Singh, S., and Lakanathan, G. (1992). "Computer-based cash flow model." *Proc., 36th Annual Trans., AM. Assoc. of Cost Engineers*, AACE, R.5.1–R.5.14.

Trimble, E. G. (1982). "Micro computers in construction management." *Building Technology Management*, 2(2), 11–13.