FINANCIAL LIQUIDITY AND FINANCIAL COST FACTORS ASSESSMENT IN CONSTRUCTION GOVERNMENT CONTRACTS

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ABSTRACT: The construction industry operates in a highly competitive environment that encourages contractors to use low markups on their bids for government construction contracts affecting companies' financial liquidity and financial costs. There is common agreement in the literature that cash flow, financial liquidity, and accurate estimation of financial costs are crucial elements for the construction contractors' survival and their projects' successful completion. Many factors affect the financial liquidity and the financial cost of the projects, such as the advance payment, collection and payment frequency, delay of payments, the project schedule, the credit agreed with the suppliers, credit institutions' interest rates, etc. The authors investigated some of these factors' contractual and actual values in Yucatan, Mexico. In addition, they assessed their impact on financial liquidity and the financial cost of construction projects derived from government contracts. The authors proposed a methodology based on a cost-time integration model; they show a step-by-step procedure using specific software and BIM technology to make information management more effortless. This procedure was tested on a complex building construction project. The results show that assessing the variation in liquidity and financial cost for different combinations of factors is feasible and practical and has the potential to improve decision-making in project management.

KEYWORDS: Construction Management, Cash Flow, Financial Liquidity, Financial Cost, Cost and Time Integration, Contractor.

INTRODUCTION

The construction industry operates in a highly competitive environment, and contractors cannot survive without effective project management (Liu et al., 2009). This environment leads contractors to use meager profit margins in public works tenders to compete, consequently affecting the companies' liquidity (Mahamid I, 2012).

There is, therefore, a common consensus that cash flow management and liquidity are crucial elements for the survival of contractors (Navon, 1996; Mohsin et al., 2014; Adjei et al., 2018); inadequate cash flow management is likely to be one of the main reasons why insolvency is more likely to occur in the construction industry than in any other (Jiang et al., 2011).

The construction project execution stage demands the highest amount of economic resources. During this stage, there is an intense financial movement of collections and payments between the owner and contractors, contractors and subcontractors, and contractors and suppliers. When the contractor requires financing to prevent the execution from stopping, they may resort to credit institutions. The interest payment for the money obtained is the traditional financial cost, which tends to be significantly higher in Mexico than international standards (Vargas, 2020). This situation has forced builders to negotiate debts with suppliers who, by force or negotiation, accept sharing or assuming part of the financing costs (García et al., 2004). Construction companies with low-profit margins to absorb financing costs risk running out of resources to complete a project and even going bankrupt (El-Kholy, A.M., 2014). The risk increases when the agreed payment terms delay for any reason, which is common in public works where political timing due to changes in government increases the risk of delays. Late payment is closely related to cash flow and is a matter of great concern in the construction industry, perhaps more so than in other sectors (Yang and Chang, 2013; Albdul-Rahman et al., 2014).

Therefore, financial costs must be effectively estimated and considered in the indirect costs of construction projects. It is pertinent for contractors to have a more precise understanding of the factors that affect the behavior of the financial cost of their projects, such as the payment conditions agreed upon in the contract and the actual conditions, to determine more realistic cash outflows, which help decide on whether accepting those conditions is convenient for them.

LITERATURE REVIEW

Various studies have identified factors that affect cash flow forecasting. For example, Chen et al. (2005) considered that three factors affect it: the time to receive payment from the client, the frequency of payment to subcontractors, and the component of disbursement for materials and labor; Park et al. (2005) considered the project duration, retention conditions, time to receive payment from the client, agreed upon credits with vendors and suppliers, equipment rentals, and subcontractor payment time. Other authors have investigated more variables, such as Kaka and Lewis (2003), who studied 20 variables divided into characteristic and classification variables; Al-Issa and Zayed (2007), who identified 43 factors that affect cash flow, and grouped them into seven categories; and Liu and Zayed (2009), who analyzed the 43 factors identified by Al-Issa and Zayed and concluded that "financial management" was the most critical category. Adjei et al. (2018) studied the impact of 12 significant factors, including labor and administrative salaries, progress payment durations, bank interest rates, and defective work replacement.

Various models have been developed to forecast cash flow. The most popular can be divided into two categories: mathematical models and cost-time integration models. Cost-time integration models are more accurate because they use more detailed information, including the cost and quantity of resources, construction elements, activities, subcontractor costs, overheads, a detailed schedule, and a list of all activities' associated resources. The biggest issue with this model is its requirement for extensive labor (Navon, 1996).

Several other authors propose cash flow models, such as Kenley and Wilson (2006), who propose a model based on a logarithmic transformation; Boussabaine and Elhag (1999), who apply fuzzy techniques to analyze cash flow; and Jiang et al. (2011), who provide a model that considers typical banking instruments, financial market constraints, budget constraints, and retentions, but does not include factors such as delays in owner payments and penalties for delayed payments.

