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BIM-INTEGRATED SYSTEM: A SUCCESSFUL ALTERNATIVE FOR ESTIMATING CASH FLOW IN BUILDING PROJECTS

Hang Thu Thi Le*, Tinh Dinh Cong

196 Pasteur, District 3, Ho Chi Minh City, 700000, Vietnam

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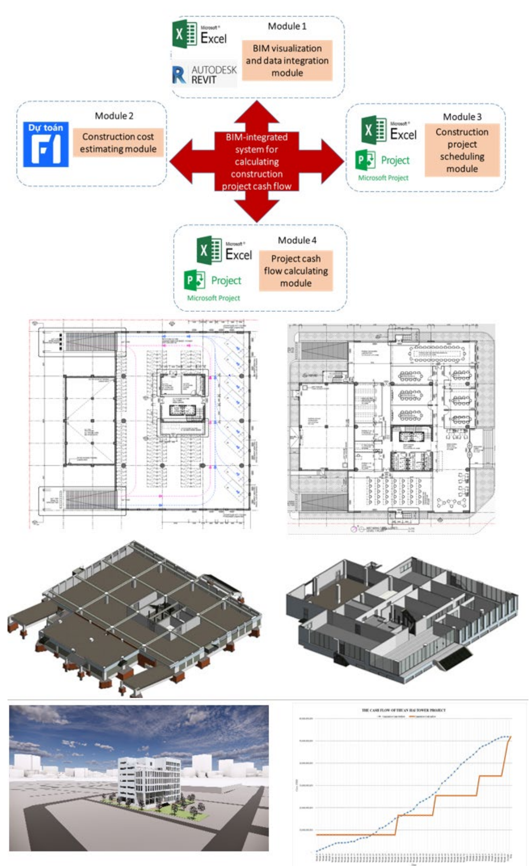
*Corresponding author
hang.lethithu@uah.edu.vn

Graphical abstract



Abstract

Cash flow calculation is an essential economic aspect of evaluating the success of a construction project. Strong cash flow positively impacts not only project effectiveness but also company profitability. Cash flow calculation is a good way for the contractors to avoid risks related to delay, cost overrun, or incompletion caused by financial deficits in the project's performance. Building Information Modeling (BIM) is a revolutionary technology 4.0 that has been mandated and adopted by many countries all over the world. In Vietnam, a roadmap for BIM application in the construction sector was issued in 2023, under which obligatory new investment projects in public investment state capital provide BIM files to serve the appraisal of feasibility study reports, construction designs carried out after fundamental designs, applications for construction permits, and acceptance testing tasks. However, BIM authoring programming is still limited to cost management, especially cash flow calculations, because Vietnamese contractors are still facing a lot of difficulties in applying BIM to their projects, especially cash flow calculations. Therefore, this paper proposes a BIM-integrated system for calculating construction cash flow at the early phase of the project life cycle. The proposed system includes four modules: BIM visualization and data integration, construction cost estimating, construction project scheduling, and project cash flow calculation. The main functionality of the BIM visualization and data integration module is to provide a 3D visualized model with enough geometric and non-geometric data for the project quantity take-off. The functionality of the construction cost estimating module is to provide the direct cost categories, such as labor, material, and machine, and the indirect cost categories to perform all work tasks in the construction project. The main functionality of the construction project scheduling module is to provide the required time to complete all work tasks in the project implementation process. The main functionality of the project cash flow calculating module is to present cash inflows such as advance payment, payments from the owner, and cash outflows such as construction costs, equipment costs, project management costs, and project consultant costs to carry out the projects. The BIM-integrated system will make the calculation process of construction project cash flow easier and more accurate.

Keywords: Building Information Modeling, cash flow calculation, construction projects visualization, data integration.

1.0 INTRODUCTION

Monetary risk is an initial concern for each construction project. Cash flow analysis has an enormous role in determining the failure or success of a construction project by evaluating whether or not there are enough funds to execute following the beginning project plan. The money is used to perform almost all work tasks during the construction stage such as buying raw construction material, equipment, hiring labor, paying overheads and taxes, paying for subcontractors, suppliers, and vendors. The consequences of poor cash flow control can be project delays or incomplete work due to the contractor's inability to pay suppliers, subcontractors, and laborers, which can lead to the contractor's bankruptcy. Although cash flow analysis is the most important factor in each construction project, the number of papers presented about this problem is limited because of the unavailability of required data and the time-consuming for a huge of single and repetitive calculating process. Kim and Grobler (2013) argued that it is time-consuming and human error prone to perform the construction cash flow calculation relying on the conventional bill of quantities (BOQ) and project scheduling [1]. Therefore, the contractors only consider their project cash flow at the tender stage in this simple situation. It is not frequently updated in practice, which may lead to an unclear understanding of project finance. The contractor's cash flow is often in negative status for most projects until the final payment is received from the owner. The contractors usually submit the volume of finished work to the owner for payment at the end of each month. After receiving the contractor's document, the owner will review documents then make a payment to the contractor in seven to fourteen days following the project agreement terms. The payment amount will be reduced by a retainage percentage.

There are some papers present about failed projects and companies due to poor cash flow management in the construction industry. Arditi *et al.* (2000) concluded that cash flow problems are the cause of more than 80 percent of company and project failures within the construction industry [2]. Navon (1996) explained that construction companies cannot survive due to cash flow constraints despite showing profits on their financial statements [3]. Wong and Thomas (2010) argued that the poor financial management causes construction failures [4]. Park *et al.,* (2005) showed that 60 percent of contractor failures in finishing projects are caused by financial issues [5].

