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Optimization of Cash Flow and Financing Costs in Construction Projects

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OPTIMIZATION OF CASH FLOW AND FINANCING COSTS IN CONSTRUCTION PROJECTS

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Abstract

The contractor's cash shortage during the progress of a construction project leads to delays, penalties and may lead to project failure. Since the net difference between the cash inflow and cash outflow during construction shall be financed by the contractor, the contractor must consider methods to improve their cash flow in order to maximize the profit margin and minimize the financing costs. Several studies have covered optimization of cash flow and optimization of financing costs, separately. This model integrates both approaches in an attempt to determine the best project schedule and financing alternative; that cover the cash shortage with maximum profitability. The model proposes different ways that attempt to overcome the deficit in cash flow; first by minimizing the amount of financing required through shifting the activities with lag to enhance the cash flow, without extending the project duration, then evaluating different financing alternatives; namely long and short-term loans. The outcome of the model is a modified cash flow for the project with less financing required from the contractor, and feasible schedules of financing inflow and outflow based on the best financing alternative, that attempts to cover the lack of cash with the minimum financing cost. In addition, the model provides the user with a negotiable bid alternative that determines the optimum increase in advance payment, that shall overcome the cash shortage, without borrowing funds. The model has been tested and validated on a case study, and a sensitivity analysis has been performed.

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Chapter 1

1 Introduction

1.1 General Background

One of the most crucial and complicated challenges faced by governments, different sized companies and even individuals; is cash flow management (Barbosa and Pimentel, 2001). Cash flow management is a key tool to attain a successful profitable business (Al-Joburi et al., 2012), the lack of proper planning and effective cash flow management leads to financial burden and stress and may eventually lead to the failure of the whole entity (Hussin and Omran, 2009). As previously stated by Russel (1992) that "an excess of 60% of construction contractor failures are due to economic factors", mainly as a result of improper financial management (Ross et al., 2013). Moreover, as stated by Peer and Rosental (1982), that a firm can overcome temporary periods without achieving profits, however it will breakdown from insufficient cash flow (Al-Joburi et al., 2012). Several previous studies have analyzed the causes of failure in the construction industry, and their outcome is that improper management and lack of liquidity are the key reasons (Al-Joburi et al., 2012). In the construction companies, the organization cash flow comprises of a set of their projects' cash flows, hence one project failure may lead to the failure of the company (Ross et al., 2013). Cash is considered the fundamental resource in construction projects in order to perform the day-to-day activities on site; since insufficient liquidity to support the ongoing project activities is the main cause of project delays and hence failure (Al-Joburi et al., 2012). In addition, cash is recognized as the most influential project resource because the negative impact of improper cash flow management outweighs the ineffective management of any other resource (Ross et al., 2013). Therefore, carrying out adequate cash flow management is of extreme importance for the continuation and success of the projects and the organization as a whole (Odeyinka and Kaka, 2005). Effective cash flow management requires forecasting, planning, monitoring and controlling the cash in and cash out during the project. Project cash flow forecast is based on estimating the expenses and revenues throughout the project duration and enables the contractor to monitor and control the progress of the project (Cui et al., 2010). According to McCaffer (1976), cash flow forecasting enables the contractor to foresee potential cost overruns and schedule delays, and take the appropriate actions at early stages of the project (Odeyinka et al., 2003; Cui et al., 2010). Moreover, project scheduling and financing should be linked to avoid nonexecutable schedule that may cause financial burden (Alavipour and Arditi, 2018b). Generally, in construction projects, there is a time lag between the project expenses incurred by the contractor and the progress payments received from the client, which results in cash shortages that require financing. Proper cash flow estimation allows the contractor determine the financing requirements and their corresponding period (Cui et al., 2010), which may be one of the main requirements to attain loans, since a reliable cash flow forecast may be a necessity by the lending institutions and tends to strengthen the company's position (Odeyinka and Kaka, 2005). Accurate cash flow forecasting plays a huge role in achieving proper cash flow management. Cash flow forecasting is usually carried out in the pre-tendering stages, to estimate the amount of cash inflows from the client and cash outflows to direct costs, suppliers and subcontractors, throughout the duration of the construction project. Moreover, to determine the times of cash surplus and cash deficit and not only the amount the firm will need to borrow to overcome the deficit, but also the financing costs associated with this borrowing (Odeyinka and Kaka, 2005; Ross et al., 2013). The contractor shall predict the initial and interim financial obligations throughout the project to effectively manage the cash flow and secure sufficient funds; to avoid failure to pay loan repayment installments that could negatively affect the company's reputation and credit rating (Canadian Construction Association, 1996). Ultimately, one of the main goals of accurate cash flow forecasting is to build up a competitive contract bid price that shall cover the cost of conducting the project activities, in addition to the financing costs associated with borrowing funds to overcome the negative cash flow throughout the project, besides achieving a profit margin (Görög, 2009). Thus, accurate and reliable cash flow forecast is the key tool to tackle the challenge of building up a competitive yet profitable contract bid price. In order to achieve this balance, cash flow optimization is necessary. Cash flow optimization means reducing the negative net cash flow (Yu et al., 2017); which may be achieved using various strategies that will be discussed later in the Literature Review. However, some of the essential tools of achieving optimum cash flow are: 1- to integrate project scheduling and financing to establish a feasible schedule that minimizes the negative cash flow throughout the project; without causing project delay. 2- to determine the most feasible financing plan to cover for the cash deficit with the least financing costs. These are the main focus of this study.

1.2 Problem Statement

According to Kazaz et al, the main reasons behind the construction projects' delays are related to financial risk factors; including payment delays and liquidity problems (Yu et al., 2017). Ideally, the contractors prospect getting paid for the work conducted on site regularly, with no time lags in order to attain cash surplus throughout the project, for the project to be self-financed. However, realistically this is never the case, cash deficit inevitably occurs during construction projects and several construction projects suffer from negative net cash flows until the very end of the project when the final payment is received (Jiang et al., 2011). As stated by Abeysekera (2002), two key issues cause this problem: 1. The time lag between construction expenses and progress payments by the client; which is a long-known practice that the contractor shall do the work first then get paid later after conducting a substantial amount of work on site. 2. Cash retentions from progress payments; which affect the amount of cash inflow to the contractor (Odeyinka and Kaka, 2005). This imposes a financial burden on the contractor, who shall figure out the appropriate ways of funding the project to be able to carry out the daily construction activities with no delay. Project financing methods and plans hugely affect the project cash flow and profitability; therefore, it is a key issue that should be well analyzed by the contractor and must be accounted for in the project cash flow forecast to obtain a precise cost estimate and profit. Since effective cash flow management has proven to be crucial for the survival of any construction company; several studies have been conducted to address various aspects of cash flow management; including cash flow forecasting models that were developed using different methods, cash flow optimization models that aimed to improve the cash flow and maximize the profit using diverse strategies, and finance-based scheduling models that integrate scheduling and financing based on the financial constraints. Nevertheless, only a few studies considered financing costs and determined the optimum financing plans in their proposed models. And almost none of the developed models integrated more than one strategy to optimize cash flow and tackle the problem of cash shortage during the project, this is the literature gap determined. It would be more practical and more beneficial if the contractors can access one comprehensive tool that illustrates the project cash flow forecast, determines the cash deficit amounts and corresponding periods, offers various approaches to enhance the project cash flow and maximize the profit margin, and clearly demonstrates the consequent optimum financing plan.

1.3 Research Objectives

The main objective of this study is to develop an easy and accessible cash flow optimization model for construction projects. This model aims to be an effective decision-making tool for Contractors. The purpose of this model is to enhance their cash flow throughout the projects by minimizing the required financing, in addition to analyzing different feasible financing options in an attempt to cover for their cash deficit, and finally providing the best financing option.

In order to meet this objective, the model is established;

- To obtain a user-friendly and easily accessible Cash Flow Optimization model
- To develop a realistic cash flow forecast that takes into account the different payment parameters and contract conditions.
- To determine the cash deficit amounts and corresponding periods.
- To minimize the required financing by developing a feasible project schedule that utilizes the activities' floats and decides on the optimal start times, in order to minimize the negative cash flow.
- To analyze the different financing options by trying to cover most of the options proposed by lenders, besides analyzing multiple borrowing scenarios to attain the least financing costs.
- To decide on the best financing option
- To create a Monthly financing inflow and outflow schedule
- To study and analyze a Negotiable Bid option

1.4 Research Methodology

The research methodology for this study is as follows:

1. A literature review has been conducted to cover the main concepts and previous studies and models developed regarding this topic.
2. Based on this literature review, the problem statement is identified. Literature gap is highlighted and the development of this optimization model is considered.
3. The cash flow and financing optimization model is developed on Microsoft Excel using Solver Add-In.
4. The verification of the developed model is done by conducting a sensitivity analysis on different project parameters.
5. The validation of the developed model is done based on a case study application, in order to demonstrate the project processes and ensure the viability of the model.

1.5 Thesis Structure

- Chapter 1: Introduction

This chapter covers a general background about the topic of this study, which is cash flow management. In addition; this chapter includes the problem statement and highlights the importance of cash flow management. Moreover, the research objectives and research methodology are clearly determined.

- Chapter 2: Literature Review

In this chapter, the basic concepts and characteristics of cash and cash flow are discussed, in addition to emphasizing on the importance of effective cash flow management in Construction projects by reviewing the previous studies and models developed in this area. Furthermore, the literature gap is emphasized and the idea of the developed model is explained.

- Chapter 3: Model Development

In this chapter, the model is thoroughly explained. All the steps carried out in order to establish this model are illustrated and discussed in detail. The model inputs, calculations, optimization method and outputs are all covered in this part of the thesis.

- Chapter 4: Model Verification

In order to verify the viability of the model developed, a sensitivity analysis is conducted to ensure that the model meets the main objectives specified, while changing the different project parameters. This chapter includes the sensitivity analysis results for each parameter adjusted and a discussion on this outcome.

- Chapter 5: Model Validation

In this chapter, the model validation conducted by testing the model and applying it on an example project similar to the one considered in a previous research, is discussed and the results are analyzed. This illustrates how the model processes are carried out and how the outcomes of the model are presented.

- Chapter 6: Conclusion, Limitations and Recommendations

This chapter concludes the thesis findings and outcomes, covering a summary of the literature review, the model development and the results of the model verification and validation. Moreover, the model limitations and recommendations for further studies are discussed as well.

Chapter 2

2 Literature Review

2.1 Cash Flow Management in Construction Projects

Cash is considered as the fundamental resource for construction companies to start and successfully run different projects (Son et al., 2006). According to Cooke and Jepson (1986), Cash In is the positive cash flow where the money is flowing in whereas Cash Out is the negative cash flow where the money is disbursed. The difference between the Cash In and Cash Out is defined as the Net Cash Flow (Odeyinka et al., 2003). In construction projects, the Cash In is received from the payments from the client; which are generally in the form of advance payment, periodic payments, final account settlements and retention release. Whereas, the Cash Out is spent on the requirements to carry out the work on site; such as labor wages, materials, equipment and subcontractors (Al-Joburi et al., 2012), besides the indirect costs such as site overheads.

Cash flow modelling and optimization have long proven their importance in construction projects. Cash flow is a financial model that helps the contractor make a proper estimation of the anticipated expenses and revenues, in addition to clearly illustrating the expected cash deficit throughout the project; in order to plan and prepare the most appropriate financial management strategies (Melik, 2010). Cash flow models aim to summarize the expected financial situation throughout the project at an early stage. To effectively manage the flow of cash in and out of the contractors' companies and to be able to economically finance the project execution costs, avoiding financial loss; it is crucial to develop a proper cash flow estimate for each project. Besides, it is recommended during the bid stage to build up a competitive bid price that shall cover all the costs of implementing the project including financing costs (Görög, 2009). Cash flow forecasting models are vital to ensure cash availability required to cover the project expenses, in addition to highlighting the maximum amount of cash needed to be financed by the contractor and the corresponding time, which is necessary to make financing plans to overcome the cash shortages. Furthermore, it may be required by the lending institutions to strengthen the company's position; as it is a reliable indicator that loans can be repaid according to a planned schedule (Elbeltagi, 2012). The usual method of cash flow forecast is based on the cost breakdown of the project in the bill of quantities, along with the project time schedule; to produce a correct estimate of the cash flow profile (Odeyinka et al., 2003). It is of extreme importance to estimate the amount and timing of the incurred costs and the payments received, to estimate the required amount to be funded by the contractor during the project. One of the main aspects of an accurate project cash flow forecast is properly integrating the cash flow schedules, with the construction time schedule, in order to estimate the periodic progress payments throughout the project (Al Mohsin et al., 2014). Cash inflow forecast represents the anticipated revenues and payments received, whereas the cash outflow forecast considers the cost of carrying out the required activities on site. Although this is mainly a project-based forecast, it takes part in predicting the company's financial situation and directly affects the company's finance management (Khosrowshahi and Kaka, 2007; Melik, 2010).

Since construction projects do not completely comply with the initial plan, cash flow forecasts conducted during the bid stage do not necessarily turn out to be totally accurate, due to differences in the actual progress and payments (Ross et al., 2013). There are several factors that may cause these variances, and affect the value of the interim payments; such as earlier or later delivery of materials and supplies, hence modifications in the time of works completion (Al Mohsin et al., 2014). However, it is essential to develop a precise cash flow forecast model, that accounts for the different project parameters and contract conditions, in order to achieve the closest estimate to the actual project cash flow.

2.1.1 Cash In

Cash inflow during construction progress, is made through periodic payments to the contractor, based on the amount of work performed on site (Son et al., 2006). The contractor periodically estimates the amount of work carried out on site, then the progress is approved by the Engineer or the owner's representative. The method of progress valuation depends on the contract type and conditions; it might be as a percentage of the total contract or quantification of the actual work performed on site (Elbeltagi, 2012). An accurate Cash In forecast shall be achieved by incorporating the conditions of contract for the concerned project, such as the advance payment terms, periodic payment terms, retention terms and final account settlement conditions. These parameters shall be properly accounted for in the cash flow forecast model, in order to calculate the amounts anticipated for each payment and the time of receiving these amounts. In addition, the advance payment and retention deductions must be calculated to get the most accurate figure for the net anticipated amounts of each payment.

Payment Terms

One of the fundamentals of cash in forecast, is to take into consideration the time lag between the interim payment request and the actual receipt of payment, in addition to the deductions usually made from each payment (such as: advance payment and retention deductions) to get the planned net earned values. These net values shall be precisely applied in the cash inflow forecast with the relevant time lags (Park et al., 2005). Hence, it is crucial to account for the payment terms that shall be clearly stated in the contract, namely; payment request intervals, the accepted time lag for the client to respond to payment requests, and the time of returning the retained amounts deducted from each payment (Alavipour and Arditi, 2018b).

Advance Payment

Advance Payments are down payments made by the client to the contractor before the execution of works, to relief the financial burden on the contractor during the mobilization and initiation phase of construction works. They are generally liquidated from the periodic payments throughout the project (Hussin and Omran, 2009). Since most of the construction contracts allow for an advance payment in the beginning of the project; it is essential to consider the time and amount of this payment in the project cash flow forecast; which is usually a percentage from the Contract Price (Alavipour and Arditi, 2018b). Besides, applying the relative deductions from each payment during the project.