The mentioned models have the disadvantage that the user would have to learn to program one of these systems, capture resources, apply conditions so that they can be moved in time, design a routine for cash flow, and perform financing analysis, which is very complicated for a common user. In the local context, this problem is accentuated because most construction companies (SMEs) approach project planning superficially, as there is little experience (González et al., 2008).

RESEARCH OBJECTIVES

González et al. (2008) developed the "comprehensive system for planning and control of construction projects" model to respond to the needs of the typical scenario faced by construction companies in the study research. With these and other ideas, this study proposes a cash flow-based analysis model to effectively evaluate the impact of factors that influence public works' financial cost.

The model is based on the integration of cost and time to achieve a good degree of precision. To reduce the effort required by this type of model and to achieve a practical application by contracting companies, a procedure is also put forward that proposes the use of *ad-hoc* software and BIM technology (Building Information Modeling), whose use is on the rise due to the way it has facilitated the management processes of construction projects (Eastman et al., 2011). With support from BIM models, it is possible to quickly and accurately generate work volumes to assign them, along with their various resources, to the multiple activities of the work schedule during cost and time planning. It is relevant to mention that BIM technology is already mandatory in public works in various European countries, the USA, Chile, etc., and it will surely be in Mexico too.

The procedure was tested on a real construction project with high complexity to determine the financial cost for different combinations of agreed-upon and actual factors. The authors investigated these factors through surveys directed to officials from governmental agencies and executives from construction companies in the study region. The result showed that it is feasible and practical to evaluate the significance of the variation in the financial cost for different combinations of factors, which leads to better decision-making and actions for construction companies.

ANALYTICAL MODEL

The first part of the methodology to achieve the objectives consisted in developing an analysis model based on the cash flow method and the ideas of González et al. (2008), García et al. (2004), and Alcudia (2002). Figure 1 shows this model; the symbols in the figure are documents (input/output), process (rectangle), external data (parallelogram), decision (diamond), and flow of information (arrows).

The proposed model is based on the unit price cost system, which is the most common in Mexico. It should take as input a unit price cost estimate, a construction schedule, and the contractual payment terms (agreed-upon and real factors). The unit price cost estimate is understood to be composed of the work items catalog, the quantity of those items, and unit prices of work items without the financial cost, which is the subject of this study. With this information, all resources must be calculated (bill of quantities) and allocated to activities, paying particular attention to those consumed by the activities the company itself will develop. The resources managed by subcontractors are subtracted from the cost estimate and then integrated into the network as a subcontract item, as the details of their management correspond to the subcontractor companies. It must be verified that the assigned quantities match the resources in the cost estimate.

The operations mentioned above cannot be carried out without the support of software for construction project management due to the large amount of information from the unit price cost estimates. These tools should facilitate the extraction of data from cost estimates, which are generally prepared through specialized software for unit prices; it is important to ensure good interaction and compatibility of information between different software.

A software program developed at the School of Engineering of UADY for academic purposes and has been available since 2015 was used to facilitate the analysis proposed in this study. This tool, known as “ProFin,” is capable of a) facilitating the development of a construction schedule using a network of activities; b) automatically extracting resources information from cost estimates created by using commercial software from different developers; c) facilitating allocation of resources from cost estimates to activities in the construction schedule.

The next step is to forecast the cash flow of the construction project, which includes, on one hand, the expenditure program, which consists of payment schedules (payroll, materials, equipment, and subcontractors), information about suppliers' credit terms, and a program of indirect costs expenses; and on the other hand, an income program, based on the contractual payment terms such as advance payment, revision periods of payment progress estimates, and forecast of income of those payments. All this information constitutes the agreed-upon and actual factors whose impact will be evaluated and is essential to carry out the tasks and analysis proposed in the procedures of the analytical model.

Once this is done, the calculation of the financial cost of the project is straightforward; it only requires knowing the active interest rate charged by credit institutions. This rate is applied in the months (or periods) when the cash flow is negative, e.g., when the accumulated disbursements exceed the accumulated income.