Building Information Modeling (BIM) has now become mainstream in the construction industry. It is acknowledged as a supporting technology to increase productivity, reduce waste, improve environmental impacts, and decrease the total cost of occupancy of construction projects. BIM technology is mandated by many governments all over the world, such as the Netherlands, Denmark, Finland, and Norway. BIM was also mandated on government projects with a primary capital value of over 5 million GBP by 2016 in the United Kingdom [6]. BIM strongly encouraged the adoption of BIM technologies in the architecture, engineering, and construction (AEC) industry in the Chinese government [7]. A number of projects adopting BIM was only 28 percent in 2007, but reached 71 percent in 2012 and continued growing in the United States [8]. In Vietnam, a roadmap for BIM application in the construction sector is issued in 2023 and mentions that from 2023, the application of BIM is compulsory for works in class I and higher in public investment projects; from 2025, the application of BIM is compulsory for works in class II and higher in public investment projects, projects funded by non-public investment state capital, and PPP projects. In addition, for new investment projects funded by other capital sources, main investors are required to provide BIM files to serve the appraisal of feasibility study reports, construction designs carried out after fundamental designs, applications for construction permits, and acceptance testing tasks according to the following roadmap: class I and special class works from 2024; all class I, class II, and special class works from 2026. However, the Vietnamese contractors still face a lot of difficulties in applying BIM to their projects.

Although BIM provides many advantages to the construction industry, BIM technology has limited applications for cost management, especially for construction project cash flow. Goucher and Thurairajah established that the cost database and the measurement unit are based on traditional standards, which are not applicable to BIM models [9]. Therefore, the current cash flow estimation cannot be performed without a critical change from the cost per standard method to the cost per BIM object. There are two barriers to implementing BIM for project cash flow estimation. First, the BIM authoring program does not conform with the cash flow calculation method. It is difficult to create a formal plan with the BIM design tool per the standard methodology of measurement. Second, 5D quantity surveying cannot find the BIM technology that is sufficient for cost plan modeling since the data structure of the BIM model is not suitable for the elemental or trade code organization required by classification structures. Sabol (2017), Shen and Issa (2010) pointed out that the current BIM tools are not rich enough to cover all data structural processes and job conditions [10, 11]. Although BIM research has been increasing in both academia and industry, there have been limited studies on BIM implementation for cash flow control. Fu *et al.,* (2007) pointed out that without standards guidelines, BIM models cannot directly organize the elemental building classification in the cost database [12]. So, it is necessary to integrate BIM platforms to account for the project cash flow for the contractors at the construction stage. Goucher and Thurairajah (2012) also pointed out that the existing BIM tools did not have enough capability to accommodate the required data for calculating the project cash flow [9]. Hjelseth (2017) identified that the lack of integration of the calculation methods, the collaborative people, and the interoperable technology were critical factors that limited the use of BIM for the project cash flow calculation [13]. Therefore, the objective of the current study is to develop a BIM-integrated system to achieve the difficult conventional cash flow calculation for the contractor in building projects.

2.0 RELATED RESEARCH

Cash flow is the most important role of a construction project because money determines the failure or success of a construction project. A positive cash flow indicates that the project is able to finance itself. Poor cash flow control was one of the primary causes of construction company failure [14]. However, cash flow calculation was a difficult issue in Saudi Arabia that contributed to the failure of construction contractors [15]. Nguyen and Ogunlana (2004) found that Vietnam's construction contractors lost around 30 percent of total construction capital due to inefficient capital management [16]. Park *et al.*, (2005) stated that 60 percent of contractors fail to finish projects because of financial issues [5]. Adjei *et al.,* (2018) stated that money is one of the most significant resources of each construction company. Money requirements and profitability are two different problems, but they have a connection. Most construction companies all over the world failed due to a lack of capital requirements, even though they had profits [17]. Therefore, it is very important to frequently investigate the cash flow from the early project tendering phase until the end of the project execution.

Cash flow calculations are very important from the contractor's perspective. The cash flow calculation process is concerned with estimating cash outflow, cash inflow, and the variance between inflow and outflow. It is an absolutely necessary technology for the contractor to manage cash inflows and cash outflows during the implementation process of construction projects. However, cash flow calculation requires large amounts of information that is difficult to collect and immediately compute by the contractor. Mohsin (2014) pointed out that a good cash flow tool can help the contractor avoid risk related to a lack of liquidity that leads to the incompletion of construction projects [18]. Navon (1996) also stated that a sufficient cash flow system is necessary for the contractor to convince money [3]. However, Nesan (2006) presented that construction companies are facing with the weak measurement tools for their financial [19]. Castaneda (2021) pointed out that most of the literature mentions mathematical models of cash flow management systems that are inaccurate because of the unavailability of data requirements, the time-consuming nature of many computations, and the unavoidable errors in manual calculation [20]. Boomen *et al.,* (2021) presented that accurate cash flow estimation plays a vital role in driving sustainable economics and socialization in the construction industry. Therefore, the QS must accurately predict the cost flows of the proposed works before creating a very accurate cash flow profile [21].