Retention

Cash retention is an amount retained by the client from each payment. With reference to Hughes et. al. (2000), cash retention is considered the owner's guarantee in case the contractor fails to comply with the project scope. Moreover, to urge the contractor to avoid having any outstanding items not executed according to the project requirements. The amount of cash retained is calculated according to the retention percentage usually stipulated in the contract. The release of retention is managed according to the conditions of contract, commonly after the project completion and acceptance by the client. Cash In forecast shall consider the retained values from each payment, and the date of retention release, since this inevitably affects the project cash inflow (Zayed and Liu, 2014).

All these conditions shall be undoubtedly applied in the Cash Inflow forecasting model, in order to properly plan the cash availability, and allocate the necessary funds to meet the project requirements with the least borrowing needs; hence minimizing the financing costs (Zayed and Liu, 2014).

2.1.2 Cash Out

Cash outflows during construction are represented by the direct and indirect costs needed to carry out the project activities. It expresses the amount required by the contractor to implement the project activities and the associated payment terms (Görög, 2009). In order to attain the most precise cash out flow forecast, a reliable historical data base of costs is vital to accurately estimate the project costs, moreover, it is essential to take into consideration the time lags between the time of incurred costs and the time when the payment is due (Barbosa and Pimentel, 200; Park et al., 2005). These delays differ depending on several factors; such as the type of resource and credit payment terms agreed upon with suppliers and subcontractors (Park et al., 2005). Cash disbursements are represented by the amounts paid to suppliers, subcontractors and directs costs required to carry out the day-to day site activities such as labor, materials and plants. These payments' terms depend on the negotiations with the suppliers and subcontractors (Odeyinka and Kaka, 2005). In addition, other cash outflows are related to the indirect costs represented by project and site overheads.

Direct Costs

Direct costs are defined as the costs directly required to perform the project activities; including paying labor wages, purchasing materials, plants and equipment, in addition to payments to subcontractors. Direct cost forecasts are based on accurately analyzing the project activities, the method statements to be used in construction, and productivity rates of each resource (Elbeltagi, 2012).

Indirect Costs

Indirect costs of the construction projects are related to the overheads needed to accomplish the work on site. Indirect costs can be classified into Fixed Overheads and Variable Overheads. Fixed overheads are the constant expenses required throughout the project duration; they are the costs that are not affected by the amount of work performed on site, such as the administrative costs and head-office expenses; including the company's office rental. Such costs are usually apportioned to the company's running projects and historical data of similar costs is used to estimate the fixed overheads, that shall be properly incorporated in the cash flow forecasting model (Alavipour and Arditi, 2018b; Elbeltagi, 2012). Whereas the variable overheads are the inconstant costs that depend on the amount of work carried out on site. This includes site utilities such as water and electricity expenses, insurances, taxes and management costs. Variable Overheads are generally calculated by multiplying the monthly direct costs with a percentage based on the company's historical figures (Alavipour and Arditi, 2018b).

2.1.3 Net Cash Flow and Cash Deficit

The net cash flow represents the difference between the expenses and income at any point of time (Al Mohsin et al., 2014). In the cash flow forecasting models, the net cash flow is calculated by getting the difference between the monthly cash in and cash out (Odeyinka et al., 2003). A positive net cash flow value means there is cash surplus and the project is financing itself; however, a negative net cash flow value means that there is a cash deficit and external financing is required to cover this shortage (Odeyinka et al., 2003). Some of the factors that affect the amount of overdraft are the profit and retention amounts, besides the time lag between billing and receiving the payment (Yu et al., 2017). Cash deficit occurs when the expenses exceed the income which is a typical case in the construction projects, due to the fact that time lags between incurred costs and cash payments do not match the time lags between the accrued income and cash earnings (Al Mohsin et al., 2014). This results in a time gap between the cash payments and cash receipts. Commonly, the net cash flow is negative in the early stages of the project, and becomes positive in the later stages (Yu et al., 2017). Negative cash flow financing plans are based on the cash flow configuration; hence the contractor shall estimate the maximum overdraft amount throughout the project duration, in order to determine the required borrowing amounts (Yu et al., 2017). A study that analyzes the impact of negative cash flow on construction performance, proves that the longer the cash deficit period, the higher the probability that the project will fail or be terminated (Al-Joburi et al., 2012). Therefore, one of the main goals of the cash flow forecasting models, is to determine the amount and timing of cash deficits, and attempt to decrease the amount and periods of negative cash flow (Al-Joburi et al., 2012).

2.1.4 Cash Flow and Project Scheduling

One of the key tools used in construction project management and one of the main aspects of developing a cash flow projection model is project scheduling. The most common technique used in project scheduling is the Critical Path Method (CPM), which determines the early start, early finish, late start and late finish of the project activities based on deterministic values of activity durations and activities' dependencies (Mohagheghi et al., 2017; Alavipour and Arditi, 2018b). In addition, using the CPM, the contractor shall compute the total and free floats for each activity. According to the PMBOK guide, the total float is defined as the amount of time where an activity *"may be delayed from its early start date without delaying the project finish date",* while the free float is defined as the amount of time where an activity *"may be delayed from its early start without delaying the early start date"* of the successor activities (Project Management Institute, 2013). Since the critical activities are known as the activities with zero Total float, therefore; these calculations will allow the contractor distinguish the critical activities and the non-critical activities that can be shifted without affecting the total project duration. Ultimately, it is crucial to integrate project scheduling and financing to avoid having nonexecutable schedules that may result in project failure (Alavipour and Arditi, 2018b).

2.1.5 Cash Flow Diagrams

Cash flow diagrams are a vital tool to clearly illustrate the cash flow profile of the project against time, to be able to easily control the project finances (Zayed and Liu, 2014). Cash flow diagrams show the cash in versus the cash out profiles, where the difference between them represents the net cash flow. Hence, the financing requirements can be determined. As per Figure 1; the Cash Out profile is a curve that represents the contactor's estimated progress and on-going cumulative cash out values throughout the project (Ross et al., 2013; Cui et al., 2010). While, the Cash In profile is demonstrated as a stepped curve that denotes the anticipated periodic payments from the owner to the contractor.

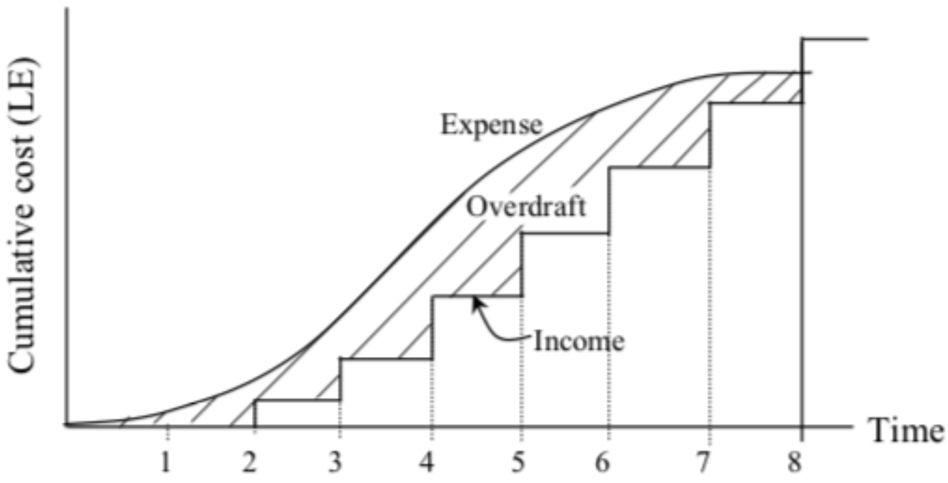


Figure 1: Cash Flow Profile (Elbeltagi, 2012)

Having an effective cash flow forecasting model, guides the contractor to precisely manage and monitor the cash flow during construction. Cash flow diagrams can compare the planned to the actual progress on site, and determine whether there is a cost reduction or cost overrun, and whether the project is going ahead schedule or behind schedule, in order to avoid extra expenses and project failure (Zayed and Liu, 2014).

2.1.6 Cash Flow Optimization Methods

Contractors certainly aim to minimize the required financing amounts in order to avoid financing costs, hence increase profitability. The optimum cash flow from the contractor's point of view is attained when the cash in and cash out curves are as close as possible, which means that the project is almost financing itself, with minimum overdraft. Therefore, the contractor shall implement some strategies to minimize the distance between the two curves, by reducing the overdraft (Yu et al., 2017). The objective of these strategies is to decrease the area between both curves, hence minimize the maximum cash shortage. This may be achieved by shifting the cash in curve to the left, and/or shifting the cash out curve to the right.

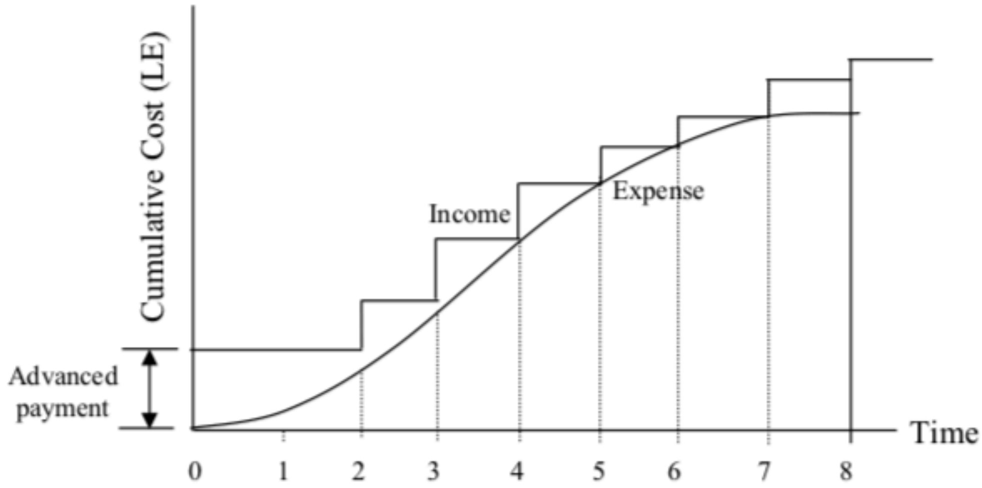


Figure 2: Effect of Advance Payment on Cash Flow Profile (Elbeltagi, 2012)

Some of the cash flow optimization strategies are stated below:

- The contractor shall request an Advance Payment at the beginning of the project, that should cover the mobilization costs and give the contractor a financial booster to efficiently start the project, as illustrated in Figure 2 (Hussin and Omran, 2009; Elbeltagi, 2012).
- Minimize cash inflow delays, by timely submitting the periodic payment requests and urging the owner to pay on time; since payment delays massively affect the cash flow and increases the financial burden on the contractor by not being able to cover the project expenses, leading to project schedule delays (Hussin and Omran, 2009).
- Front-loading is a technique used in the tender stage to improve the project cash flow, by increasing the rates of the project activities conducted on site at the beginning of the project and decreasing the rate of the later activities, in order to guarantee more cash inflow at the early stages of the project, without affecting the total contract bid price (Melik, 2010; Elbeltagi, 2012)
- Project schedule optimization, which may be achieved by several strategies such as developing a finance-based schedule that satisfies the finance availability constraints. This may be accomplished by shifting the non-critical activities within their available floats, and finding the optimum start time, that shall comply with the available funds and achieve less cash deficit (Basha et al., 2016).

- Negotiate with the client reducing the retention amount, and apply at least the same retention percentage to the subcontractors, to diminish the gap between the cash in and cash out (Melik, 2010; Zayed and Liu, 2014).
- Delay in payment of expenses by negotiating the payment terms to subcontractors and suppliers. For instance, by paying part of the amount due immediately and the remaining amount later (Khosrowshahi and Kaka, 2007).

2.1.7 Financing Alternatives and Financing Costs

Project financing is one of the key factors in the project management, since the progress on site cannot keep going without sufficient funds and the cost of securing the adequate funds can be quite large (Hendrickson and Au, 2000). According to Halpin and Senior (2011), it is essential for the contractor to be aware of the maximum cash deficit amount and its timing, in order to plan how to overcome this shortage. Inadequate cash flow necessitates the contractor to explore the different borrowing options (Canadian Construction Association, 1996). It is important to find the optimum financing plan that shall cover the cash shortage with the least financing costs. With reference to Hendrickson and Au (1989), the financing alternatives for contractors to overcome their cash shortage during construction are somehow limited. Commercial banks are the most common financial institutions that contractors resort to, in order to finance their projects; therefore, the contractors shall establish and maintain strong relationship with their bankers and lending institutes (Canadian Construction Association, 1996; Yu et al., 2017). Banks usually offer various financing alternatives including short-term loans, long-term loans and line of credit (Elazouni and Abido, 2013; Alavipour and Arditi, 2018c). Short-term loans are defined as the loans scheduled to be repaid in less than a year, whereas long-term loans are usually taken at the beginning of the project and have repayment schedules of one year or more (Alavipour and Arditi, 2018a). Although financial institutions generally prefer lending money for shorter periods of time for better financing to their operations, long-term loans have been extensively used in financing large scale projects (Alavipour and Arditi, 2019). In most of the loan financing scenarios, the borrowers (contractors) are required to repay a fixed amount monthly, incorporating both interest and principal amounts, whereas in other cases, the borrowers shall pay off the compounded interest besides the principal amount at the end of the project (Alavipour and Arditi, 2018a). As for the Line of Credit, this option allows the contractor to borrow the credit amounts required at any time, with a maximum specified limit agreed upon between the contractor and the bank, therefore the contractor shall comply to the credit limit. Interest charges are paid by contractors based on the amount of cash borrowed during each period (Fathi and Afshar, 2010). Since the contractor can access the money and repay the due amounts on an unscheduled basis, with no specified amounts and timings of borrowing, hence managing the lines of credit can be more complex than short- and long-term loans (Alavipour and Arditi, 2019).

Nominal and Effective Interest Rate Calculations

With reference to Hendrickson and Au, generally the borrowing interest rate offered by the lending institutions and banks, is provided as annual percentage rate (APR) (Hendrickson and Au, 2000). There are two types of interest rate calculations; nominal and effective interest rates. A nominal interest rate is defined as an interest rate that does not account for compounding. In order to account for compounding, effective interest rate shall be calculated. The effective interest rate considers all the compounding periods, to match the borrowing agreement and precisely calculate the accrued interest per period (Blank and Tarquin, 2012). The effective annual interest rate ($\boldsymbol{i_a}$), which is typically quoted by the banks, is calculated using the following formula:

$$\boldsymbol{i_a = (1 + i)^m - 1} \qquad \textbf{(2.1)}$$

Where:

$\boldsymbol{i}$ = the rate for one compounding period

$\boldsymbol{m}$ = number of compounding periods per year

Since the effective annual interest rate ($\boldsymbol{i_a}$), is usually offered by the banks, thus to determine the amount of interest accrued per period, the effective interest rate per compounding period ($\boldsymbol{i}$), shall be solved for using the following (Blank and Tarquin, 2012);

$$\boldsymbol{i = (1 + i_a)^{\frac{1}{m}} - 1} \qquad \textbf{(2.2)}$$

The contractor shall study and analyze the different financing options and consider the most optimum scenario that would cover the cash deficit with the least financing costs. Since ineffective financial forecasting often leads to many financial risks, financing schedule forecasting is inevitable to summarize the required amounts to be borrowed and the anticipated repayment amounts and their corresponding time. Besides, the financing costs calculations (such as: interest accrued), that shall be taken into consideration in the cash flow model (Yu et al., 2017). In order to attain the least financing costs and the highest profitability, contractors shall consider and proceed with the optimum combination of financing options offered by the lending institutions, obtained in the form of one or a series of loans with different conditions (Alavipour and Arditi, 2018c).