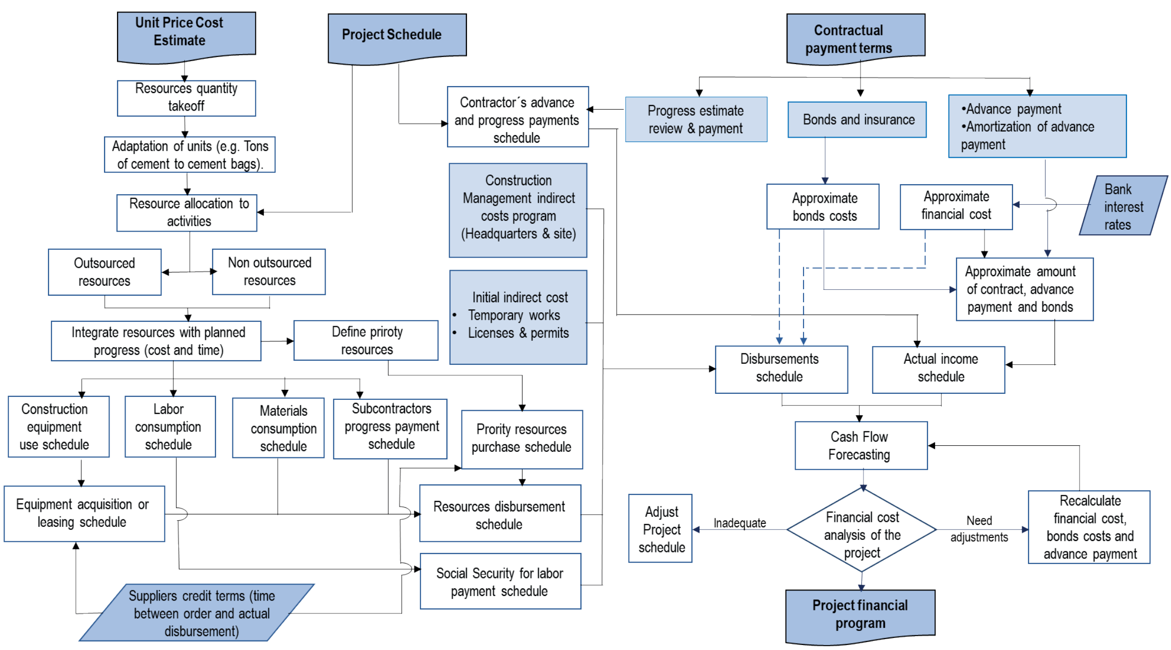

Figure 1. Proposed Analysis Model.

Source: own elaboration with references from González et al. (2008), García et al. (2004), and Alcudia (2002).

PROOF OF CONCEPT

A complete project was chosen to test the analytical model in a real-life project; this construction project provided all the necessary information to carry out the exercise. Thanks to the Construction Department of UADY, the executive project (architectural and engineering blueprints) and the database of the unit price cost estimate of the main building of the new School of Accounting and Administration of UADY, consisting of 4 levels and more than 2,500 m2 of construction, were obtained. Structural, masonry, electrical, hydraulic, and sanitary installation plans, as well as window plans, among others, were available, making it an ideal building to test.

A decision was taken to use volumes obtained from a BIM (Building Information Modeling) model in the analysis, which would provide greater accuracy for the quantities of work, which must be allocated to each activity in the work schedule. The procedure also allows using conventional methods to obtain quantities of work, either with a spreadsheet or by hand, and then capture the volumes obtained.

One of the main reasons for integrating the BIM model as an input information element in the analysis is the ease of handling the information represented in a virtual model and the possibility of breaking down a complex project, such as the one used, into more minor elements. Without a BIM virtual model, much more time would be invested to achieve the level of detail and precision in handling the information sought in this study.

It was considered convenient to complement the development of the ProFin software mentioned above to facilitate: a) the integration of information on work volumes generated with the support of a BIM model; b) the assignment of these volumes and their corresponding resources to construction activities; c) modeling of contractual conditions of the contracting agency; d) modeling of some payment conditions agreed between contractors and suppliers; e) calculation of cash flow closest to reality; f) consideration of the active interest rate from credit institutions; g) calculation of financial cost for a particular project. It should be noted that all these operations can be carried out exclusively with the support of a spreadsheet, but their handling would be highly facilitated with software that includes them.

Field Data Collection

The second part of the methodology consisted of obtaining the factors that affect the financial cost of public works contracts. By reviewing the literature, the factors that affect financing were identified, and then four public sector agencies that carry out building works were consulted to obtain information about their contractual and payment conditions, which were called “agreed-upon factors.” In addition, contractors who work for these agencies were also consulted to obtain the actual estimation and payment periods they are subject to, as well as the types of credit they obtain from suppliers and credit institutions, which will be referred to as “real factors.”

A guided interview was chosen to obtain the necessary information; this type of instrument would allow for direct interaction with the interviewees and facilitate clarification of doubts. Questionnaires were developed to support both types of interviews. The questions were designed to obtain the necessary information to analyze the income and expenses for the cash flow forecast, that is, to collect the data that would serve as input to the analytical model.

For the agreed-upon factors, high-level officials from four governmental agencies responsible for developing and bidding on public projects were interviewed: the Public Works Agency of the State of Yucatan (SOP), the Institute for the Development and Certification of Physical Educational Infrastructure of Yucatan (IDEFEY), the Public Works Agency of City Council of Merida (PW City Council), and the Construction Department of the Autonomous University of Yucatan (Construction Department - UADY). All of them met the criterion of having carried out building work at the time of the research.

For the real factors, the analyzed population was determined from a sample of contractor companies in the registry of construction companies that obtained contracts from the four agencies, with amounts exceeding the equivalent of 1 million Mexican pesos or 60,000 USD. Top executives of 21 companies were interviewed face to face. They were randomly selected from the 47 companies on the registry that met the requirements.