In recent years, BIM has become a digital technology in many larger construction projects all over the world. BIM technology supported faster decision-making throughout new visualized approach, the consistency of design information, the better management of documents in the construction industry [22]. According to Le *at el.,* (2021) BIM was described as the tool to improve design decision-making, increase coordination, increase the consistency of data, improve the productivity of works, simulate building performance, estimate construction costs, and improve construction planning [23]. The 3D visualized model is created by the BIM authoring program at the early design phase. When the change occurs during project implementation process, the BIM technology helps to guarantee the consistency of the drawings that are created by the design modification [24]. Thus, BIM helps to save time in the design process. Likhitruangsilp (2019) proposed a new methodology to evaluate the impact of changes in construction [25]. Muzvimwe (2011) stated that the value of the cost management service will increase when the cost manager use BIM to analyze the information generated by the model and manage various design [26]. However, the number of the integration research between BIM and the cash flow calculation is limited. For example, Kim and Grobler (2013) proposed an approach to use output from BIM models for financial reports by integrating project schedule with BIM [1]. However, they only presented a framework. Khalaf and Akbas (2019) investigated the integration BIM models with cash flow models that consist of cash inflow parameters and cash outflow parameters for the calculation process [17]. Lu *et al.,* (2016) proposed a framework to extract data from BIM model including quantity take-off, equipment, manpower, and material usage to a financial model [28]. Khalaf (2019) presented a tool to predict project cash flow with the project entities based on Critical Path Method (CPM) schedule; however, this research did not applied BIM to analyze project cash flow [29]. Khosrowshahi and Kara (2007) proposed a 3D visual model for estimating project cash flow through analyzing the data from the application of the tacit knowledge of the users. However, this model required a series of mathematical input variables that did not reach down to the individual cost element levels [30]. Unlike with the previous research, Elghaish et al. developed a novel framework for estimating project cash flow through integrating the 5D BIM cost dimension and 4D BIM schedule simulation into the Integrated Project Delivery (IPD) approach. This novel framework showed in the maximum and minimum cash flow estimation to the Contractor for relocating their resources to avoid the negative cash flow [31].

3.0 METHODOLOGY

In this paper, the authors propose a method to calculate construction project cash flow by integrating BIM authoring programming, a project cost estimating system, a project scheduling system, and a spreadsheet system. Figure 1 illustrates six steps for developing the BIM-integrated system for calculating contractor cash flow in the project implementation stage. The first step is the review of relevant literature, including academic papers, legislative documents, books, standards, and regulations, to define problem statements, related research gaps, and information requirements to identify system requirements, modules, system architecture, and required data. The second step is the identification of potential platforms to develop the system, and the most suitable ones were chosen to construct the proposed system. These platforms were selected based on system requirements and the outstanding attributes of potential platforms. Autodesk Revit is represented for BIM authoring programming. F1 is a cost estimation software that was developed by F1 Tech Joint Stock Company. This is an enterprise that specializes in producing software for the construction industry in Vietnam. The F1 system applied Vietnamese new legal documents such as Circular No. 12/2021/TT-BXD on construction norms, Circular No. 09/2019/TT-BXD on guilding the determination and management of construction investment costs, ect. Based on the opinions of lecturers and students, F1 was convenient software that was easy to use in establishing unit prices and cost estimates. It is also confirmed to be an effective solution to improve training quality and scientific research. Furthermore, F1 is selected as a popular cost estimating software for 4th-year and 5th-year students to carrry out the problem related to estimating costs for projects in the construction industry, in particular in Vietnam. In this research, the F1 system is selected as a representative for the project cost estimation system. Microsoft Project is represented for the project scheduling system. Microsoft Excel is represented for the spreadsheet system. The third step is the development of the system architecture and system modules. The output of this step is a BIM-integrated system for calculating construction project cash flow consisting of four element modules. All modules were then integrated into the unified system. The fourth step is to collect the necessary data and information for each module of the proposed system. The fifth step is the validation of the proposed system. An actual building project was applied to examine the efficiency and practicality of the proposed system. The sixth step is the conclusion of this research, including summaries, conclusions, limitations of this research, and suggestions for future research.

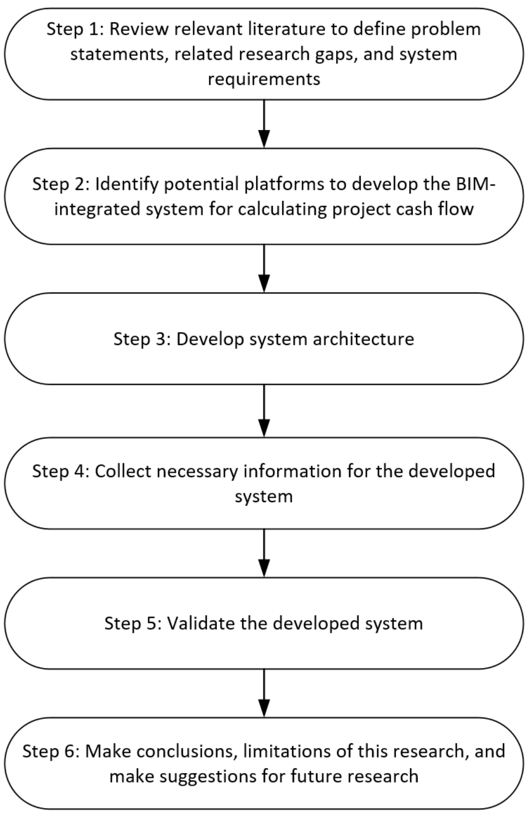


Figure 1 The steps of research methodology

In this paper, construction project cash flow refers to the total spending cash that the contractors use to build their project and the total payment cash that the contractors receive from the owner for their construction works. This paper proposed two types of cash flows for the construction project in the implementation stage: cash inflow and cash outflow. Cash inflow consists of advanced payment, payments, and retainage. Cash outflow consists of direct costs, indirect costs, pre-tax income, and value-added tax (VAT) [32].