2.2 Existing Cash Flow Forecasting and Optimization Models

There are numerous studies and models developed related to the cash flow management in construction projects due to the importance and criticality of this issue. These include various cash flow forecasting models and cash flow optimization models, following different strategies, techniques and levels of detail and accuracy. Most of the researches conducted in the area of cash flow forecasting and optimization were developed from the contractor's point of view, in an attempt to enhance the cash flow management process and provide them with decision support models and different strategies to assess their overall performance and increase their profitability.

2.2.1 Cash Flow Forecasting Models

Various aspects of cash flow management have been extensively studied and analyzed by several researchers. Some of the cash flow forecasting methods include: (1) The cost-breakdown approach which is based on predicting the project costs by breaking down the expected expenditures (Ross et al., 2013). (2) Models based on mathematical methods by analyzing the project characteristics and flow of expenses (Ross et al., 2013). (3) Non-mathematical cash flow forecasting models that are mainly dependent on the historical data obtained from previous projects (Zayed and Liu, 2014).

Cash flow forecasting and management has been an area of concern in the construction industry along the years. One of the earlier cash flow forecasting models introduced was by Nazem (1968), which was based on historical data of previously accomplished projects (Melik, 2010). In 1977, another cash flow forecasting model was proposed by Ashley and Teicholz, where the direct costs were classified into labor, material and equipment and identified as percentages of the total project cost (Park et al., 2005). Several studies established cash flow estimating models based on mathematical formulas, and the outcome was a set of typical S-curves.

These models assume that depending on some of the project variables (including project duration, contract type, location, value and project scale), a reasonable estimation may be provided (Odeyinka et al., 2003). One of the first studies conducted in the cash flow analysis, is by Gates and Scarpa (1979), who introduced a simple approach for cash in, cash out and net cash flow as a function of time throughout the project duration (Jiang et al., 2011). Along the years, researchers worked on enhancing the accuracy of the cash flow forecasts using different methods and strategies; such as the model introduced by Kaka and Price in 1991 (Jiang et al., 2011). Moreover, in order to attain more accurate cash flow forecasts, computer simulation models were utilized. Navon 1995, established a dynamic resource-based cash flow forecasting model, using non-project specific database. This is a computerized model that automatically integrates the bill of quantities, the cost estimates and the schedule of activities' databases, and it overcomes the compatibility issues between the different breakdown structure of the cost and schedule items; where cost items are generally defined in terms of elements such as slabs, whereas schedules are illustrated in terms of activities such as concrete pouring (Jiang et al., 2011). Khosrowshahi (2000) developed a software named "Advanced S-Curve (TASC)" to achieve cash flow forecasting with higher accuracy (Odeyinka et al., 2003). In 2005, Park et al. established a cash flow forecasting model that takes into account cost and time lags according to the contractual terms and cash-out payment agreements of the concerned project to achieve a more realistic forecasting model, besides implementing moving weights of the cost categories based on the construction progress on site (Park et al., 2005; Jiang et al., 2011). A multiple linear regression model was later introduced by Blyth and Kaka (2006) to illustrate S-curve profiles on a project level, the purpose of this model is to estimate the schedule of activities and their relevant costs (Jiang et al., 2011). Some of the numerous mathematical models established include a decision support model developed by (Khosrowshahi and Kaka, 2007). It is a visual mathematical model that produces cash flow forecasts by integrating the model data base with the experience of the model user. There are several estimating profiles based on mathematical expressions, developed in this model, and according to the project characteristics, a cash flow profile is generated. Moreover, the model allows the user to view and analyze the impact of changing several project variables, in order to strengthen their position during negotiations with other parties to enhance the project cash flow profile (Görög, 2009). Other techniques were applied in cash flow forecasting models; for instance, (Zayed and Liu, 2014) proposed a model that estimates the cash flow and amount of overdraft using integrated analytic hierarchy process, in addition (Mohagheghi et al., 2017), developed cash flow analysis model established on interval type-2 fuzzy project scheduling, to produce a cash flow forecast throughout the project duration, that overcomes the lack of sufficient project data related to the activity costs and durations.

2.2.2 Cash Flow Optimization Models

There are numerous cash flow optimization models developed in the existing literature. Several studies using different techniques and diverse levels of complexity were proposed in the recent decades. Some of the relevant models and techniques are discussed in this section.

Karshenas and Haber (1990) were one of the first researchers who developed cash flow optimization models. A linear integer model was developed to minimize the cost of all project resources including labor, material, equipment and time, and ultimately achieve the optimum project schedule with the least corresponding project costs (Jiang et al., 2011). A Linear programming model was established by Barbosa and Pimentel (2001) to achieve the optimum cash flow management by adopting the typical cash flow problems in construction projects; including potential payment delays, credit line limits, the impact of interest rate changes and budget limitations. The model input is the cash flow forecast, and the model aims to attain higher profitability using an optimization algorithm (Barbosa and Pimentel, 2001). In addition, in 2001, Hegazy and Wassef introduced a cost optimization model for repetitive non-serial activities, developed on Excel using Genetic Algorithms (Hegazy and Wassef, 2001). In 2006, Son et. al proposed a model that is based on adopting a combination of two strategies used to improve the cash flow and hence increase the project profits; these strategies are front end loading and shifting of activities to attain the optimum cash flow profile (Son et al., 2006). Constraint programming method was used by Liu and Wang (2008), in a cash flow optimization model that considers the resource constraints and aims to enhance the project cash flow besides achieving higher profitability (Fathi and Afshar, 2010). Chen et al. (2010) presented a cash flow optimization model based on an ant colony optimization technique to maximize the net present value of the project, using a set of functions and algorithms (Li et al., 2013). Liu and Wang (2010) established a profit optimization cash flow model for multi-projects, aiming to reach the optimum schedules and cash flow profiles that will attain overall maximum profits (Li et al., 2013; Jiang et al., 2011). (Abdel-Khalek et al., 2011), introduced financing-scheduling optimization model using genetic algorithms. This model searches for the optimum start time of the activities in order to obtain the least negative overdraft values and minimum financing requirements (Abdel-Khalek et al., 2011).

2.2.3 Finance-based Optimization Models

Financing costs were mostly disregarded in the cash flow management studies until 2004, when the concept of finance-based scheduling was first proposed by Elazouni and Gab-Allah (Alavipour and Arditi, 2018b), where both scheduling and financing functions are integrated. This is accomplished by determining the optimum schedule of activities, taking into consideration the financial restraints and the activities' dependencies (Alavipour and Arditi, 2018b). The developed model incorporates the integer-linear programming technique to develop the optimum financially feasible schedule of activities with the minimum total project duration. The activities' start time are modified to reach the optimum schedule that satisfies the cash availability constraints and credit limits, in order to balance the amount of work with the existing cash (Alavipour and Arditi, 2018b; Jiang et al., 2011). The main objective of finance-based scheduling is to adjust the start time of project activities to enhance the project cash flow and minimize the negative cash flow amounts, subject to the financial constraints, hence minimizing the financing costs (Fathi and Afshar, 2010; Alavipour and Arditi, 2018b). In case the cash overdrafts, including financing costs, exceed the available financial resources, the start time of the activities are modified within the total activities' floats to comply with the project duration, or if needed extend the project duration, in order to meet the financial limitations (Alavipour and Arditi, 2018b). In 2005, Elazouni and Metwally applied the genetic algorithm method to formulate finance-based scheduling model that aims to maximize profitability through interest rates negotiations with lending institutions (Jiang et al., 2011; Fathi and Afshar, 2010). Elazouni and Metwally (2007) then extended the finance-based scheduling concept using genetic algorithms and proposed more practical schedules incorporating resource allocation and levelling, besides time-cost trade off analysis (Fathi and Afshar, 2010). A heuristic method was applied by Elazouni (2009) in developing finance-based schedules for multiple projects (Al-Joburi et al., 2012). The strength Pareto evolutionary algorithm was utilized by Abido and Elazouni 2010 to improve the finance-based scheduling (Al-Joburi et al., 2012). Another novel modelling technique was investigated by Lucko 2011, who developed a cash flow forecasting model using singularity functions and determined the optimum profits by applying simulated annealing algorithms. Optimization using this technique shifts the activities randomly, yet incorporating the project cost and time constraints, in an attempt to maximize the profit (Li et al., 2013; Lucko, 2011).

2.3 Existing Optimum Financing Cost Models

In spite of the extensive research and countless studies conducted in the aspect of cash flow modelling and optimization; only a few studies took into consideration the financing costs and optimum financing alternatives relevant to the project constraints (Fathi and Afshar, 2010). Most of the current finance-based scheduling techniques are based on the assumption of a predetermined credit amount, and the schedule of activities is adjusted accordingly. Nevertheless, this does not investigate the optimum credit requirements based on the specific situation of the project and the different conditions of the lending institutions. In order to achieve more efficient finance-based scheduling, Fathi and Afshar (2010), developed a multi-objective finance-based optimization model using Non-dominated Sorting Genetic Algorithm (NSGA-II) that accounts for financing costs as well (i.e. interest charges). The objective of this model is to guide the user to determine the optimum line of credit financing option corresponding to the optimum project duration and minimum financing costs (Fathi and Afshar, 2010). Since most of the few models incorporating financing cost optimization, only considered the line of credit financing alternative and disregarded the different types of financing options; and almost none of the studies conducted targeted investigating the optimum financing alternative out of the numerous alternatives offered by lending institutions; (Alavipour and Arditi, 2018b) developed an optimization model that overcomes these shortfalls. The introduced model optimizes the financing costs by analyzing different financing options (short-term loans, long-term loans and line of credit), without modifying the initial project schedule or activities' durations. The model ultimately produces feasible optimum schedules of financing inflows and outflows, corresponding to the optimal financing alternative with the least financing costs (Alavipour and Arditi, 2018b). (Alavipour and Arditi, 2018a) additionally developed another similar model that targets optimizing financing cost using line of credit and long-term loans. Then (Alavipour and Arditi, 2018c) later extended their research and utilized the same concept in introducing another tool that assists the contractors in calculating the bid price incorporating financing costs. The objective of the developed model is to optimize the financing costs by choosing the optimal combination of the available financing options, consequently achieve the best bid price that would increase the competitiveness of the bidder, with the highest profitability. Furthermore, (Alavipour and Arditi, 2019), established another model based on time-cost trade off analysis to attain minimal financing costs. This tool produces a project schedule based on the early start times of activities and the optimal financial schedule, hence achieving maximum profitability. The model determines the optimum financing options combination and produces the ideal financing schedule for project completion times between normal and crash activities durations (Alavipour and Arditi, 2019).

2.4 Outcomes of the Literature Review

Financial management and cash flow planning is complex and critical issue in the construction industry, due to the huge amount of on-going cash transactions throughout the project duration. Therefore, reaching the optimum project schedule that satisfies the available funds is a tremendous challenge (Lucko, 2011). This has been an area of concern over the years, thus numerous studies have been proposed for cash flow optimization, using different mathematical and heuristic techniques (Fathi and Afshar, 2010). In addition, incorporating financing costs has proven to be an important aspect of the contractor's cash flow management, since building up the bid price in any project shall cover the financing costs associated with overcoming the negative cash flow during the project. Besides, reaching the optimum solution of the best financing alternatives with the least financing costs, leads to higher profits, which is the ultimate goal of the contracting companies (Görög, 2009).

As discussed earlier, various studies were conducted to obtain cash flow forecasts, others were to achieve cash flow optimization using diverse methods and levels of accuracy. Further studies proposed models to optimize the financing costs by determining the optimal financing alternative that attains the least financing costs. In this thesis, the main objective is to combine all these concepts to come up with an integrated multi-objective cash flow optimization model. The model aims to (1) formulate a cash flow forecast according to the project data input by the user, and illustrate the project schedule against the cash flow using CPM calculations and GANTT charts, (2) enhance the project schedule by shifting noncritical activities within their float to minimize the cash shortage, and (3) analyze different financing options and propose the most feasible financing combination, associated with the least financing costs.

Chapter 3

3 Model Development

In this Chapter, an integrated Cash Flow Optimization Model is introduced to help contractors in the Construction industry reduce the cash deficit throughout their projects, with the minimum financing costs. A workflow of the optimization model developed is explained in detail. Flow charts are created to clarify the User Input Data, how the Optimization Model works, and the Calculations and Outputs produced by the Model. This study aims to develop an easily accessible tool; hence the proposed model is developed using spreadsheets on ***Microsoft Excel*** and the optimization tool utilized is ***Microsoft Excel Solver Add-In***. Spreadsheets are powerful tools that are simple and easily used, besides incorporating several features that can allow developers/researchers to develop a customized model that fits the purpose of their study (Hegazy and Wassef, 2001). All the calculations, charts and tables generated in the model are developed using the tools available in Microsoft Excel; including formulas, charts and different formatting options. In order to achieve the best outcome of this model, the user shall input reliable and coherent project data. The main inputs required by the user are deterministic data including; the activities' estimated durations, costs and dependencies, cash-out payment terms to suppliers and subcontractors, and payment contract terms required for the cash-in calculations.

3.1 General Overview of the Cash Flow Optimization Model

This thesis presents a comprehensive and user-friendly Cash Flow Optimization Model (CFOM) that aims to enhance the negative net cash flow problem encountered by the Contractors when the Cash Out exceeds the Cash In in a certain period and the Contractor shall bridge this gap by funding the project. The cash flow management in this model is based on an individual project, without any cash transfers to/from any other project in the company. The model first formulates the Cash Flow schedules and profile for the concerned project based on the input data, the initial schedule is illustrated in the form of a bar GANTT chart of project activities against time and cumulative cash in and cash out schedules, then the model produces an improved Project Schedule by shifting the noncritical activities within their float to decrease the cash deficit, hence the corresponding Cash Flow Forecast is portrayed, and subsequently the deficit in cash is determined at early stages of the project, afterwards it analyzes different options to reduce this deficit and selects the best alternative which attains the least financing costs and highest profitability. This model analyzes three Financing Alternatives: 1. Long Term Loan at the beginning of the project, 2. Short Term Loans, and 3. a Combined Option of Long- and Short Term Loans. Moreover, a Negotiable Bid option is introduced at the end of the model where the model proposes a possible decrease in profit against an increase in Advance Payment by the client to overcome the cash shortage throughout the project; for the Contractor to analyze and decide if this option would be more feasible and better than borrowing funds. This model enables contractors to have a proper Cash Flow Management system. It is intended to help Contractors in lumpsum projects, since the model is based on having a fixed Contract Price. The model overview and a flowchart of the model are illustrated in Figure 3 and Figure 4.