Analysis cases

With the survey results already processed, the values of the agreed-upon and actual factors were obtained. This made it possible to have the necessary information to apply the proposed analytical model to a real-life building project in different situations or cases and thus be able to evaluate the impact of the most important groups of factors. Below are the different combinations of factors grouped into cases.

Case 1. In this case, the best scenario for financial costs that can be expected was analyzed according to the contractual conditions of the agencies included in the study. Contracts' income conditions correspond to the IDEFEY and UADY, which behave similarly, so the conditions of both are represented in this case. For the expenses, two situations were considered: a) a staggered distribution of payments considering the credit conditions of the suppliers (case 1A-SD or staggered payment distribution), and b) uniform distribution of resource payments or "as consumed," according to the durations of the activities (case 1B-UD or uniform payment distribution).

Case 2. The intermediate scenario was analyzed in terms of income for contractors, which occurs with the Public Works Agency of the State Government. For the expenses, the two situations were also studied, as in cases 1, 2A-SD, and 2B-UD.

Case 3. The worst scenario that can be expected in relation to financial costs was analyzed according to the income conditions of the Public Works Agency of the City Council of Merida contracts. For expenses, situations 3A-SD and 3B-UD were also studied.

Case 4. A hypothetical scenario was analyzed, which would occur when a dependency delayed paying the advance payment three months after the start of the work, and with a uniform distribution of resource payments since it is considered the most unfavorable, not considering the help that credits with suppliers can provide.

Case 5. In this case, a hypothetical scenario was presented in which the dependency does not provide an advance payment, and estimates are paid three months later, as in Case 3. The objective is to evaluate the economic impact that a contractor would have in financing practically the entire project. This scenario could occur, mainly in private projects.

In this context, "estimate" refers to the progressive payment request made by the constructor to the public Agency; it consists of a set of documents and procedures that support the progress of the work in a period allowed by the Agency. The times for preparation, processing, approval, and payment of each "estimate" are different depending on the public agencies' contractual and payment policies and the constructors' collection practices. The impact on the cash flow of the different collection/payment durations of the public agencies was observed.

The effect of contractor payment practices on their suppliers was also observed when considering the DD and DU conditions. By contrasting the methods used to model resource payment, the aim was to determine the magnitude of their impact on cash flow and whether these conditions are significant in financial costs.

RESULTS

Survey for government agencies

Table 1 shows the results from questionnaires administered during interviews with the officials of the four government agencies that administer public works projects included in this study. These results correspond to the agreed-upon factors that impact the financial cost of the projects.

Factors	Public Works – State Government	IDEFEY – State Government	Public Works Agency – City Council of Merida	Construction Department - UADY
a) Advance payment	30% - 50%	30%	30%	30% y 50% in special purchases
b) Minimum periodicity allowed to contractors to prepare "estimates" for progressive payments	30 days	30 days	30 days	15 days
c) Actual time between contractor's estimates for progress payments.	1 to 4 months	1 to 1.5 months	monthly	monthly
d) Supervision's review time for estimates of progressive payments	10 days	7 days	10 days	7 days
e) Time between supervision's approval and actual income.	15 days	3 to 15 days	20 days	15 days

f) Bonds	• Advance payment bond • Performance bond 10% • Guarantee and hidden defects bond 10%	• Advance payment bond • Performance bond 10% • Guarantee and hidden defects bond 10%	• Advance payment bond • Performance bond 10% • Guarantee and hidden defects bond 10%	• Advance payment bond • Guarantee and hidden defects bond 10%
g) Penalties for delay	5% of the amount of the works not executed at the cut-off date (according to schedule).	3% of the amount of the works not executed at the cut-off date (according to schedule). 0.03% of the contract amount for each day of delay.	5% of the amount of the works not executed at the cut-off date (according to schedule). 0.02% of the contract amount for each day of delay.	0.01% of the contract amount for each day of delay.

Table 1. Summary of agreed-upon factors according to government agencies.

Survey for construction companies

Figure 2 shows the percentage of interviewed companies that contract with the four analyzed government agencies. Most of these 21 companies participate in tenders and contracts with more than one of the four public agencies analyzed.

