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# A financial decision making framework for construction projects based on 5D Building Information Modeling (BIM)

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**Abstract**

Analyzing cash flows and undertaking project financing are important for contractors in managing construction projects. Traditional methods for cash flow analysis are based on the manual integration of time and cost information. However, the manual integration process can be automated by using five-dimensional building information modeling (5D BIM). Previous studies on 5D BIM have focused on estimating cash outflow rather than cash inflow analysis and project financing. This paper proposes a BIM-based methodology framework for cash flow analysis and project financing. The framework considers contract types and retainage to estimate cash inflow, and cash outflow patterns for equipment, manpower, and materials in order to more accurately measure cash outflow. Project financing scenarios can also be evaluated using the framework. Illustrative examples are demonstrated to validate the proposed framework by considering two what-if scenarios. Results show that the framework can help contractors analyze the cash flow and make appropriate decisions for different design and payment scheme alternatives in construction projects.


*Keywords:* 5D BIM; Cash flow analysis; Financial decision making; Project financing

## 1. Introduction

Managing and forecasting the cash inflows and outflows of a project is crucial to ensure the success of the project and the contractor (Park et al., 2005). More than 60% of construction contractor failures are mainly due to economic factors (Russell and Jaselskis, 1992). More construction companies fail due to a lack of liquidity in supporting their daily activities rather than inadequate management of other resources (Kaka and Price, 1991; Kangari, 1988; Navon, 1996; Park et al., 2005; Pate-Cornell et al., 1990; Singh and Lokanathan, 1992). Poor cash flow management may result in inadequate cash flows and thus undermine the sustainability of a project (Cui et al., 2010). Mismanagement of cash flow can result in times when cash availability is critically low, which could disrupt the project or even result in bankruptcy for the contractor.

Therefore, there have been many studies to analyze the cash flows of projects. Cash flows consist of cash inflow and outflow. Cash inflow is the result of progress payments received from the owners. Cash outflow results from the contractor's expenses such as materials, labor, equipment, subcontractor payments, and overheads. The resulting project net cash flows often involve gaps between expenses and owner payments (Kishore et al., 2011). Most previous studies were based on historical cost and schedule data. When sufficient historical cost data are available, the concepts of probability theory and statistical theory can be used for cash-flow prediction (Park et al., 2005). Integrating the scheduling and financing functions of construction project management is required to analyze cash flows (Elazouni, 2009). Construction firms use spreadsheets or other software packages to estimate project cash flows. The computerized estimation is developed with the integrated costs/schedule method, which involves a detailed project schedule with full costing based on the bill of quantities (BOQ) (Cui et al., 2010). However, scheduling and financing are not effectively integrated (Lee et al., 2011). The traditional process of

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forecasting cost flow curves entails the calculation of production quantities for each time interval, according to the progress schedules, and then multiplying them by the estimated unit costs. This manual process has been found to be tedious and time consuming, leading to alternative automated methods being sought (Kaka, 1996; Kim and Grobler, 2013).

On the other hand, the manual process can be improved upon with technological advancements, especially building information modeling (BIM) (Kim and Grobler, 2013). A BIM model is a digital representation of physical and functional characteristics of a facility (NIST, 2012). BIM models contain a wealth of information such as material resources and can be integrated with the schedule and cost information to perform five-dimensional (5D) BIM. There are several software tools used to create 5D BIM models, such as Autodesk Navisworks, Vico Office, CostX, etc. Current 5D BIM models are mainly used for cost estimation of a project and enable various disciplines to visualize the progress of construction activities and related costs over time (Multiconsult AS, 2012; URS, 2012a, b; Vicosoftware, 2007). The current BIM-based cost estimating processes still have several limitations. For example, they cannot be used for cash flow analysis since they do not consider payment delays, retention, material orders, etc. Moreover, there have been few studies on the cash flow analysis in a project based on 5D BIM (Kim and Grobler, 2013). Kim and Grobler (2013) proposed methodologies to analyze cash flows of a project by integrating a BIM model with schedule, cost, and cash inflow payment patterns databases. However, they assumed that cash outflows are made continuously according to the completion status of individual tasks. In reality, based on the contract, some payments need to be settled at the time of ordering, while some payments are made a period after the associated tasks are completed. Therefore, they did not consider cash outflow patterns based on contracts that would provide decision making for project financing.