The model is constructed of several tabs:

- User Input
- 1. Project Schedule and Cash Flow
- 2. Project Optimized Schedule
- Financing Alternatives:
  - 3.1 Long Term Loan
  - 3.2 Short Term Loans (every 3, 6 and 9 months)
  - 3.3 Combined Alternative of Long Term and Short-Term Loans
- 4. Negotiable Bid

The Cash Flow Optimization is conducted on two stages:

i. **Stage One**
   - Shifting activities with free float to find the ideal start time between the early start and late start, in an attempt to improve the Cash Flow and minimize the required amount to be financed by the Contractor; and hence minimize the financing costs.

ii. **Stage Two**
   - Analyzing different Financing Alternatives and finding the best alternative; by generating the schedules of financing and repayment, and selecting the best alternative with the least financing cost.

A Negotiable Bid option is introduced at the end of the model; which proposes a decision-support tool that guides the user to analyze the option of decreasing the profit against an increase in Advance Payment to overcome the cash shortage throughout the project, instead of resorting to the financing alternatives and borrowing funds.

3.2 Model Flow Charts

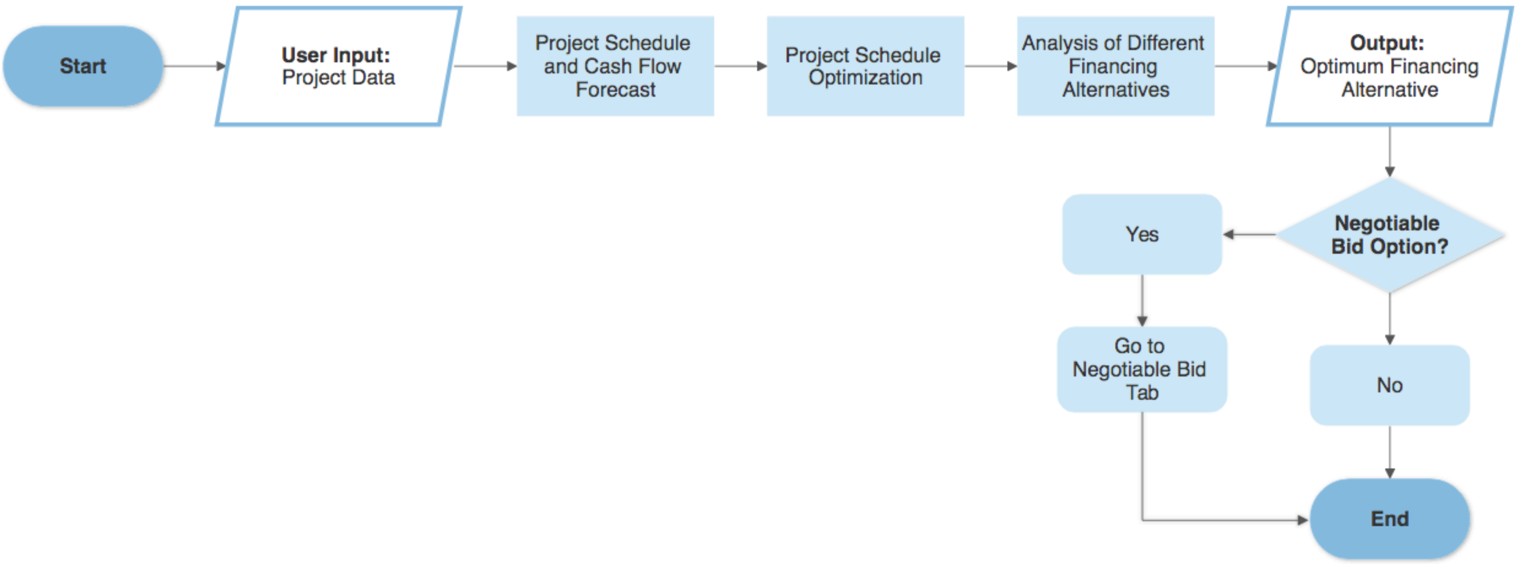


Figure 3: Model Overview

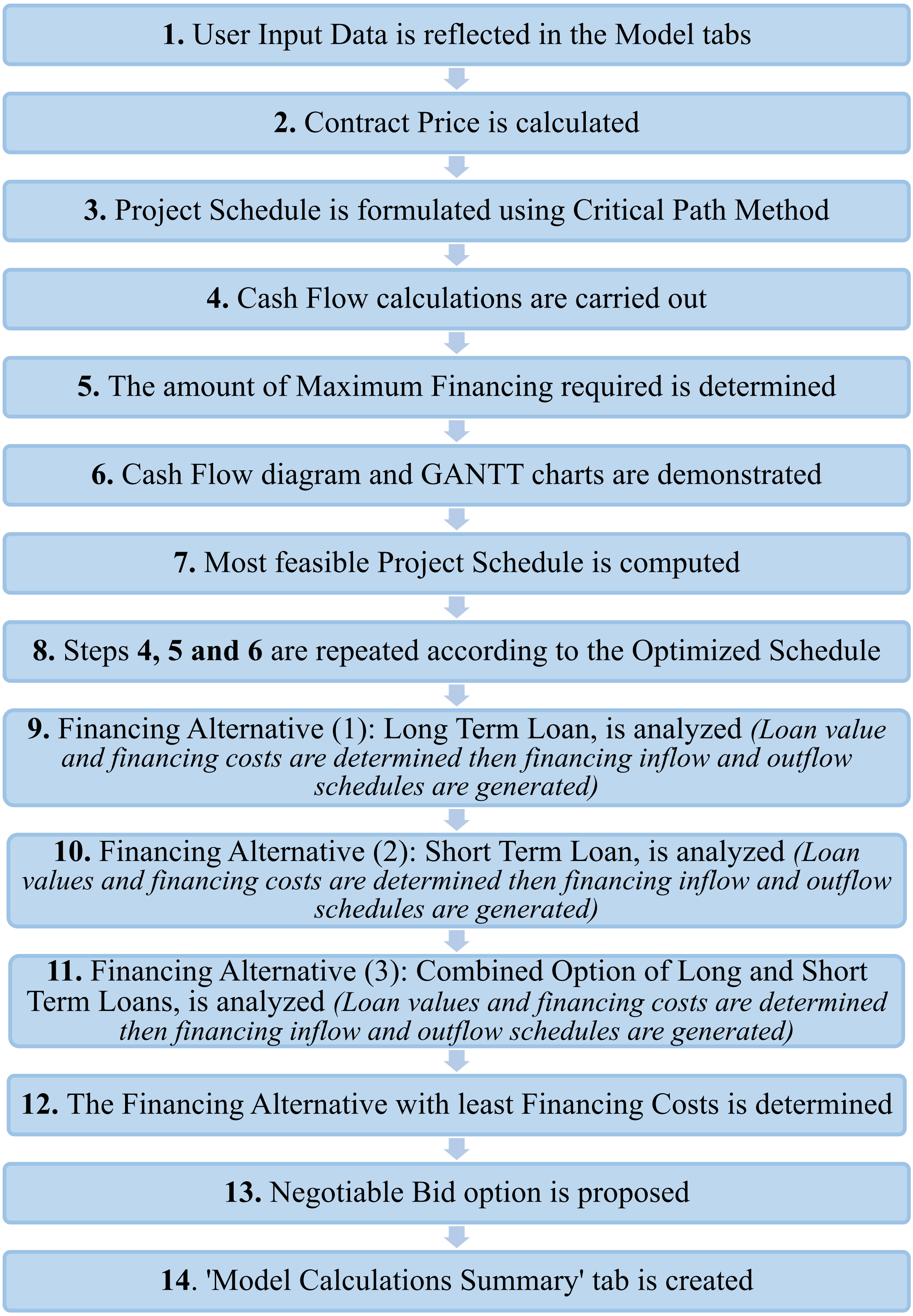


Figure 4: Model Flowchart

3.3 Input Data

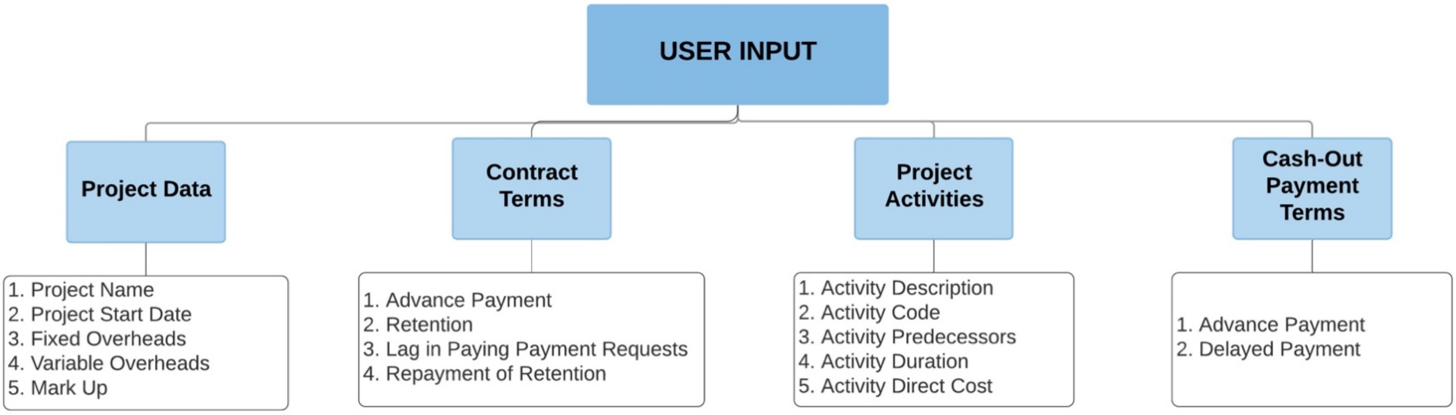


Figure 5: User Input

The first tab of the model is the '**User Input Data'** tab, where the user is required to enter all the necessary data of the project, as per Figure 5. Below is a detailed description of the inputs required by the User.

3.3.1 Project Data

The general project properties such as the starting date of the project, indirect costs and project markup are input into the model in the *Project Data table*.

- **Project Name:** [Text]
- **Project Start Date:** [Date]
- **Fixed Overheads Percentage**: [%]
  - The amount of Fixed Overhead (FOH), which is the fixed value of indirect cost, is calculated as a percentage of the Total Direct Cost.
  - The user is required to enter this percentage based on the company's historical data.
- **Variable Overheads Percentage**: [%]
  - The amount of Variable Overhead (VOH), which is the variable portion of the indirect cost, depends on the amount of work performed. It is calculated in the model as a percentage of the Direct Cost of work performed in each period.
  - The user is required to carry out the variable cost calculations and then find the corresponding percentage from the direct costs, to be input in the model.

- **Mark Up:** [%]
  - According to (Alavipour and Arditi, 2018b), the Mark Up value is the profit margin gained by the contractor, and it is calculated as a percentage of the Total Direct and Indirect Costs of the project.
  - Contingency and risk shall be included in the Mark Up percentage.
  - The user is required to enter the Markup percentage included in the Contract Price.

3.3.2 Contract Terms

The user shall enter the following data, according to the project's Contractual terms, in the *Contract Terms table*.

- **Advance Payment:** [%]
  - It is common in construction contracts that the owner makes an advance payment to the contractor. It is a percentage of the Contract Price, included in the Contract terms (Alavipour and Arditi, 2018b).
- **Retention:** [%]
  - The retention is the owner's retained amount from each payment to ensure proper completion of the project and it is usually released at the end of the project (Fathi and Afshar, 2010). It is calculated as a percentage of the certified amount to the Contractor. This percentage is typically included in the Contract terms.
- **Lag in paying Payment Requests (L_p):** [Number of Months]
  - This is the time lag between the Contractor's submission of the Interim Payment Application and the owner's certification of the payment. The payment time-lag is commonly included in the Contract Terms.
- **Repayment of Retention (L_R):** [Number of Months]
  - This is the time lag between the last progress payment, and making the final payment and returning the retained amount to the Contractor (Alavipour and Arditi, 2018b). This lag is normally included in the Contract Terms.

3.3.3 Project Activities

In the *Project Activities table*, the user shall input all the data related to the project activities.

- **Activity Description:** [Text]
- **Activity Code:** [Text, Code]
  - A unique activity code is denoted for each activity.
- **Activity Predecessors:** [Text, Code of Predecessor Activities]
  - The model incorporates up to three Predecessors for each activity, assuming the relationship between all activities is Finish-to-Start, where the activity can only start when the predecessor activities are finished.
- **Activity Duration:** [Number, Months]
  - The time scheduled to complete each activity, in months.
- **Activity Direct Costs:** [Number, Amount of Direct Cost]
  - The direct costs forecasted for each activity.

3.3.4 Cash-Out Payment Terms

This model takes into account the cash-out payment terms to suppliers and subcontractors. The user shall enter these data in the *Cash-Out Payment Terms table.*

- **Advance Payment:** [%]
  - The model allows the user to enter the agreed Advance Payment to suppliers and subcontractors, if any, for each activity. It is considered as a percentage of the activity cost.
- **Delayed Payment:** [Number]
  - The remaining amount of the activity cost is assumed to be equally divided on the activity duration. The user shall determine after how many months from the start of the activity, will these payments start.

3.4 Model Calculations and Outputs

The introduced model aims to integrate project scheduling and financing optimization, so the data input by the user is used to formulate Project Schedule and Cash Flow Forecast. In Project Scheduling, it is recommended in the Literature to find the ideal start date of activities with float, between the early and late start times to find the schedule that satisfies the cash limitations and therefore minimizes the financing costs of the project (Alavipour and Arditi, 2018b).

Thus, the model incorporates this concept and intends to find the optimum schedule that requires less financing from the contractor. Then financing optimization, based on the optimized schedule, is implemented by analyzing different financing alternatives taking into consideration the schedules of financing inflow and outflow. Ultimately, the optimum financing alternative with the least financing costs is selected by the model. This section covers a detailed explanation of all the outputs produced and calculations carried out by this model.

3.4.1 Contract Price Calculation

The data entered by the user enables the model to automatically carry out the necessary calculations to get the Total Contract Price in the *Contract Price Calculation table*.