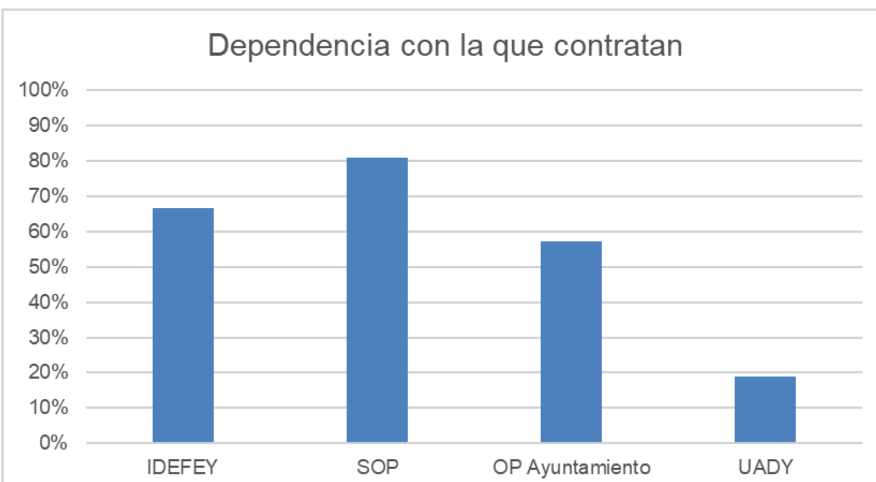

Figure 2. Percentage of interviewed construction firms that contract with the four Public agencies.

Table 2 shows the information provided by the contractors to determine the actual periodicity of progress payments for partial advances in the works. The payment period is understood as the time lag between the partial advance of the work included in an "estimate" and the actual payment received by the contractor for that estimate.

Periodicities and times	IDEFEY – State Government	Public Works – State Government	Public Works Agency – City Council of Merida	Construction Department - UADY
Minimum periodicity that the Agency allows to submit an “estimate” for progress payments	15	15	30	15
Contractor periodicity for submission of “estimates” for progress payments	15	30	30	15
Time to review “estimates” for progress payments by Agency’s supervision	7	15	15	7
Time between revision and authorization in Agencies	7	15	15	7
Time between authorization and actual income of progress payments	7	30	30	15

Table 2. Information to determine payment periods by Agency according to contractors.

Due to the effect that actual periods of progress payments can have on liquidity and financial cost and considering that periods not only depend on Agencies’ contractual and policy conditions but also on actual collection and payment practices, constructors were questioned about whether they delay submitting their estimates and the main reasons for delays. Constructors were able to indicate more than one reason; the following results were obtained from the set of responses: delays in preparing estimates (23%); corrections requested from calculations of the actual volume of works that support the estimates (19%); lack of coordination between the Agency supervisor and the constructor’s resident (20%); delays by the supervisors (18%); reconciliation of volumes and additional work items (12%); changes in the project (8%).

According to contractors’ responses, Table 3 shows the most important materials for the work, as their cost impacts 80% of the total material expenses; it also shows the credit days the suppliers grant in most cases.

Material		Credit days
1	Steel	30
2	Cement	30
3	Wood	Cash payment
4	Pre-mixed concrete	30
5	Stone aggregates	30
6	Blocks	30
7	Joists	30
8	Lime	30
9	Tile adhesive	30

10	Porcelain tile	Cash payment
11	Welded wire mesh	30
12	Electrical cable	30
13	Lamps	30
14	Sanitary fixtures	30

Table 3. Relationship of materials with the highest cost impact and credit time.

This list of materials was considered in this study as priority materials, meaning they require the most attention to obtain the best possible credit terms, thereby improving the company's liquidity and reducing the financial cost if necessary. This suppliers' information is the only one to be considered in the "Suppliers credit terms" in the analytical model.

Step-by-step procedure

A procedure based on the analytical model was applied to assess the impact of factors that influence the financial cost of projects. As described before, different situations or cases were considered in a large project's cash flow forecast procedure, where authors had access to plans, specifications, and cost estimates.

In addition to the above information, it was necessary to develop a construction schedule, work quantities generators, and have the contractual terms of the contracting agencies based on the surveys conducted. Additionally, to coincide with the real environment, contractors can include their actual billing practices, actual payment times from the agencies, and payment times and contractual terms from their suppliers in the analysis; this information was also obtained from surveys.

The "ProFin" software mentioned before was used to facilitate information handling; this software was designed to facilitate detailed planning and scheduling of a construction project. The tool allows the elaboration of complex construction programs and integrates them with cost estimates prepared in other software; its original function was to integrate cost and time. It was modified for this research to add functions that would make it easier to apply the proposed financial analytical model.

With the modifications made to the "ProFin" software, the tool now allows compatibility and manipulation of BIM models. It also allows the entry of factors that impact financing (advance payment, estimation periodicity, interest rates, credit with suppliers, among others), as well as financial runs and the calculation of financial cost.

The BIM model of this building was developed in Autodesk's Revit software. All structural elements such as footings, pads, columns, slabs, walls, slabs, and metal structures were modeled as shown in Figure 3. Architectural elements such as windows, doors, ceilings, etc., and electrical, hydraulic, sanitary, and rainwater installations were also modeled.

Figure 3. BIM model of the test building.

Source: own elaboration from CAD plans.

Next, the procedure carried out to obtain the results of this study is described as follows:

1. Have a unit price cost estimate from which the quantification of resources will be obtained.

2. Adjust resource units to facilitate construction control where necessary. Example: cement in tons to cement in 50 kg bags.