This paper proposes a methodology framework to accurately analyze cash flows (cash inflow and cash outflow) of construction projects and to support financial decision making for contractors based on 5D BIM. The framework considers quantities of equipment, quantities of manpower, and quantities of materials, project schedule, payment period, down payment, and lead time of material orders in order to calculate the actual cash outflow. The cash inflow of a project is analyzed in the proposed framework by considering cash inflow patterns as defined in contracts. Furthermore, contractors can compare various alternatives through considering the different designs, overdrafts, and interest rates and decide how to finance the overdraft costs for managing a project smoothly.

This paper is organized as follows. The next section reviews various previous studies on cash flow analyses in the architecture, engineering, and construction (AEC) industry. Section 3 introduces the proposed methodology to analyze cash flows and to support financial decision making at the project level. Examples to demonstrate the framework are illustrated in Section 4. Findings and contributions of this paper as well as future work are discussed in Section 5.

## 2. Literature review

Considerable research on analyzing the cash flows of a project has been conducted. In order to accurately forecast cash flow, detailed data are required. Detailed data include resources, cost estimation, bill of quantities, schedule, information about subcontractors, contract information between owners and subcontractors, and general data (Navon, 1996). Various studies developed methods to analyze the cash flow of a project with detailed data by integrating the schedule and cost. Reinschmidt and Frank (1976) proposed a model for cash flow forecasting in the early planning stage of a project by integrating the schedule and cost items manually. Sears (1981) also proposed a technique to manually integrate the schedule and cost items for cash flow analysis. However, the manual process was time-consuming. To avoid extensive manual work, each of these cost elements was assumed to be a fixed percentage of the total cost over the project's duration. For example, Ashley and Teicholz (1977) suggested a cash flow forecast based on detailed methods of cost flow and divided the direct cost into labor, materials, and equipment costs, which were specified as percentages of the total cost. However, since cost items were not calculated based on the accurate quantity of each resource, cash flows cannot be analyzed accurately. Moreover, many of the early cash flow models in the 1970s did not account for the time lag between cost payments (Navon, 1996).

Various approaches were proposed for more accurate cash flow forecasting (Boussabaine and Kaka, 1998; Kaka, 1996; Kenley and Wilson, 1986; Miskawi, 1989; Navon, 1996; Tucker, 1986). Barbosa and Pimentel (2001) developed a linear programming model by dealing with typical financial transactions, possible delays on payments, use of available credit lines, effect of changing interest rates, and budget constraints. Park et al. (2005) proposed a moving weights model considering the progress of construction work and incorporating the time lags in accordance with change orders or changes in the contractual payment conditions and credit times given by subcontractors.

However, if either the BOQ or the schedule is altered due to particular changes, the integration process is likely to be more complicated and time consuming. Therefore, researchers have proposed several systems that could support this process. Hwee and Tiong (2002) developed a computer model to forecast cash flows through analyzing risk factors. Hegazy and Ersahin (2001) proposed a cash-flow modeling and analysis system that considers cash inflows, cash outflows, and overdraft size. Lee et al. (2011) proposed a stochastic system that can handle the variability in cash-flow inputs and outputs by finding the best-fit probability distribution function and by integrating project financing and stochastic simulation-based scheduling into a single system. It appears that existing finance-based scheduling methods are valuable and effective project management tools.

The existing proposed models still require extensive manual processes by contractors. Although previous studies have proposed new algorithms for cash flow analysis, it is a daunting task for project planners to develop a time–cost integration for