- **Project Direct Cost (DC):** This is the summation of the Direct Costs of all the project activities input by the user.
- **Fixed Overheads (FOH):** The Fixed Overheads percentage input by the user, is multiplied by the Total Direct Costs (DC) to get the total amount of the project Fixed Overheads.
- **Monthly Fixed Overheads (MFOH):** The Monthly Fixed Overheads, is calculated by dividing the total amount of the project Fixed Overheads (FOH) by the total duration of the project, in order to get a fixed amount of overheads for each month throughout the project.
- **Variable Overheads (VOH):** The Variable Overheads percentage input by the user, is multiplied by the Total Direct Costs (DC) to get the total amount of the project Variable Overheads.
- **Markup Value (MP):** The Markup percentage input by the user is multiplied by the summation of Project Direct Costs, Fixed Overheads and Variable Overheads.

$$Markup\ Value = [Markup\% \times (DC + FOH + VOH)] \tag{3.1}$$

- **Total Contract Price:** The Total Contract Price is calculated by the addition of Project Direct Costs, Fixed Overheads, Variable Overheads, and Markup Value.

$$Total\ Contract\ Price = (DC + FOH + VOH + MP) \tag{3.2}$$

3.4.2 Project Schedule and Cash Flow

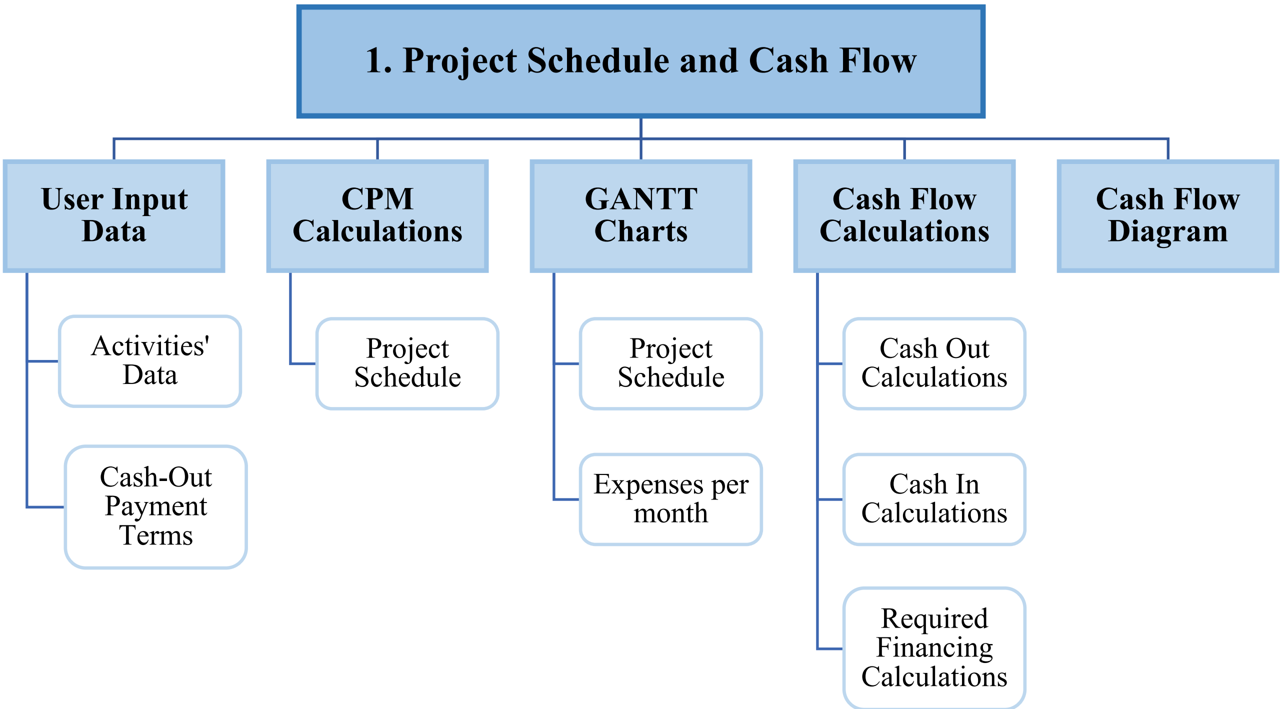


Figure 6: Project Schedule and Cash Flow

The first tab of the model **'1. Project Schedule & Cash Flow'** aims to generate the project schedule and cash flow forecast based on the input project data. It consists of five main sections summarized in **Figure 6**:

I. **User Input Data**; in which the activities' data and cash-out payment terms entered by the user are copied in form of tables to this tab. A column is added to the *Project Activities' Data table*, to calculate the Direct Cost per month for each activity by dividing the Total Activity Direct Cost by the Activity Duration. Other columns are added to the *Cash-Out Payment terms table,* to calculate the value corresponding to the Advance Payment percentage input by the user, by multiplying the Advance Payment percentage by the total direct cost of the activity. It is assumed in this model that the remaining amount after paying the advance payment will be equally distributed on the delayed payments. Regarding the delayed payment, the value entered by the user represents the lag between the start date of the activity and the date of the first payment, hence the dates for the first and last payments are calculated, besides the value of each payment.

II. **Critical Path Method (CPM) Calculations:** The model generates a table with the project schedule based on the project activities' data input by the user. In the *Project Schedule table*, scheduling is carried out using the Critical Path Method (CPM) technique, where the early start, early finish, late start, and late finish of the activities are calculated. Based on these calculations, the free float, total float and critical activities are determined. Moreover, the Total Project Duration and Project End Date are computed. An explanation of these calculations is listed below.

- **Early Start time:** The Early Start time of an activity is equal to the maximum Early Finish time of the preceding activities.
- **Early Finish time:** The Early Finish time of an activity is equal to *[Early Start time of this activity + Activity Duration].*
- **Late Start time:** The Late Start time of an activity is equal to *[Computed Late Finish time of this activity - Activity Duration].*
- **Late Finish time:** The Late Finish time of an activity is equal to the minimum Late Start time of succeeding activities. In case of the last activity, when the activity code is "Finish", the Late Finish time is equal to the maximum Early Finish time of all activities, which is also equal to the project finish time.
- **Free Float:** According to the PMBOK Guide, the activity Free Float is the amount of time an activity can be delayed without affecting the Early Start time of any successor activity. The Free Float of an activity is equal to *[Minimum Early Start time of the succeeding activities – Early Finish time of the activity].* (Project Management Institute, 2013).
- **Total Float:** According to the PMBOK Guide, the Total Float of an activity is the amount of time an activity can be delayed without affecting the *Finish date* of the project. The Total Float of an activity is equal to *[Late Finish time of the activity – Early Finish time of the activity].* (Project Management Institute, 2013).
- **Critical Activities:** The Critical Activities are the activities with zero Total Float, and if delayed, they will increase the project duration and delay the project completion date. The Critical Activities are determined by the model, in the *Project Schedule Table* as well.
- **Total Project Duration:** In this model the Total Project Duration is calculated in months. It is computed based on the CPM calculations; as the maximum Early Finish time of all the activities.

- **Project Completion Date:** The Project Completion Date is equal to the *[Project Start Date + Total Project Duration].*

III. GANTT Charts: GANTT charts graphically illustrate the activities' durations, dependencies and critical path; which creates a clear representation of the project's timeline. The Project Schedule in this model is based on the early start and early finish times of the activities. Subsequently, a GANTT chart is generated according to the Project Schedule, named *'Project Schedule GANTT chart'*. The developed GANTT chart is a horizontal bar chart that displays project activities against time, showing the duration of each activity, and its corresponding Direct Costs per month. This model assumes that the Direct Cost of each activity is distributed equally on the activity duration, for simplicity. Hence, the sum of the direct costs of the activities for each month, the monthly Fixed and Variable Overheads are computed in the last rows of the GANTT chart table. Then, adding the direct and indirect costs generates the Total Costs per month. An explanation of these calculations is listed below:

- **Total Direct Costs per month:** The sum of direct costs of activities carried out each month.
- **Monthly Fixed Overheads (MFOH):** Calculated earlier in the model and explained in section 4.4.1 in this thesis.
- **Variable Overheads (VOH):** The Variable Overheads percentage input by the user, is multiplied by the Total Direct Costs (DC) each month, to get the amount of the Variable Overheads.
- **Total Costs per month:** *[Total Direct Costs per month + MFOH + VOH]* **(3.3)**

IV. Cash Flow Calculations: In order to generate the Project Cash Flow Forecast, it is essential to carry out the Cash In and Cash Out calculations per month, then compute the corresponding cumulative values and ultimately calculate the Net Cash Flow and determine the expected amount of negative cash flows and their corresponding time, throughout the project, to be able to find the best financing alternative to minimize the cash deficit. The Cash in and Cash Out calculations are estimates assuming the amount of work performed each month match the project schedule generated.

- **Project Cash Out Calculations:** The total project cost consists of Direct Costs and Indirect Costs. The components of the direct cost of the project include material, labor, equipment and subcontractor costs incurred by the contractor (Fathi and Afshar 2010; Hinze 2012; Peterson 2013). Indirect cost is composed of the Fixed and Variable Overheads formerly explained. It is necessary to differentiate between the time when the work is done and the time when the cost of this work is actually incurred, in this case it becomes an expense. This model enables the user to input any cash-out payment terms to suppliers and/or subcontractors, including Advance Payment and delayed payment options. The Advance Payment value for each activity and the time of the delayed payments' first and last payments are determined, besides the value of each payment. The cash-out calculations of the model are computed based on the cash-out payment terms, if input by the user. If the user does not input cash-out payment terms, it is assumed that equal direct costs are incurred throughout the activity duration. The cash-out calculations are reflected in another cost-loaded GANTT chart named *'Expenses per month'* generated to display the value of the activities' expenses against time. Unlike the previous GANTT chart, the sum of the direct costs of the activities denote the amounts incurred each month, in other words these are the expenses to be paid by the contractor to carry out the project activities, based on the forecasted activities' costs and cash-out payment terms input by the user. Subsequently, adding the direct and indirect expenses generates the Total Expenses incurred each month. The monthly Fixed and Variable Overheads are read automatically from the previously explained Project Schedule GANTT chart for each month, since these overheads are not related to the time of making the payments, but related to the time when the work was performed, which is displayed in the Project Schedule GANTT chart. In order to generate a schedule showing the cash out for each month and the corresponding cumulative cash out throughout the project, a table is created including the following columns: ***Date, Months, Cost of Work Done, Invoice Submission date, Monthly Expenses and Cumulative Cash Out***. This table shows the project months and their corresponding date, then matches the cost of work done in each month, as calculated from the Project Schedule GANTT chart, using the "HLOOKUP" formula. The invoice submission date for the work done is considered to be in the beginning of the following month. For instance, the invoice for the work done in January, would be submitted in the beginning of February. The monthly expenses are matched from the Expenses per month GANTT chart using the "HLOOKUP" formula as well. Then, the corresponding cumulative cash out is calculated, by adding the expenses of the previous month to the expenses of the current month.

- **Project Cash In Calculations:** The project Cash Inflow is the amount received in periodic payments from the owner against the work performed for each period of time. The proposed model allows the user to reflect the contract conditions of the concerned project. The contractors generally submit periodic payment requests; however usually there is a time lag between the submission of payment requests and receiving the payments (denoted by L_p in this model, in months). This time lag is accounted for in the cash in calculations. In addition to the time lag between making the final progress payment and the repayment of retention (denoted by L_R in this model, in months). In this model, the periodic payments are assumed to be monthly payments. The cash in forecast is based on the planned earned values taking into consideration the billing time, besides advance payment and retention deductions. In order to estimate the amount that shall be claimed by the Contractor each month, a table is generated showing the required calculations to determine the amount of Net Cash In received by the Contractor for each month throughout the project duration, taking into consideration the Advance Payment, the Advance Payment deduction, the Retention deduction and Retention repayment. This table includes the following columns:

  - The ***Price of Work Done*** for each month; which is calculated by adding the mark up to the cost of work done each month.

$$[Cost\ of\ Work\ Done \times\ (1 + Mark\ up\ \%\ )] \qquad \textbf{(3.4)}$$

  - The ***Advance Payment***; which is the down payment made in the beginning of the project. In this model it is in "Month 0" which represents the project start date. It is calculated by multiplying the Advance Payment percentage entered by the user by the Total Contract Price.

$$[Total\ Contract\ Price \times\ (Advance\ Payment\%\ )] \qquad \textbf{(3.5)}$$

  - The ***Retention Deduction***; which is the amount retained by the owner from each progress payment. It is calculated by multiplying the Retention percentage entered by the user by the Price of Work Done for each payment.

$$[Price\ of\ Work\ Done \times\ (Retention\ \%\ )] \qquad \textbf{(3.6)}$$

  - The ***Advance Payment deduction***; which is the amount deducted from each progress payment against the advance payment paid in the beginning of the project.

$$[Price\ of\ Work\ Done \times\ (Advance\ Payment\ \%\ )] \qquad \textbf{(3.7)}$$

- The ***Repayment of retention***; which is usually made with the final payment where the retained amount is returned to the Contractor. The date of this payment is determined according to the input entered by the user in the beginning of the model, in terms of how many months after the project completion. The amount is reflected in this table in the corresponding date determined. It is calculated by multiplying the Retention percentage by the Total Contract Price to get the total amount retained from the progress payments throughout the project.

$$[Total\ Contract\ Price \times\ (Retention\ \%\ )] \qquad \textbf{(3.8)}$$

- The ***Net Cash In***; that shall be received by the contractor monthly is calculated as follows:

$$[Price\ of\ Work\ Done_{\ (each\ month)} - Retention\ Deduction - Advance\ Payment\ Deduction] \quad \textbf{(3.9)}$$

- The ***Payment due date***; is determined based on the user input value of after how many months from the invoice submission, using the "EDATE" formula. The model generates a schedule showing the Net Cash In amount and the corresponding Payment due date for this amount.

➢ **Required Financing Calculations:** Since one of the main objectives of this model is to minimize the financial costs, it is essential to forecast the cash deficit and the corresponding period of this deficit in order to determine the required financing and find the best financing alternative. The Cumulative Cash In, Cumulative Cash out, the Cumulative Finance and Monthly Finance for each month throughout the project are calculated in this part of the model, in order to determine when the maximum financing is required by the contractor and its corresponding amount. The "Required Financing Calculations" table consists of five columns: *Date, Cumulative Cash In, Cumulative Cash Out, Cumulative Finance and Monthly Finance.*

- ***Cumulative Cash In***: Cumulative values for the Net Cash In calculated in the "Cash In" schedules, according to the Payment due date. These values are automatically reflected using "VLOOKUP" formula and added to get the cumulative value for each month.
- ***Cumulative Cash Out***: Cumulative cash out values are matched from the "Cash Out" schedules, according to the Payment due date. These values are automatically reflected using "LOOKUP" formula to get the cumulative value for each month.

- ***Cumulative Finance:*** This value is calculated as *[Cumulative Cash Out $_{(this\ month)}$ – Cumulative Cash In $_{(previous\ month)}$]*. It represents the amount of financing required by the contractor. Hence, if the value is negative, it means that the Cumulative Cash In exceeds the Cumulative Cash Out by this value, so there is no cash deficit. However, if the value is positive, it means that the Cumulative Cash Out exceeds the Cumulative Cash In by this value, which is the cash deficit that requires funding. The model also determines the ***'Maximum Financing Required'*** throughout the project by getting the maximum value of Cumulative Finance throughout the project, and the corresponding month when this deficit occurs. This will be later used in the model to determine the best financing alternative that will secure sufficient funds and minimize the deficits throughout the project.
- ***Monthly Finance:*** This value is calculated as *[Cumulative Finance of this month – Cumulative Finance of the previous month]*. It represents the amount of financing required by the contractor each month separately.

V. Cash Flow Diagram: It is essential in any Cash Flow forecasting model to illustrate the Cumulative Cash In and the Cumulative Cash Out values on a chart against the corresponding months to give the user a broad idea of how the Cash Flow of the project will likely be throughout the project. Moreover, Cash Flow diagrams might be one of the requirements by the owner under the contract. Therefore, this model demonstrates the Cash Flow diagram for the project input by the user. A Table is generated by matching the Cumulative Cash In and Cumulative Cash Out values for each month using the "LOOKUP" formula, and a chart is generated based on this data. The Cumulative Cash Out curve is a curve that represents the contractor's expenses. While the Cumulative Cash In curve is a stepped curve. The area between the two curves represents the difference between the Cumulative Cash In and the Cumulative Cash out. When the cumulative Cash Out exceeds the Cumulative Cash In, this area demonstrates the shortage in cash.