Cash inflow is the actual income of revenue. Advanced payment is amount money that the Contractor is paid to deliver material, equipment, or plant to the site. In this paper, the first cash inflow category is the advance payment. The value of advanced payment is 15 percent of the total construction contract price. Payment period is stages where the Owner pay money to the Contractor for their completed work package in each month following the construction contract terms. In this paper, the progress payment is divided into 6 stages. This first stage is after the completion of underground. The value payment of this stage is equal to 20 percent of the total construction contract price. The second stage is conducted after completing the structure of the fourth floor. The value payment of this stage is equal to 20 percent of the total construction contract price. The third stage is performed after the completion of the frame part of the project. The value payment of this stage is equal to 20 percent of the total construction contract price. The fourth stage is conducted after the completion of the finishing part of the project. The value payment of this stage is equal to 20 percent of the total construction contract price. The fifth stage is conducted when the Owner takes over and makes formal written acceptance for all project works that are completed in accordance with the construction contract terms. The value payment of this stage is equal to 15 percent of the total construction contract price. The sixth stage is a final payment which is conducted at the end of the warranty period in accordance with the construction contract terms. The value payment of this stage is equal to 5 percent of the total construction contract price. Retainage is an amount money of each payment stage that the Owner often retain until the completed work had accepted by the Architecture, Engineering, and Construction (AEC) and Owner. In this paper, the prescribed percentage of retained value is equal to 15 percent of each payment stage in accordance with the construction contract terms.

Cash outflow is the necessary expense to carry out the project. The first cost category of cash outflow is the direct cost. It is the expense associated with materials, equipment, and labors to perform the project. Direct cost is defined based on the detailed quantity take-off and the unit price. The second cost category of cash outflow is the indirect cost. It is the expense associated with general expense, temporary office expense, the expense of undefined works from the design. General expense is overhead and administrative cost of office, operation and management cost for producing at the site, and insurance cost for employees. General expense is accounted based on a certain percentage of direct cost. In this paper, it is equal to 7.1 percent of direct cost [33]. Temporary office expense is accounted based on a prescribed percentage of direct cost. In this paper, it is equal to 1 percent of direct cost [33]. The expense of undefined works from the design is accounted based on a prescribed percentage of direct cost. In this paper, it is equal to 2.5 percent of direct cost [33]. Pre-tax income is an amount money earning of the project before taxes, It can be accounted based on a certain percentage of total direct and indirect costs, In this paper, it is equal to 5.5 percent of total direct and indirect costs [33]. VAT is an indirect tax assessed on construction goods or services for value added at the production stage. In this paper, the value of VAT is equal to 8 percent of the direct cost, indirect cost, and pre-tax income [34].

The BIM model cannot accommodate all required data for the calculation of construction project cash flow. Therefore, we integrated the BIM model with the construction cost estimating tool and the construction project scheduling tool for analyzing construction project cash flow. The BIM visualization and data integration module contains geometry and non-geometry information of all element models of the case study project. The construction cost estimating module contains the unit cost, the expense of material, equipment and labor of all building elements. The project scheduling module contains the lead time for materials, equipment, manpower, and payment information to perform all building works. The project cash flow calculating module is created from all three previous modules. The proposed system was applied to an actual project in order to examine the efficiency and practicality of this system.

4.0 SYSTEM ARCHITECTURE

The development of architecture becomes mandatory for constructing the general system. According to Jaakkola and Thalheim (2011), an essential role of system architecture is to communicate among software, establish the requirements of system components and interfaces, and take advantage of software development [35]. The role of system architecture in this paper is elaborated in the structure of the paper. The architecture of the BIM-integrated system for calculating contractor cash flow in construction projects consisted of four modules: (1) the BIM visualization and data integration module; (2) the construction cost estimating module; (3) the construction project scheduling module; (4) the project cash flow calculating module; and the relationships among the four element modules that together create a defined output detailed in Section 4.0. Figure 2 illustrates the detailed architecture of the BIM-integrated system for calculating construction project cash flow in the form of a matrix that describes the various platforms and modules as well as summarizes the detailed steps entailed in each module. In this research, Autodesk Revit is selected as one of the most popular representatives for the BIM authoring programming to create the structure BIM model and the architecture BIM model.

The development of the BIM visualization and data integration module is to provide dimensions for each element model for automatically taking off quantities. The developed process entails three steps. In the first step, the required information and data are collected from relevant sources such as legislative documents, books, standards, construction contracts, material specifications, and preliminary drawings. The second step is to create the structure BIM model and the architecture BIM model. The 3D BIM model is created by the BIM authoring program. This research proposed the LOD 400 of the BIM model to fit with the requirements for construction cost estimation. The designers need to identify the geometry information of each element, such as length, width, height, and thinness, before creating the 3D element of the BIM model. The third step is to manually export the necessary quantity of BIM models to the construction cost estimation module.

The construction cost estimating module is developed based on information collection and data exporting from the BIM visualization and data integration modules. The main function of this module is to provide material unit costs for each element model. This module also provides non-geometrical data, which is the unit cost of all work items for the estimating process. In this research, F1 software is selected as a representative for the cost estimation system to construct the total construction cost estimation table.