3. Elaborate on a detailed construction schedule using a network scheduling method. This schedule was created with the help of the ProFin tool, and a view of it can be seen in Figure 4. In this study, the Precedence Diagram Method was used because of its flexibility in using four types of relationships between activities and any number of connections between them.

4. Allocate work volumes to activities. The work volumes from the BIM model or a spreadsheet must be allocated to their corresponding activities. To facilitate this task, a work volumes quantifier was created for the construction activities (in the ProFin tool), and then the BIM elements were allocated to them. The quantifier can extract the required properties from the model (length, area, volume, weight, etc.). Figure 5 shows a view of the BIM elements that are allocated to the activities with their quantifiers (volume for concrete and weight for steel).

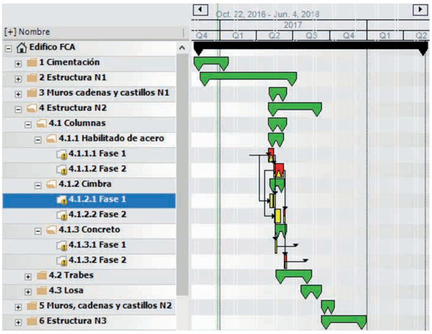

Figure 4. View of the project schedule in the ProFin software.

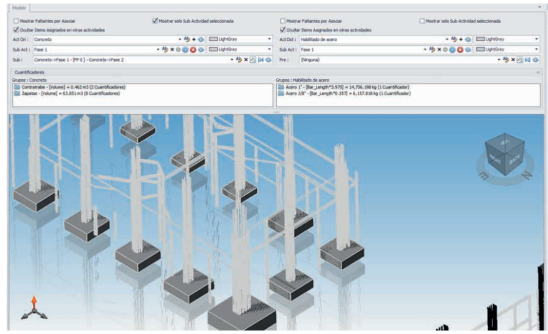

Figure 5. Assignment of BIM elements to activities.

Allocate resources to activities. The ProFin tool also assists in allocating cost items from the unit price cost estimate to activities; these unit price items are composed of resources (materials, labor, tools, etc.). The items that need to be allocated are selected in the corresponding cost estimate tab. Then the “associate the selected item to the activity” command is used, as shown in Figure 6.

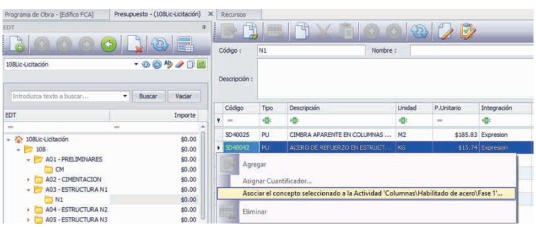

Figure 6. Cost items assignment to activities.

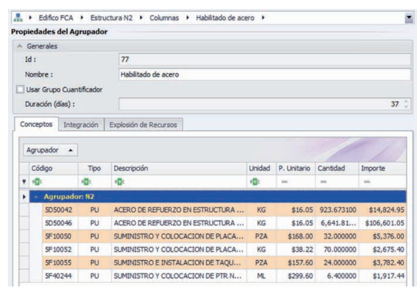

Figure 7. Cost items associated with the activity.

6. Integrate the work volumes with unit price items. Once the cost estimate items are associated with the activities, as shown in Figure 7, their resources are also automatically associated. The quantifiers, which come from either the BIM model or a generating spreadsheet, are integrated with the resources, as shown in Figure 8, and then the tool automatically quantifies each activity’s resources, as shown in Figure 9.

7. The corresponding subcontract activities are created for the items that were decided to be managed as subcontracts, such as the metal structure, electrical, hydraulic, and sanitary installations. Instead of allocating resources from a cost estimate to the activities, a new resource is created, and the total cost of the subcontracted item is captured. This new resource is directly assigned to the subcontracting activity, and in this way, the subcontracts are included in the analysis in a global way.

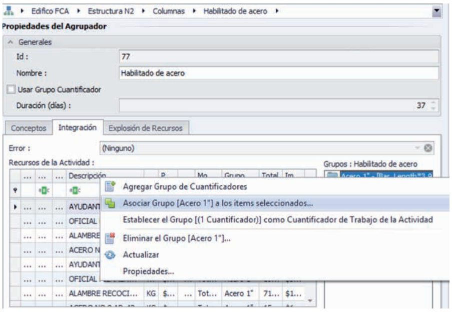

Figure 8. Integration of work volumes with resources.