3.4.3 Project Modified Schedule

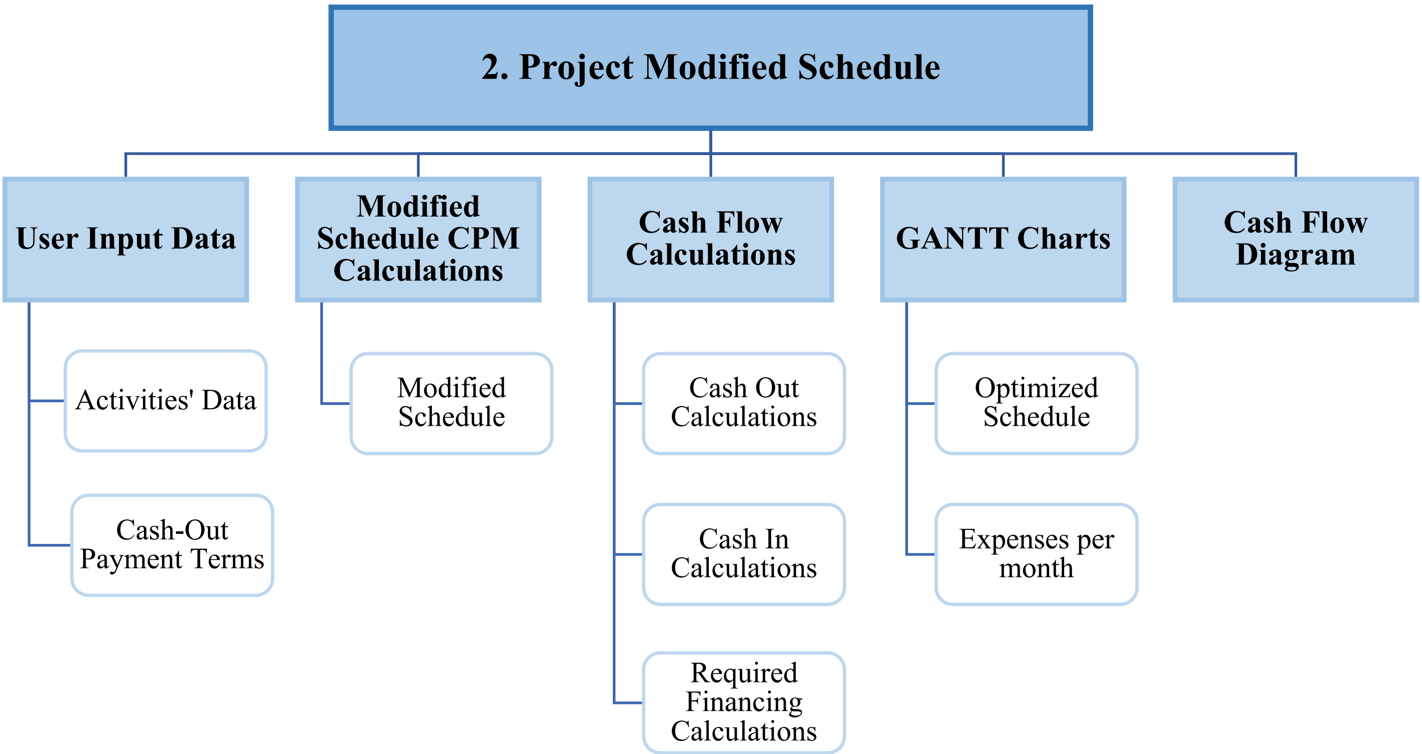


Figure 7: Project Optimized Schedule

The second tab of the model **'2. Project Modified Schedule'** aims to determine the best project schedule and generate the corresponding cash flow forecast based on the input project data. It consists of five main sections demonstrated in **Figure 7**, which are the same components of the first tab, in addition to a few tools that shall produce a Modified Schedule for the project to minimize the amount of the required financing. A copy of the previous tab is made and slight modifications are added in order to produce the enhanced Schedule and the corresponding cash flow. Optimization is carried out to generate the most feasible Project Schedule and consequently the CPM calculations, GANTT charts and all the Cash Flow calculations are computed accordingly.

I. **User Input Data**; in which the activities' data and cash-out payment terms entered by the user are automatically reflected in form of tables to this tab.

II. **Modified Schedule Critical Path Method (CPM) Calculations:** The model generates a table with the project schedule based on the project activities' data input by the user. Optimization is carried out by ***Microsoft Excel Solver Add-In***. All of the CPM calculations are similar to the ones conducted in the previous tab, however in this tab, a Modified Schedule is generated. The table consists of the following columns: Early Start, Early Finish, Late Start, Late Finish, Total Float, Free Float, and Critical Activities. A column named *'Lag'* is added to this table, this will represent the number of months that the activity can be shifted by to reach the optimum schedule and improve the cash flow, and all the values in this column are initially zero. The main objective of this optimization is to determine the modifications in the project schedule that shall improve the project cash flow and decrease the financing required by the contractor without affecting the project duration. With reference to the Literature Review and the previous optimization models that followed this concept, cash flow optimization may be achieved by shifting the non-critical activities within their free float to reach the ideal schedule with the least amount of financing required by the contractor. The total float is defined as the maximum amount of days the activities can be shifted by, without extending the project duration.

Below is an explanation of how the Solver Add-In is incorporated in this part of the model to generate a modified schedule for the project. Solver is an Excel Add-In used for optimization purposes. Solver mainly functions by optimizing an objective while satisfying the constraints. It attempts to find the optimum values for a set of decision variables in order to maximize or minimize the objective function, subject to the specified constraints (Powell and Batt, 2008). The Solver parameters consist of three main components, shown in Figure 8:

1. **The Objective function;** is a mathematical formula that is either maximized or minimized (Powell and Batt, 2008).
2. **The Changing Variable Cells**
3. **The Constraints;** are requirements and restrictions that the changing variable cells shall satisfy (Powell and Batt, 2008).

- The Objective of this optimization is to minimize the ***'Maximum Financing Required'***, which is the maximum value determined by the model from the Cumulative Finance table, formerly explained. Hence, the objective set in the model is to minimize the cell denoting the maximum financing required.
- The Changing Variable Cells, are the lags assigned for each activity, which is the 'Lag' column added. This will represent the optimum number of months that the activity can be shifted by, hence delayed by the value of this lag.

➢ The Constraints in this model are:

- The 'Lag' must be less than or equal to the 'Free Float' for each activity, in order to ensure that shifting the activities will not affect the project duration.
- The values of the 'Lag' must be integers.
- The values of the 'Lag' must be greater than or equal to zero.

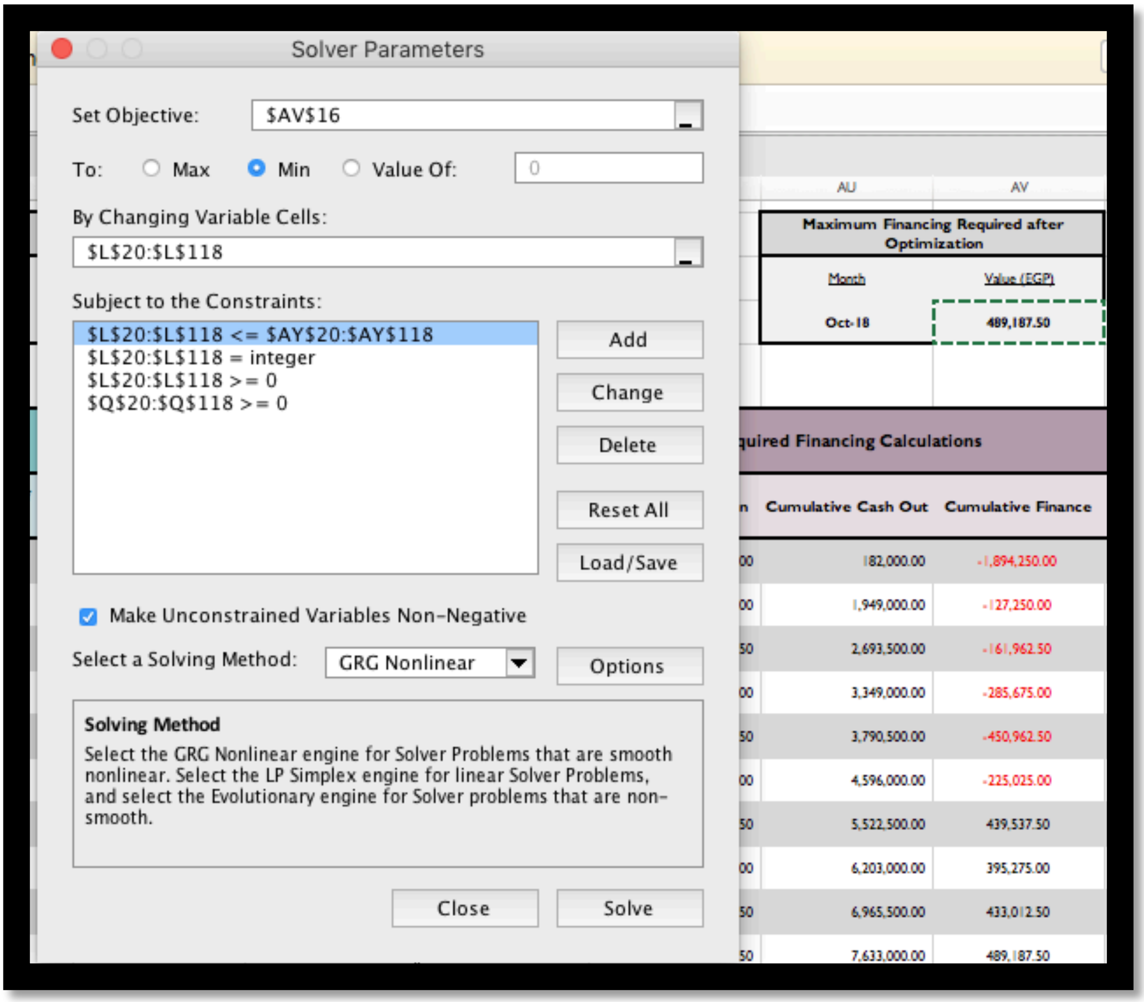


Figure 8: Solver Parameters

The '*Solving Method'* selected in this model is the '*GRG Nonlinear'* since the problem in this model is considered smooth nonlinear. The GRG (Generalized Reduced Gradient) Nonlinear solving method is intended to solve optimization problems with nonlinear objectives and constraints. Solver modifies the initial values in the changing variable cells to reach the optimum solution in the objective cell, while satisfying the specified constraints.

All of these parameters are already incorporated in the model, all the user has to do is click on 'Data', 'Solver', then 'Solve'.

Solver finds the optimum solution using iterations. The Excel Solver add-in calculates the optimal values for the 'Lag' meeting the constraints specified in the parameters, which shifts and delays some of the activities within their float, hence this leads to modification in the Project Schedule and the Project Cash Flow. In the *Modified Schedule table*, scheduling is carried out using the Critical Path Method (CPM) technique as well, where the early start, early finish, late start, and late finish of the activities are calculated. Based on these calculations, the free float, total float and critical activities are determined. All these calculations are carried out using the equations and concepts explained earlier in the tab of the base schedule, however the *Early Start time* of each activity is calculated by adding the 'Lag' to the maximum Early Finish time of the preceding activities to get the modified start date for each activity.

III. **GANTT Charts** are illustrated based on the produced enhanced Schedule and the corresponding expenses per month.

IV. **Cash Flow Calculations** incorporating Cash In, Cash Out and the Required Financing, are calculated using the same concepts and calculations formerly explained, however in this tab these calculations are based on the Modified Project Schedule produced. The corresponding maximum financing required by the contractor, shall be less after solver optimization. Hence, a table is added to compare between the maximum financing required before optimization and after optimization for the user to observe the difference achieved by shifting the activities, and reaching the first objective of this model.

V. **Cash Flow Diagram:** the model demonstrates the Cash Flow diagram based on the modified optimized project schedule and the consequent Cumulative Cash In and Cumulative Cash Out schedules.

3.4.4 Financing Alternatives

One of the key objectives of this model is to identify the amount of cash deficit and the corresponding time, then find the best financing solution that attempts to cover this deficit with the least financing cost. In the previous stages of the model, as explained, the model forecasts the amount of cash deficit, subsequently in this stage the model detects the most feasible solution to minimize this deficit with the least financing costs. Therefore, different financing alternatives are analyzed and the optimal solution is identified to the user, along with a financing schedule for the cash inflows and outflows associated with the best financing alternative. This provides the user with a comprehensive cash flow forecast incorporating the financing costs; hence the user will be able to identify a close figure of the profit that will be earned from the concerned project. There are several financing options provided by lenders with different scenarios and cases related to the time and frequency of borrowing, besides the time of paying back the principal and interest amounts. The developed model analyzes the most common financing options; short-term loans and long-term loans. A feasible cash flow forecast incorporating financing costs is crucial for the contractors to be able to negotiate the terms for a series of loans with the lending institutions (Alavipour and Arditi, 2018b). In the introduced financing optimization model, the financing alternatives offered are (1) long term loan assumed to be taken once in the beginning of the project, (2) short-term loans taken either every 3, 6 or 9 months, and (3) a combination of long- and short-term loans. Since obtaining a bulk amount of funds from one source of financing may be costly and difficult, using a combination of different set of loans from the same or different financing source may be easier and less costly (Alavipour and Arditi, 2019). Therefore, a combination of different financing options of long- and short-term loans with different interest rates, and borrowing and repayment conditions are analyzed in the proposed model, besides considering borrowing from one type of loan. Then, the best financing solution from the alternatives analyzed, is determined according to the least financing costs. It is also worth mentioning that the developed model is flexible and allows the user to only consider the financing options offered by their lenders and disregard the ones that are not applicable.