The construction project scheduling module is developed to represent the working time, labor cost, and general cost to perform all work items. The development of this module entails six steps. In the first step, the work breakdown structure of the project (WBS) is established. In the second step, the organization breakdown structure (OBS) of the project is established. In the third step, we develop the responsibility matrix (RACI) to clarify the roles of participants within a project. It is to make sure that everything about the project is taken care of. In the fourth step, general expenses for all work items are calculated to complete the project based on the outputs from the construction cost estimating module and the RACI matrix. In the fifth step, the working time for all project activities is calculated. In the sixth step, the project schedule model is developed based on data collection and outputs from the working time table using a popular project scheduling system. In this research, Microsoft Project is selected as a representative for the project scheduling system in constructing the project planning chart.

The project cash flow calculation module is developed to represent the cash outflow and cash inflow of the project. The development of this module entails four steps. In the first step, the project cash outflow from the project scheduling model is developed. The second step is to receive the cash inflow from the construction contract terms. In the third step, the project cash flow model is developed based on the difference between cumulative cash outflow and cumulative cash inflow. And the final step is to report the results and make conclusions.

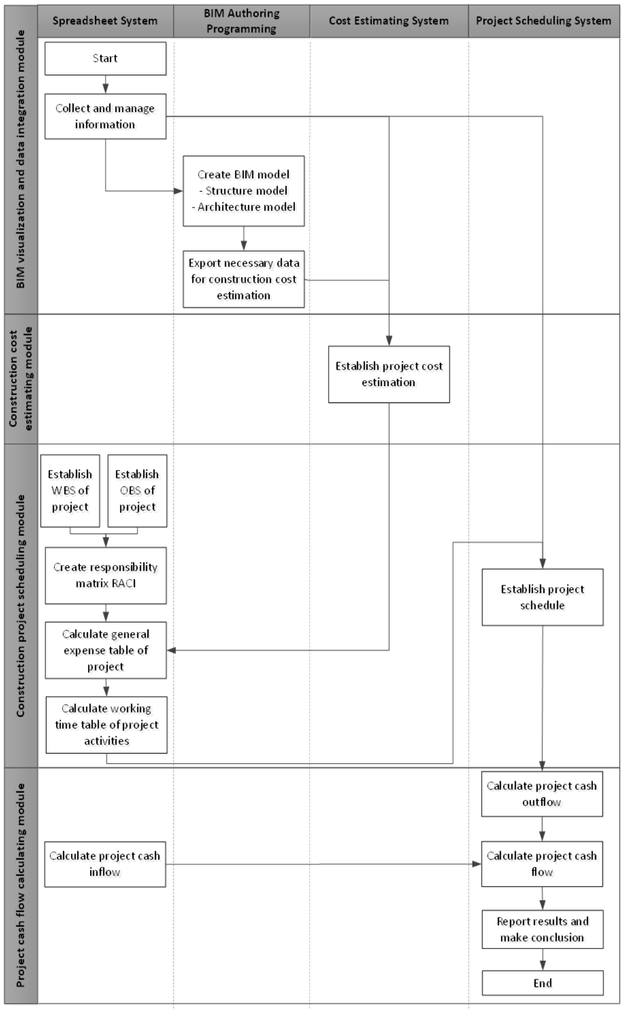


Figure 2 System architecture of the BIM-integrated system for calculating contractor cash flow in construction projects

5.0 RESULTS

In order to evaluate the efficacy and practicality of the BIM-integrated system for calculating contractor cash flows in construction projects, the details of the proposed system were applied to an actual building project. This is a construction bidding package for the Thuan Hai Tower project that is built on the 6,415 sq m land with 7 floors, located in Lot Vb 20a.2, Road 24, Tan Thuan export processing zone, Tan Thuan Dong Ward, District 7, Ho Chi Minh City. The type of contract in construction is a lump-sum contract. The total contract value is 51,837,348,000 VND. Figure 3 illustrates the structure of the BIM model of the case study building. Figure 4 illustrates the architectural BIM model of the case study building.

An example for exporting the necessary quantity of BIM models is shown in Figure 5.

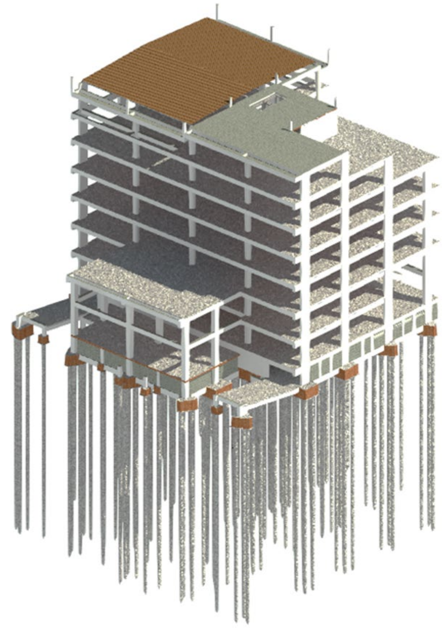


Figure 3 The structure BIM model of the case study building- Thuan Hai Tower project

Figure 4 The architecture BIM model of the case study building – Thuan Hai Tower project

The outcome of the construction cost estimating module is the cash outflow of the contractor during construction period, which consists of four cost categories in the total cost estimation table as shown in Table 1. There are eight steps to developing this table into the cost estimating system, namely F1. The first step is to calculate the volume for each work item. The second step is to look up of the basic construction unit costs of the local area to identify labor unit costs and machine unit costs. The third step is to look up the norm to identify the material analysis table. The fourth step is to establish the summary table of material value. The fifth step is to establish a summary table of construction costs. The sixth step is to establish the table of general item costs. The seventh step is to establish the equipment cost table for the construction project.