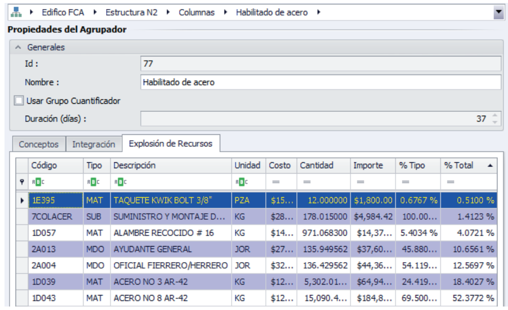

Figure 9. Resource Quantity Take-off for an activity

8. Define priority materials. As shown in Table 3, these materials represent 80% of the total material cost. Once these materials are identified, possible suppliers are assigned to them. The programmer captures the supplier's relevant information, such as a) the number of credit days, if offered, and b) the number of delivery days. This procedure allows for a more realistic distribution of resources.

9. Program initial indirect expenses such as provisional works, licenses, and permits, assigning their associated cost to an activity.

10. Program periodic indirect costs, such as office administration on the construction site and central office administration, assigning their associated cost to an activity.

11. Capture contractual information or agreed-upon factors such as the advance payment percentage, estimation periods, and payment periods in the corresponding fields.

12. Capture the expected additional cost factors in its designated field. For this case, only the profit was considered, as indirect costs were assigned to activities for programming.

13. Capture financial information, such as the active interest rate and the frequency of financial analysis. For this study, biweekly periods were used.

14. Determine the cash flow and financial cost. This is done automatically with the help of the ProFin tool, having all the previously described information captured and loaded. Proceed to execute the "generate flows" command. The result is a financial run and the calculation of the project's financial cost and can be sent to a spreadsheet.

Financial runs

Table 4 shows the results of each combination of factors proposed as different analysis cases. Case 1 corresponds to the conditions of the IDEFEY and UADY agencies, Case 2 to those of the Secretariat of Public Works, Case 3 to those of the Public Works Department of the Municipality of Mérida, Case 4 corresponds to a scenario where the advance payment takes three months to be paid, and Case 5 to a scenario where no advance payment is available; SD and UD represent a staggered or uniform distribution of payments to suppliers, respectively.

Input Data	CASE 1. A-SD	CASE 1. B-UD	CASE 2. A-SD	CASE 2. B-UD	CASE 3. A-SD	CASE 3. B-UD	CASE 4 UD	CASE 5 UD
Advance payment	30%	30%	30%	30%	30%	30%	30% 90 days after	0%
Days between "estimates"	30 days	30 days	30 days	30 days	30 days	30 days	30 days	30 days
Review days for payment of estimate	35 days	35 days	60 days	60 days	90 days	90 days	90 days	90 days
Results								
Financial Cost	$13,870.74	$18,720.38	$20,473.20	$21,480.85	$34,635.71	$72,134.07	$308,082.10	$561,341.97
% Financing	0.06%	0.07%	0.08%	0.09%	0.14%	0.29%	1.17%	2.24%
% Profit	6.50%	6.50%	6.50%	6.50%	6.50%	6.50%	5.00%	5.00%

Table 4. Results of the financial runs

It is possible to graphically show the liquidity (income minus expenses) for each financial run. As an example, Figure 10 shows Case 2.A-SD and Figure 11 shows Case 5, which represent the most favorable and unfavorable cases, respectively, in terms of the percentage of financing. It was assumed that when expenses (orange line) are greater than or above income (blue line), financing is required.

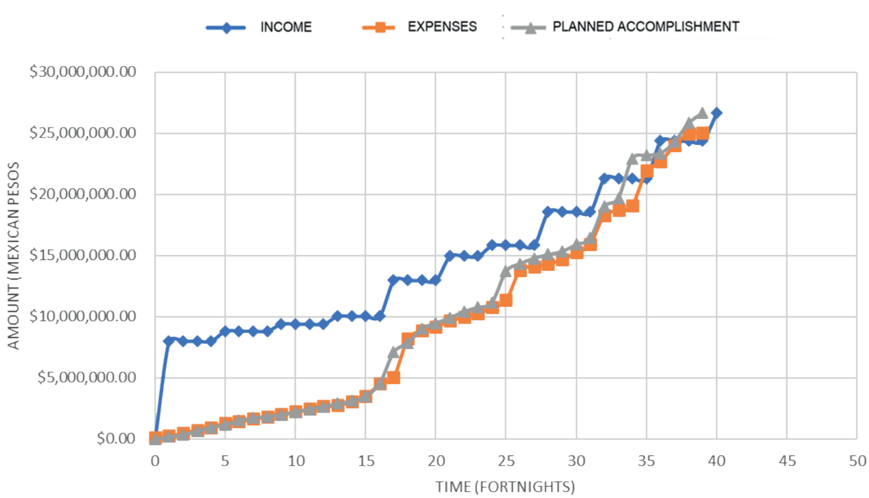

Figure 10. Liquidity for Case 1.A with staggered distribution of resources.

Source: Own elaboration.