The third part of this model consists of five tabs to analyze the different financing alternatives proposed:

1. Long Term Loan
2. Short Term Loan (every 3, 6 and 9)
3. Combination of Long and Short-Term Loans

3.4.4.1 Long Term Loan

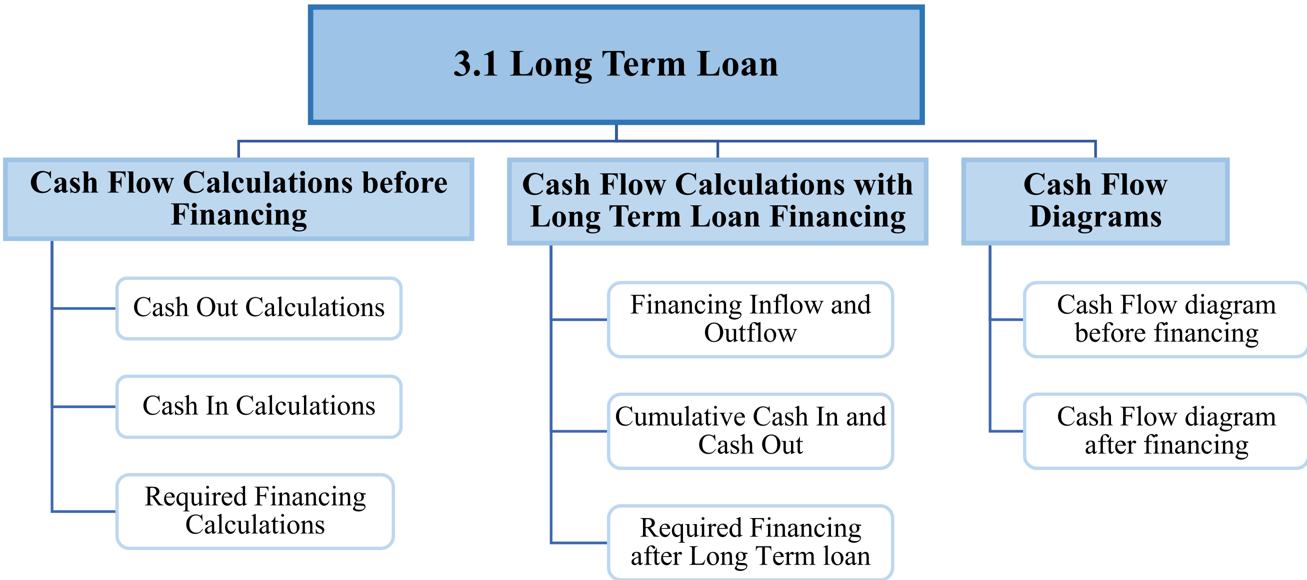


Figure 9: Long-term Loan tab

In tab **'3.1 Long Term Loan'**, the Long-Term Loan option is analyzed. According to Peavler (2016), the usual payback period for loans is either annually or semi-annually (Alavipour and Arditi, 2018c). However, according to Peterson, contractors are required by most lenders to make fixed monthly payments (Alavipour and Arditi, 2018b). In this model it is assumed to be a fixed amount taken once in the beginning of the project and monthly repayments are required; either to cover both the principal and interest amounts or to cover only the interest whereas the principal amount is paid off at the end of the project. The user is given the option to select the repayment method according to the offers proposed by the lenders.

This tab consists of three main sections; illustrated in **Figure 9,** and explained thoroughly below.

I. **Cash Flow Calculations before Financing;** reflects the values of cash flow calculations after enhancement, following the same format of the previous tab **'2. Project Modified Schedule'**, including the cumulative cash in, cash out and required financing values. The model also reflects the *'Maximum Financing Required'* throughout the project after optimization by getting the maximum value of Cumulative Finance and the corresponding month when this deficit occurs, in order to find the amount of Long-Term loan required to minimize the cash deficit throughout the project.

II. **Cash Flow Calculations with Long Term loan financing:** In this section, cash flow calculations are carried out taking into consideration the amount borrowed as a Long-

Term loan (financing inflow) and the corresponding repayment schedule (financing outflow), consequently the project cumulative cash in and cash out values are calculated incorporating the financing schedule.

A table is created to summarize the inputs and outputs of financing inflows and financing cost calculations, the table consists of following, as shown below in Figure 10:

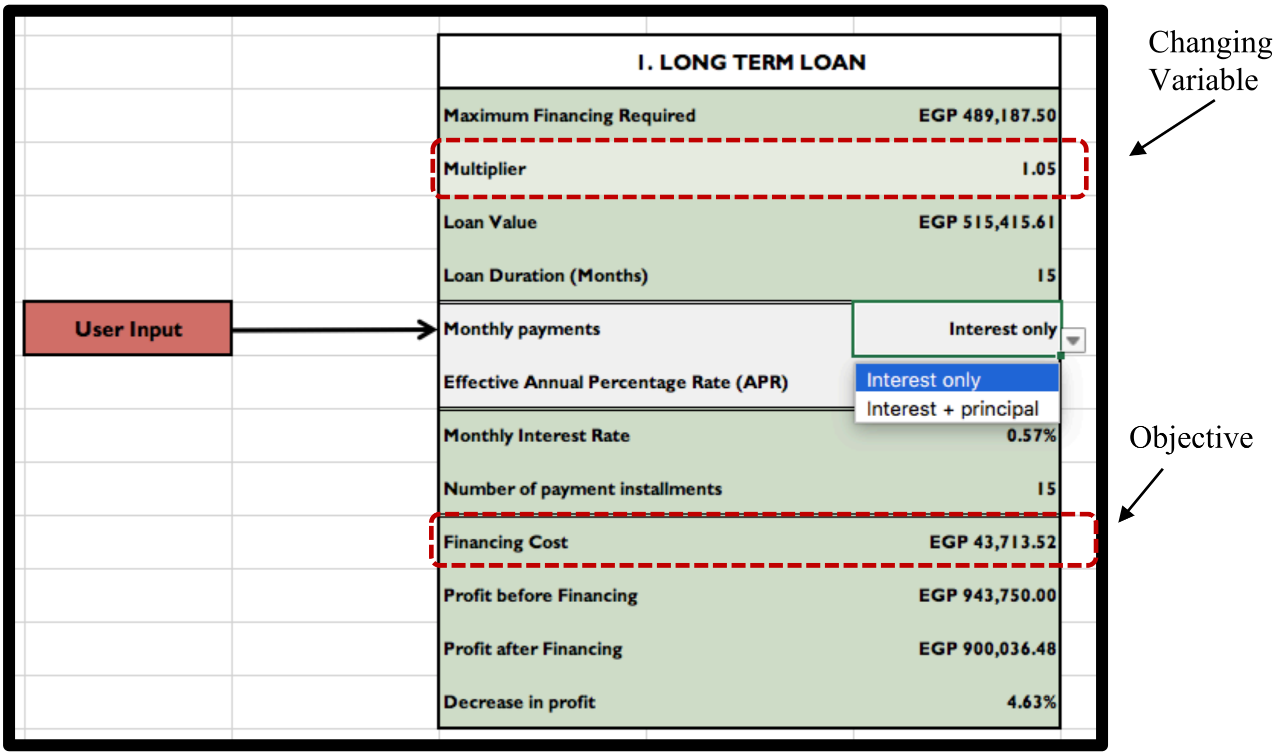


Figure 10: Long-term loan solver parameters

- The <u>maximum financing required</u> value is reflected in this table; which is the *'Maximum Financing Required'* throughout the project after optimization read from the previous section in this tab.
- <u>Multiplier;</u> where the Solver Add-In is used to identify the optimum multiplier value from the maximum amount of financing required, to cover for the cash deficit throughout the project. This will be explained in detail below.
- Hence, the <u>loan value</u> is identified by multiplying the maximum financing required value by the multiplier.
- The <u>loan duration</u> is assumed to be equal to the project duration therefore, the project duration in months is reflected in this table as the loan duration.
- This model allows the <u>Monthly Payments'</u> calculations to either cover parts of both the interest and principal, or to cover the interest only while the principal is paid off at the

end of the project. The user selects the preferred method of monthly payment calculation from the drop-down menu: "Interest only" or "Interest + principal".

- The effective annual percentage rate (APR) for the loan is input by the user (shall be offered by the lender). According to Hendrickson and Au, 2000, normally the interest rate is indicated in terms of annual percentage rate (Alavipour and Arditi, 2018b), *"which is an annualized rate that considers both compounding and lending fees"*. In the proposed model, it is assumed that the lenders offer the contractor the effective annual percentage rate (APR), which is input by the user, hence the model computes the monthly interest rate.
- The model calculates the Monthly Interest Rate using the following equation

$$(\boldsymbol{APR} + \mathbf{1})^{\frac{1}{m}} - \mathbf{1} = (\boldsymbol{APR} + \mathbf{1})^{\frac{1}{12}} - \mathbf{1} \qquad \textbf{(3.10)}$$

As formerly explained in the Literature Review chapter; incase the effective annual interest rate (APR) and compounding frequency (m, in this case 12 months per year) are identified, the abovementioned equation is the equation used to determine the effective monthly interest rate.

- Financing Costs are calculated = Total Financing Inflow – Total Financing Outflow
- Profit before Financing: automatically reflected from the 'Model Calculations Summary' tab.
- Profit after Financing = Cumulative Cash In – Cumulative Cash Out, at the end of the project, incorporating financing costs.
- Decrease in profit percentage =

$$[\frac{Profit\ before\ financing - Profit\ after\ financing}{Profit\ before\ financing}] \text{x } 100 \qquad \textbf{(3.11)}$$

Another comprehensive table is created to carry out the required calculations of the cash inflows and outflows; to prepare for the Solver Add-In optimization. This table entails the following columns: Financing Inflow, Financing Outflow, Cumulative Financing Outflow, Cumulative Cash In, Cumulative Cash Out and Cumulative Finance. These are described fully below.

- **Financing Inflow and Outflow:** In this model, the Solver Add-In is used to identify the optimum amount of funds required to be borrowed to cover the cash deficit (financing inflow), with the least financing costs. In order to solve for the optimum loan value with the least financing costs, financing cost calculations must be taken into consideration, therefore the financing outflow, which is the repayment of principal and interest is calculated. As mentioned previously, this model assumes that the long-term loan is borrowed in the beginning of the project, and fixed monthly payments are made for paying back the loan and financing costs. The financing outflow column is remarkably important; to provide the user with a clear loan repayment schedule for each month throughout the project duration.

If the "Interest + principal" option is selected by the user, each payment pays off part of the principal value along with the interest value. The financing outflow is calculated using the "**PMT" formula** in Microsoft Excel, which applies the Time Value of Money concepts in determining the amount of equal periodic loan repayments (in this model assumed to be monthly payments), taking into consideration the given interest rate. The "PMT" formula is applied in the '*Financing Outflow'* column as follows:

= -PMT(rate; length; present_value; [future_value]; [type])

- rate: monthly interest rate (%)
- length (number of periods): project duration in months
- present_value: loan value
- future_value and type: these are optional arguments that were not used in this model and put as zero
- This formula gives a negative value, so a minus sign before the equation is essential.

If the "Interest" option is selected by the user, each monthly payment includes only the interest value, and the principal is paid off at the end of the loan period. The financing outflow is calculated using the following equation: ***[Monthly Interest Rate x Loan Value],*** taking into consideration the given interest rate.

Below is an explanation of how the Solver Add-In is utilized in this part of the model to identify the optimum long-term loan amount, which is the financing inflow, required to cover the cash deficit with the least financing cost.

The Solver parameters consist of three main components:

1. **The Objective**
2. **The Changing Variable Cells**
3. **The Constraints**

The Objective of this optimization is to minimize the ***'Financing Costs'***, which is the difference between the total financing inflows and total financing outflows,
stated earlier, and it represents the interest applied by the lenders for offering the required loan. Hence, the objective set in the model is to minimize the cell representing the

financing costs, clarified in Figure 10. The Changing Variable Cells, is the ***'Multiplier'*** that shall be solved for by the Solver Add-in to determine the optimum loan value required to cover the cash shortage. The Constraints in this model are that the 'Multiplier' shall be greater than or equal to zero, and all the values in the 'Cumulative Finance' column shall be less than or equal zero; meaning that no further financing is required from the contractor after taking this loan.

The '*Solving Method'* selected in this model is the '*GRG Nonlinear'* since the problem in this model is considered smooth nonlinear. All of these parameters are already built-in in the model, all the user has to do is click on 'Data', 'Solver', then 'Solve'.

The Solver solves for the optimum Multiplier, which is then multiplied by the maximum financing required value previously determined, to get the loan value required to cover the cash shortage. This value is reflected in the Financing Inflow column which is a requirement to calculate the financing outflow values for each month and cumulative cash in and cash out values throughout the project.

- **Cumulative Financing Outflow:** In this column, the Cumulative Financing Outflow values are calculated for each month, by adding the value of the current month to the cumulative value as of the previous month, to track the total amount of loan repayments throughout the project.
- **Cumulative Cash In and Cash Out:** The Cumulative Cash In after financing value computed in this column is the summation of the Cumulative Cash received from the client (as a result of the work done on site) and the financing inflow (which is loan borrowed). Similarly, the Cumulative Cash Out after financing value is calculated by adding the Cumulative Cash expended on the project to the financing outflow amounts (interest charges and/or loan principal repayment). Hence, a comprehensive Cash In and Cash Out schedules are formed; incorporating the financing inflows and outflows for the project.
- **Required Financing after Long-Term loan:** The Cumulative Finance column calculation is carried out by subtracting the Cumulative Cash In from the Cumulative Cash out (after financing values are added), which shall produce values less than or equal to zero. This denotes that taking this loan attains its objective of covering the Contractor's cash shortage during the whole project.

III. Cash Flow Diagrams: Cash In versus Cash Out cash flow diagrams are illustrated in this part of the tab; where the cash flow profile before the loan financing is portrayed against the cash flow profile after the loan financing; to provide a comparison showing the difference in cash flows, before and after covering the shortage in cash.

In summary, this tab aims to detect the optimum value for the long-term loan to be borrowed at the beginning of the project, that would require the least financing costs, given the model assumptions and constraints, and covers all the cash shortage during the concerned project. Ultimately, a financing inflow and outflow schedule is produced to provide the user a comprehensive representation of the cash flow of their project. In addition, there is a table that summarizes the calculations and impacts of the loan (formerly explained); including the Financing Costs, Profit before financing, Profit after financing, and the percentage decrease in profit due to financing.