The eighth step is to establish the total cost estimation of the construction project. The definition of cost categories is necessary for the total cost estimation table. In this research, the project costs should be classified into four categories: direct costs, indirect costs, pre-tax income, and value added taxes.

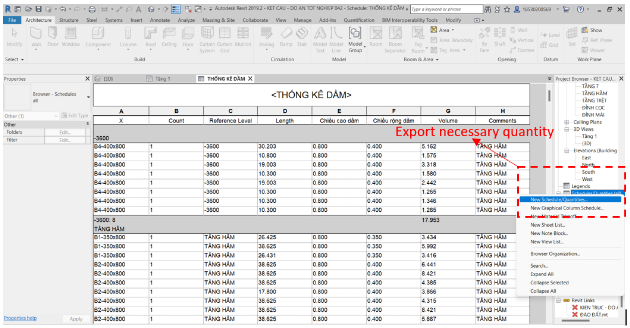


Figure 5 An example for creating the necessary quantity table

Direct cost refers to the cost spent on performing the main work items of the project, including the structure and architecture parts. Direct costs included the cost of materials that were supplied by project suppliers or owners, the cost of labor, and the cost of machinery and equipment.

Indirect cost refers to the cost of overall costs, temporary accommodation costs, and related works that cannot be identified in design. Overall costs included general administrative expenses, overhead and operating costs incurred at project sites, and insurance costs paid by the project owners for their employees' benefits. The value of money is determined by 7.1 percentage points of its direct cost value [33]. Temporary accommodation costs are the costs of building the temporary office. The value of money is determined by 1.0 percentage points of its direct cost value [33]. The costs of related non-identified works include the costs of occupational safety, the health of workers at the construction sites, the costs of environmental health, the costs of material testing by the contractor, the costs of moving the construction workforce at the site, the costs of pumping irregular water, and the costs of removing and dredging mud. The value of money is determined by adding 2.5 percentage points to its direct cost [33].

Pre-tax income refers to the profits of enterprises that were calculated in advance in construction cost estimation. The value of money is determined by 5.5 percentage of the total direct and indirect costs [33]. Pre-tax construction costs included direct costs, indirect costs, and pre-tax income.

Value-added taxes are regulated by the State. The value of money is determined by 8.0 percentage of the pre-tax construction cost value [34]. After-tax construction costs included pre-tax construction costs and value-added taxes.

The outcome of the construction cost estimating module is exported to the construcstion project scheduling module to add more non-geometry data, such as manpower to perform all work items.

Cash outflow is exported from the construction project scheduling module through six steps. The first step is to click on Report button. The second step is to choose visual reports to export. The third step is to choose Microsoft Excel in the select template box to show report templates created. The fourth step is to click cash flow report. The fifth step is to choose weeks into select level of usage data to include in the report box. The sixth step is a click view, as shown in Figure 6.

Table 1 The construction cost estimation table for the Thuan Hai Tower project

NO.	COST CONTENT	CALCULATED METHOD	AFTER-TAX VALUE	SYMBOL
1	**DIRECT COSTS**	**VL + NC + M**	**41.134.993.802**	**T**
1.1	Material costs	VLHT	29.983.713.979	VL
1.2	Labor costs	NCHT	8.802.132.698	NC
1.3	Machinery and equipment costs	MHT	2.349.147.125	M
2	**INDIRECT COSTS**	**C + LT + TT**	**4.360.309.343**	**GT**
2.1	Overall costs	T x 7,1%	2.920.584.560	C
2.2	Office and temporary accommodation costs	T x 1%	411.349.938	LT
2.3	Costs of related works that cannot be identified in design	T x 2,5%	1.028.374.845	TT
3	**PRE-TAX INCOME**	**(T + GT) x 5,5%**	**2.502.241.673**	**TL**
	PRE-TAX CONSTRUCTION COST	T + GT + TL	47.997.544.818	G
4	**VALUE ADDED TAXES**	**G x 8%**	**3.839.803.585**	**GTGT**
	AFTER-TAX CONSTRUCTION COST	G + GTGT	51.837.348.403	Gxd
	TOTAL	**Gxd**	**51.837.348.403**	
	Rounding		**51.837.348.000**	

Text: Fifty-one billion, eight hundred thirty-seven million, three hundred forty-eight thousand dong./.