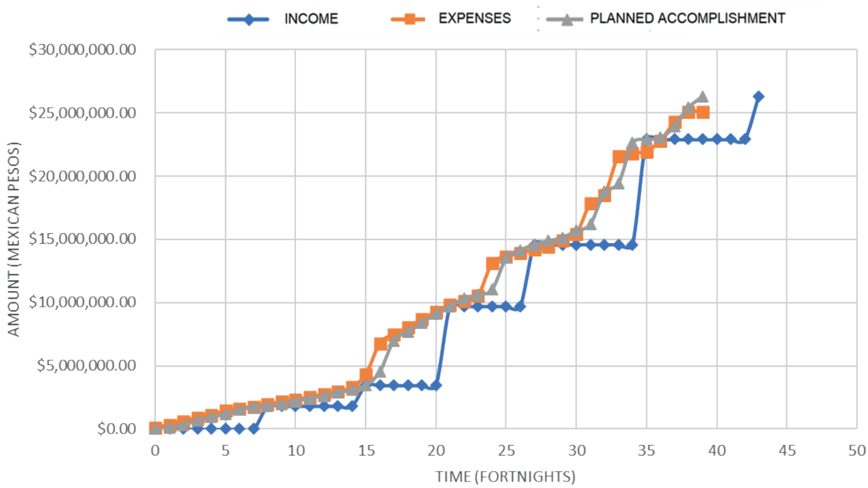

Figure 11. Liquidity for Case 5.

Source: Own elaboration.

DISCUSSION

In cases 1, 2, and 3, there is no liquidity problem until close to the end of the project. Although the impact of the financial cost is not significant, it is important to know when financing is necessary to obtain credit from a financial institution. With the help of this analysis, that information can be obtained.

Significant reduction in financial cost can be observed in these cases 1, 2, and 3 when a staggered distribution (SD) of payments to suppliers is considered compared to a uniform distribution (UD). According to Castillo (2000), suppliers have become one of the contractors' main sources of financing.

If not considered when preparing a project cost estimate, the financial cost can significantly decrease profit or even cause economic losses. For the less favorable cases 4 and 5, as shown in Table 4, the financial cost is a critical factor that must be analyzed in detail. The financial cost for Case 5, which is $561,342, contrasts substantially with the financial cost for Case 1. A-SD, which is only $13,871.

In general, cases 1, 2, and 3 did not present liquidity problems because the advance payment helped to avoid them. In contrast, in cases 4 and 5, it was demonstrated that the advance payment is a sensitive and impactful factor in the financial cost.

In this study, it was considered that the advance payment was eroded as resources were consumed, but in reality, this does not happen. It is common for contractors to provide advances to their subcontractors and significant material suppliers to secure prices and avoid inflationary increases, which means that the advance payment is eroded more quickly.

This practice is recommended in large, long-term projects but could result in more critical cash flow forecasts and higher financial costs. The effect of using the advance payment in the financial analysis of a project may be a special area of study where the procedure and tool developed in this work can be of great assistance.

Another factor that had a considerable impact is the frequency and delay in receiving payment for progress estimates. This study shows that it is very common for companies in the region to delay in receiving payment for their estimates, and 62% of the reasons why contractors are late in submitting estimates for progress payment are attributable to the lack of organization of their companies. In addition, some government agencies take longer than agreed to make payments once the estimates for progress payment have been reviewed and approved. The effect of the periodic payment of progress payment estimates can easily be represented in the proposed analytical model.

The same project schedule with early dates was used in all cases. In another study, it would be interesting to evaluate the financial impact of scheduling activities with late dates, changing durations, or moving certain activities in time, taking advantage of the slack time. Alavipour and Arditti (2018) proposed a model that optimizes the financial program of the project generated from a CPM program, considering these factors. Ahmed M.H et al. (2014) studied the impact of changing the start of activities on the liquidity of construction companies using a simulation model. These cases would be straightforward to model with the tool and methodology proposed in this study.

Navon (1996) proposed that the biggest problem with cost-time integration models for financial analyses is the time it takes to associate the cost estimate resources with the project program activities. This time duration is significantly reduced by using BIM models and the ProFin tool. However, it must be recognized that significant efforts are still required, which is compensated for by having much more detailed information for accurate decision-making.

CONCLUSIONS

The proposed methodology and software can contribute to detailed project planning; the ease of integrating resources into activities allows for supply and payment schedules to be carried out in a dynamic and flexible environment, which can be updated throughout the execution of the project. Automating resource quantification tasks through the BIM methodology for each execution period facilitates procurement tasks for construction projects.

The methodology allows to ponder on different contractual terms and contractors' practices in calculating the projects' financial cost. However, with the proposed method and tool, the impact of other factors that were not studied in this research, such as the impact of delays in payments by the agencies and the use of different work schedules, could also be analyzed.

Finally, the proposed analytical model and its tool can facilitate risk analysis by allowing the easy variation of internal and external factors that affect the financing of projects highly dependent on their cash flow. This is also true in the case of unforeseeable events, where once the project work is advancing and there are delays due to unforeseen contingencies, it is possible to quantify the financial impact of payment delays.

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