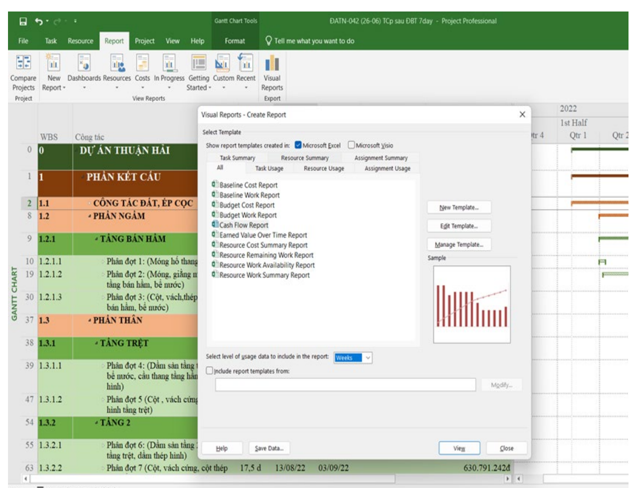


Figure 6 Creating a cash outflow report for the Thuan Hai Tower project

Cash inflow during the construction period is the actual advanced payment and the payment value for six payment stages, as shown in Table 2. In this study, the authors did not give a fixed profit percentage because it depended on the situation of the construction market. The authors assumed the value of the construction contract (cash inflow) was equal to the value of expenses (cash outflow). The contractor shall receive an advance payment equal to 15 percent of the contract value within three days from the date of the construction contract is approved and signed. This amount of money shall be retained as retention money that shall be made through a percentage deduction at each payment time until the advance payment has been repaid. The first payment shall be made after the contractor's documents for the completed underground work part of the project have been received and approved by the employer. The payment value is equal to 20 percent of the contract value. The second payment shall be made after the contractor's documents for the completed fourth-floor work part of the project have been received and approved by the employer. The payment value is equal to 20 percent of the contract value. The third payment shall be made after the contractor's documents for the completed structure work part of the project have been received and approved by the employer. The payment value is equal to 20 percent of the contract value. The fourth payment shall be made after the contractor's documents for the completed finishing work part of the project have been received and approved by the employer. The payment value is equal to 20 percent of the contract value. The fifth payment shall be made after the employer issues the taking-over certificate for the contractor's completed work. The payment value is equal to 15 percent of the contract value. The final payment shall be made at the end of the project warranty period. The payment value is equal to 5 percent of the contract value. All payments shall be made in Vietnamese Dong (VND) and subject to the Value Added Tax (VAT). The value of VAT applied for this project equals 8 percentage.

In this paper, the time to borrow money is identified when the cash outflow is higher than the cash inflow in project. The amount of money is accounted by the biggest difference between the cumulative cash outflow and the cumulative cash inflow. The interest rate is calculated each month. The value of the interest rate is equal to 10 percent per year, following the Asia Commercial Joint Stock Bank (ACB) in Vietnam. According to Figure 7, the value of cash inflow is lower than the value of cash outflow for the 22nd week of the 2022 year.

Table 2 The cash inflow of the Thuan Hai Tower project

No.	Payment progress	Description	Payment value (VAT 8%)	Unit	Percentage
1	Advance payment	Completed the contract signed	7,775,602,200	VND	15%
2	The first payment	Completed the underground part	8,812,349,160	VND	20%
3	The second payment	Completed the fourth floor	8,812,349,160	VND	20%
4	The third payment	Completed the structure part	8,812,349,160	VND	20%
5	The fourth payment	Completed the finishing part	7,257,228,720	VND	20%
6	The fifth payment	Completed project handover	7,775,602,200	VND	15%
7	The sixth payment	Completed project warranty	2,591,867,400	VND	5%
	The total contract price include VAT		51,837,348,000	VND	

6.0 DISCUSSION

The BIM-integrated system can save time in calculating construction project cash flow, which consists of many cost categories divided into cash outflow and cash inflow. The proposed system provides an automated approach for the quantity take-off of the project BIM model to conduct the cost estimation module. It also provides a method to save time by implementing many repetitive calculations when the design changes.

The BIM-integrated system provides a systematic observational approach to defining the building elements for estimating project cash flow, compared with the conventional method that identified the building elements based on lines and text drawings. Furthermore, the BIM-integrated system can help the contractor save money on investing in and maintaining commercial software.

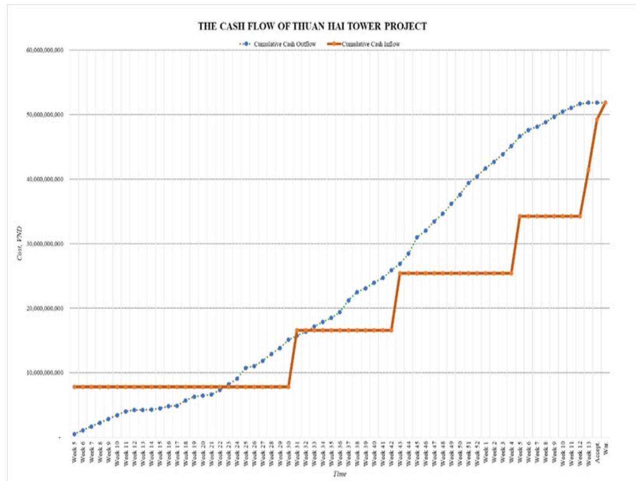


Figure 7 The difference between cash inflow and cash outflow for the Thuan Hai Tower project

In conventional project cash flow estimation, the measuring, counting, and checking methods of each building element is implemented in 2D design drawings by manual labour. It is very difficult to compute the size of building components at the intersection areas, especially the special-shape components. The errors are inevitable and will impact the accuracy of the results. The BIM-integrated system can help the quantity surveyor (QS) increase the accuracy of the project cash flow calculation by reducing mistakes in the estimation process. It also helps reduce the subjective error of the QS in a hugely repetitive calculation through automatic estimation. For example, the concrete volume of third beam and floor is 318.65 m^3 when using 3D BIM quantity take-off. However, the value changed to 327.35 m^3 when using the conventional 2D calculation method. The difference between the two methods is 8.695 m^3 equivalent, or 2.7 percent. Because it is difficult to calculate the exact volume at the intersection areas among columns and walls. Therefore, the 5D BIM takes advantage of the quantity take-off and construction cost estimation processes. It can improve the difficulties of conventional construction cost estimation.

In a construction project, changes often occur during the project's life_cycle. Conventional project cash flow usually takes a very long time to be adjusted. Therefore, the design option is limited by the findings to a sustainable design option. The BIM-integrated system is presented as an effective approach to updating the changes. When the government issues any legal documents, such as laws, circulars, decrees, or decisions related to construction costs, the QS can quickly adjust project cash flow calculation. It can help the project parties update information immediately for the future phase. It also helps the owner and contractor avoid legislative troubles in the project implementation process.

The BIM-integrated system is an innovative approach for data organization in the construction industry. The current construction companies are missing their data in the implemented projects that can help them save time and money for data collection in each new project. The developed system is a solution to increase the effective of data management throughout the data organizing and storing. It is also improve the consistency of data for calculating project cash flow, increase the work productivity.

The validation is a process to demonstrate the structure and functions of developed system are satisfied with the initial requirements. However, it does not mean that the BIM-integrated system for calculating project cash flow world be complete without errors when applied it in the practice building project. Therefore, the manual project cash flow calculation also conducted for the case study building. After conducting the comparison between the results from the manual calculation and the results from the BIM-integrated system, the authors found the near similar results from both approaches, it indicates that the reliability of the proposed system is acceptable.

7.0 CONCLUSIONS

Cash flow analysis is the most important tool to predict the profitability of construction projects. It reflects the success or failure of a construction project during execution process. The total project cost can be reduced if multiple situations can be compared in the cash flow analysis. This paper presented the BIM-integrated system for calculating the construction cash flow of building projects. This system consists of four main modules: the BIM visualization and data integration module, the construction cost estimating module, the construction project scheduling module, and the project cash flow calculating module. The BIM visualization and data integration module is created using two technologies, including the spreadsheet system and the BIM authoring programming, namely Microsoft Excel and Autodesk Revit. The construction cost estimating module is developed into the cost estimating system namely F1, and relies on data collection from the BIM visualization and data integration module. The construction project scheduling module is developed into the project scheduling system, namely Microsoft Project, by using data collection from the BIM visualization and data integration module and the construction cost estimating module. The project cash flow calculating module is developed into the spreadsheet system by using data from the BIM visualization and data integration module, the construction estimating module, and the construction project scheduling module.

The project cash flow is a criteria factor that helps the contractors determine their successful project. The time-spending for the estimating process is a main barrier to the contractor considering several situations with their cash flow during the project implementation. The current project cash flow calculation is a time-consuming process with a huge repetitive calculation, numerous data and regulatory requirements. In addition, human errors are unavoidable due to the complexity of manual data input, which usually affects the accuracy of results. The objective of this research is to help project participants understand cash flow basics and show a new approach to calculating the project cash flow using BIM technology.

The BIM-integrated system for calculating construction project cash flow is a visualized approach that clearly defines element models of the building. With the 3D BIM model of the project, BIM-users can better appreciate building details. This merit is not offered by the traditional approach, which is based on 2D CAD drawings. The BIM-integrated system also provides detailed characteristics of target objects, such as location, quantity, and material structures. This is also a vividly and efficiently visualized approach to communicating among project stakeholders.

The BIM-integrated system is a systematic method to organize data for calculating the project cash flow. The required data for the estimation process is usually store in different sources, such as paper documents, 2D drawings, and legislative documents. The estimated process required an enormous amount of data. Data collection is an extremely challenging aspect of QS that requires the collaboration of everyone involved. In addition, a standard or guideline for data organization does not exist. As a result, the construction project cash flow calculation is a costly and time-consuming process. The proposed system provides a solution for these problems through its organized data structure, which is compatible with the 3D BIM model. This is also a contribution to this research.

The BIM-integrated system provides an automated method to accommodate the required data for the project cash flow estimation. Only BIM cannot have the capacity to take care of construction project cash flow. In order to reduce the cost and time of the estimated process, the developed system is developed by integrating four platforms consist of the BIM authoring programming, the cost estimating system, the spreadsheet system, and the project scheduling system.

The BIM-integrated system is engineered to enhance the efficacy of the construction project cash flow calculation process. It is achieved through the efficient and effective interchange of both human abilities and computer capabilities. When a simple change occurs, the QS usually takes a very long time to re-calculate the project cash flow. To cope with this problem, the QS usually ignores the recalculation and makes their decision based on their subjective option. With the developed system, the contractor can now handle a design change more readily. It can not only offer a tool for facilitating collaboration among owners, contractors, and designers, but it can also guide a trend toward construction project cash flow analysis as a criterion for a sustainable procurement system.

Even though the BIM-integrated system for calculating the construction project cash flow has been successfully developed and achieved the proposed objectives, this research entails a number of limitations. This system is primarily designed for many building parts: structural, architectural, mechanical, electrical, and plumping systems. However, the case study in this paper focused only on the architectural system and structural system. This is one of the main limitations of this research. Therefore, the developed system should be extended to estimate the project cash flow for other project types. Another limitation concerns the selected platforms. The BIM-integrated system is developed on four main platforms:

Microsoft Excel, Autodesk Revit, F1, and Microsoft Project. It may limit the optons for selecting the platforms to develop the BIM-integrated system. The next limitation concerns the data input in F1, which is still conducted manually. Therefore, the data must be updated regularly to guarantee the reliability of the results. Although the BIM-integrated system might not be perfect and entail some limitations, it provides an innovative and valuable methodology to address several major challenges in the current calculation of construction project cash flow. It can therefore promote the implementation project cash flow analysis frequently at the early design phase to improve the efficiency of the construction project.

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