3.4.4.2 Short Term Loans

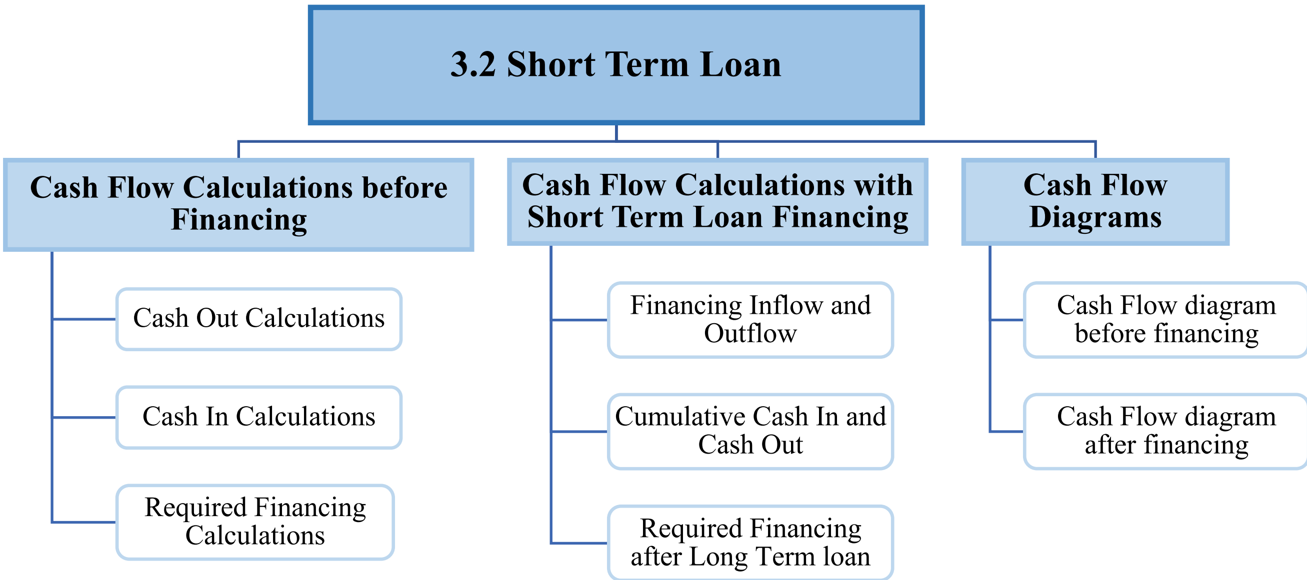


Figure 11: Short-term loans tab structure

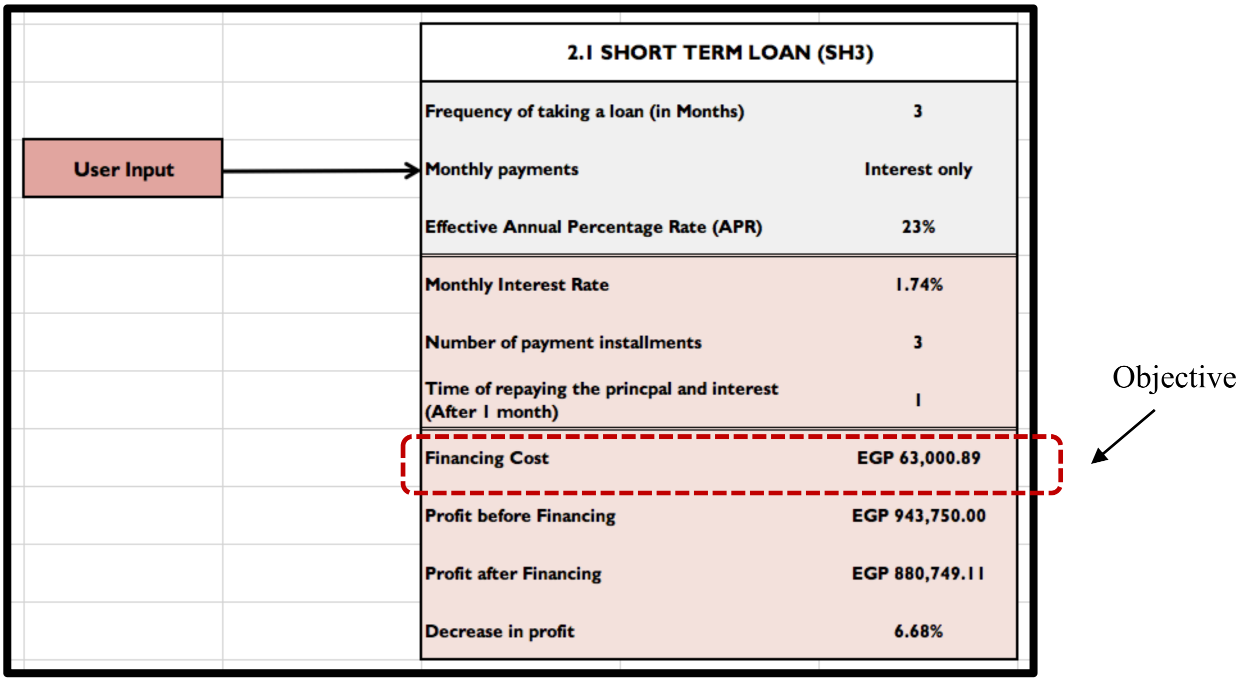
In tabs **'3.2.1 Short Term Loan (SH3)', '3.2.2 Short Term Loan (SH6)' and '3.2.3 Short Term Loan (SH9)'**, the Short-Term Loan options are studied. There are several scenarios and options proposed by the lenders providing Short-Term loans; including various borrowing frequencies, times of repaying the principal and interest, and the number of installments required to pay off the loan. This model covers three scenarios for the Short-Term loan alternative; where the borrowing frequency may be every 3, 6 or 9 months; each scenario analyzed separately. In other words, there are three tabs analyzing the short-term loans scenarios; assuming taking a loan: [1] every 3 months (SH3), [2] every 6 months (SH6), and [3] every 9 months (SH9), when needed.

The model investigates the 'Cumulative Finance' amounts every 3, 6 or 9 months; corresponding to the short-term option analyzed, and reflects the maximum financing required in the concerned period, throughout the project duration. Monthly repayments are required to cover only the interest whereas the principal amount is paid off at the end of the loan period. This tab consists of three main sections; illustrated in **Figure 11,** and explained thoroughly below.

I. **Cash Flow Calculations before Financing;** similar to the **'Long-Term Loan'** tab, values of cash flow calculations after optimization are reflected, following the same format of the previous tab **'2. Project Modified Schedule'**, including the cumulative cash in, cash out and required financing values. The model also reflects the *'Maximum Financing Required'* throughout the project after optimization by getting the maximum value of Cumulative Finance and the corresponding month when this deficit occurs, in order to determine the amounts of Short-Term loans required to minimize the cash deficit throughout the project.

II. **Cash Flow Calculations with Short Term loan financing:** In this section, cash flow calculations are carried out taking into consideration the amounts borrowed as a Short-Term loan (financing inflow) and the corresponding repayment schedule (financing outflow), consequently the project cumulative cash in and cash out values are calculated incorporating the financing schedule.

A table is created to summarize the inputs and outputs of financing inflows and financing cost calculations, the table consists of following, as shown below in Figure 12:



2.1 SHORT TERM LOAN (SH3)	
Frequency of taking a loan (in Months)	3
Monthly payments	Interest only
Effective Annual Percentage Rate (APR)	23%
Monthly Interest Rate	1.74%
Number of payment installments	3
Time of repaying the princpal and interest (After 1 month)	1
Financing Cost	EGP 63,000.89
Profit before Financing	EGP 943,750.00
Profit after Financing	EGP 880,749.11
Decrease in profit	6.68%

Figure 12: Short-term loan parameters

- The frequency of taking the loan, in months, in this model, is either every 3, 6 or 9 months.
- The <u>loan duration</u> is assumed to be equal to the frequency of borrowing funds. For instance, if the frequency of obtaining short-term loans is every 3 months, the loan duration and repayment period will be 3 months as well.
- This model allows the <u>Monthly Payments'</u> calculations to either cover parts of both the interest and principal, or to cover the interest only while the principal is paid off at the end of the project. The user selects the preferred method of monthly payment calculation from the drop-down menu: "Interest only" or "Interest + principal".
- The <u>effective annual percentage rate</u> (APR) for the loan is input by the user (shall be offered by the lender).
- The model calculates the <u>Monthly Interest Rate</u> using the equation explained earlier.
- Time of repaying the principal and/or interest; this model assumes monthly repayments that start after one month from borrowing the funds.
- <u>Financing Costs</u> are calculated = Total Financing Inflow – Total Financing Outflow

- Profit before Financing: automatically reflected from the 'Model Calculations Summary' tab.
- Profit after Financing = Cumulative Cash In – Cumulative Cash Out, at the end of the project, incorporating financing costs.

- Decrease in profit percentage =

$$\left[\frac{Profit\ before\ financing - Profit\ after\ financing}{Profit\ before\ financing}\right] x\ 100 \qquad \textbf{(3.12)}$$

In the analysis of short-term loans, the model searches for the optimum loan values that shall be borrowed and their corresponding time, in order to cover the cash shortage with the least financing costs. This is incorporated in the model through utilizing a series of Excel formulas. Referring to Figure 13, it shows an example to explain how the model determines the ideal values for the series of short-term loans in an attempt to overcome the cash deficits. In the 'Maximum Financing Required' column the model determines the maximum 'Cumulative Finance', before financing, value every 3, 6 or 9 months, depending on the scenario being analyzed. The below example is applied to the case of short-term loans every 3 months; hence the maximum values of Cumulative Finance are reflected each 3 months. Negative values of Cumulative Finance mean that the net cash flow is positive and no financing is required, therefore the Multiplier column automatically becomes zero when the maximum cumulative finance value is negative. Nevertheless, when the maximum cumulative finance value is positive, a multiplier value is determined by the model to calculate the values of short-term loans required.

Solver Add-In is used to identify the optimum multiplier value from the maximum amount of financing required every 3 months, to cover for the cash deficit throughout the project. This will be explained in detail below. Hence, the loan values are identified by multiplying the maximum financing required value by the multiplier for each period.

Changing Variables

Cumulative Finance	Maximum Financing Required	Multiplier	Months	Financing Inflow	Cumulative Financing Inflow	Financing Outflow (Interest and/or principal)	Cumulative Financing Outflow	Cumulative Cash In	Cumulative Cash Out	Cumulative Finance
-1,894,250.00	(127,250.00)	0.00	0	-	-	-		2,076,250.00	182,000.00	(1,894,250.00)
-127,250.00	0.00	0.00	1	-	-	-	-	2,076,250.00	1,949,000.00	(127,250.00)
-161,962.50	0.00	0.00	2	-	-	-	-	2,855,462.50	2,693,500.00	(161,962.50)
-285,675.00	(225,025.00)	0.00	3	-	-	-	-	3,634,675.00	3,349,000.00	(285,675.00)
-450,962.50	0.00	0.00	4	-	-	-	-	4,241,462.50	3,790,500.00	(450,962.50)
-225,025.00	0.00	0.00	5	-	-	-	-	4,821,025.00	4,596,000.00	(225,025.00)
439,537.50	**439,537.50**	**1.03**	6	451,498.78	451,498.78	-	-	5,534,461.28	5,522,500.00	(11,961.28)
395,275.00	0.00	0.00	7	-	451,498.78	7,856.46	7,856.46	6,259,223.78	6,210,856.46	(48,367.32)
433,012.50	0.00	0.00	8	-	451,498.78	7,856.46	15,712.92	6,983,986.28	6,981,212.92	(2,773.36)
489,187.50	**489,187.50**	**1.05**	9	515,976.22	967,474.99	459,355.23	475,068.15	8,111,287.49	8,108,068.15	(3,219.34)

Figure 13: Short-term loan calculations

Another comprehensive table is created to carry out the required calculations of the cash inflows and outflows; to prepare for the Solver Add-In optimization. This table entails the following columns: Financing Inflow, Financing Outflow, Cumulative Financing Outflow, Cumulative Cash In, Cumulative Cash Out and Cumulative Finance. These are described fully below.

- **Financing Inflow and Outflow:** In this model, the Solver Add-In is used to identify the optimum amount of funds required to be borrowed to cover the cash deficit (financing inflow), with the least financing costs. In order to solve for the optimum loan values with the least financing costs, financing cost calculations must be taken into consideration, therefore the financing outflow, which is the repayment of principal and interest is calculated. The model assumes that the repayments for the principal amount of the short-term loans are made 3, 6 or 9 months after the loan is obtained, matching the frequency of taking the loans, whereas the interest charges are paid monthly. In other words, each monthly payment includes only the interest value, and the principal is paid off at the end of the loan period. The financing outflow is calculated using the following equation: ***[Monthly Interest Rate x Loan Value],*** taking into consideration the given interest rate.

  Below is an explanation of how the Solver Add-In is utilized in this part of the model to identify the optimum values for the series of short-term loans, which is the financing inflow, required to minimize the cash deficit with the least financing cost.

The Solver parameters consist of three main components:

1. **The Objective**
2. **The Changing Variable Cells**
3. **The Constraints**

- The Objective of this optimization is to minimize the ***'Financing Costs'***, which is the difference between the total financing inflows and total financing outflows, stated earlier, and it represents the interest applied by the lenders for offering the required loan. Hence, the objective set in the model is to minimize the cell representing the financing costs, clarified in Figure 12.
- The Changing Variable Cells, is the ***'Multiplier'*** that shall be solved for by the Solver Add-in to determine the optimum short-term loan values required to cover the cash shortage.
- The Constraints in this model are that:
  - The 'Multiplier' shall be greater than or equal to zero
  - All the values in the 'Cumulative Finance' column after financing shall be less than or equal zero; meaning that no further financing is required from the contractor after taking this loan.
  - The Multiplier value shall be less than or equal to 10; the model specifies a ceiling for the multiplier value.

The '*Solving Method'* selected in this model is the '*GRG Nonlinear'* since the problem in this model is considered smooth nonlinear. All of these parameters are already built-in in the model, all the user has to do is click on 'Data', 'Solver', then 'Solve'. The Solver solves for the optimum Multipliers, which are then multiplied by the maximum financing required values, every 3, 6 or 9 months, to get the loan values required to cover the cash shortage. These values are reflected in the Financing Inflow column which is a requirement to calculate the financing outflow values for each month and cumulative cash in and cash out values throughout the project.

➢ **Cumulative Financing Inflow and Outflow:** In this table, the Cumulative Financing Inflow and Outflow values are calculated for each month, by adding the value of the current month to the cumulative value as of the previous month, to track the total amount of loan borrowings and repayments throughout the project.

- **Cumulative Cash In and Cash Out:** The Cumulative Cash In after financing value computed in this column is the summation of the Cumulative Cash received from the client (as a result of the work done on site) and the financing inflow (which are the loans borrowed). Similarly, the Cumulative Cash Out after financing value is calculated by adding the Cumulative Cash expended on the project to the financing outflow amounts (interest charges and/or loan principal repayment). Hence, a comprehensive Cash In and Cash Out schedules are formed; incorporating the financing inflows and outflows for the project.

- **Required Financing after Short-Term loans:** The Cumulative Finance column calculation is carried out by subtracting the Cumulative Cash In from the Cumulative Cash out (after financing values are added), which shall produce values less than or equal to zero. This denotes that obtaining the determined set of loans attains the main objective of covering the Contractor's cash shortage during the whole project.

III. **Cash Flow Diagrams:** Cash In versus Cash Out cash flow diagrams are illustrated in this part of the tab; where the cash flow profile before the series of short-term loan financing is portrayed against the cash flow profile after the loans financing; to provide a comparison showing the difference in cash flows, before and after covering the shortage in cash.

In summary, these tabs aim to detect the optimum value for a series of short-term loans to be borrowed with the selected frequency (3, 6 or 9 months), that would require the least financing costs, given the model assumptions and constraints, and covers all most possible cash shortage during the concerned project. Ultimately, a financing inflow and outflow schedule is produced to provide the user a comprehensive representation of the cash flow of their project. In addition, there is a table that summarizes the calculations and impacts of the loans (formerly explained); including the Financing Costs, Profit before financing, Profit after financing, and the percentage decrease in profit due to financing.

3.4.4.3 Combined Set of Loans

As formerly discussed, this model allows the user to analyze several financing options, where the model calculates the optimum financing amounts to be borrowed and their corresponding timing, subject to the constraints and the interest rates specified; besides producing a comprehensive financing inflow and outflow schedules throughout the whole project and the subsequent cumulative cash in and cash out calculations as well.

The financing options analyzed separately by this model are:

- Long-term loan; assumed to be taken at the beginning of the project and paid off at the end of the project.
- A set of short-term loans borrowed every 3 months, when needed, with monthly interest payments and the principal amount repaid after 3 months.
- A set of short-term loans borrowed every 6 months, when needed, with monthly interest payments and the principal amount repaid after 6 months.
- A set of short-term loans borrowed every 9 months, when needed, with monthly interest payments and the principal amount repaid after 9 months.

In this section of the model, a combined option is introduced to integrate the four alternatives that were analyzed separately to get the optimum set of different types of loans with different terms and interest rates. The main objective is to find the best set of loan combinations that would satisfy the project's cash requirements with the minimum financing costs, in order to achieve the highest profitability.

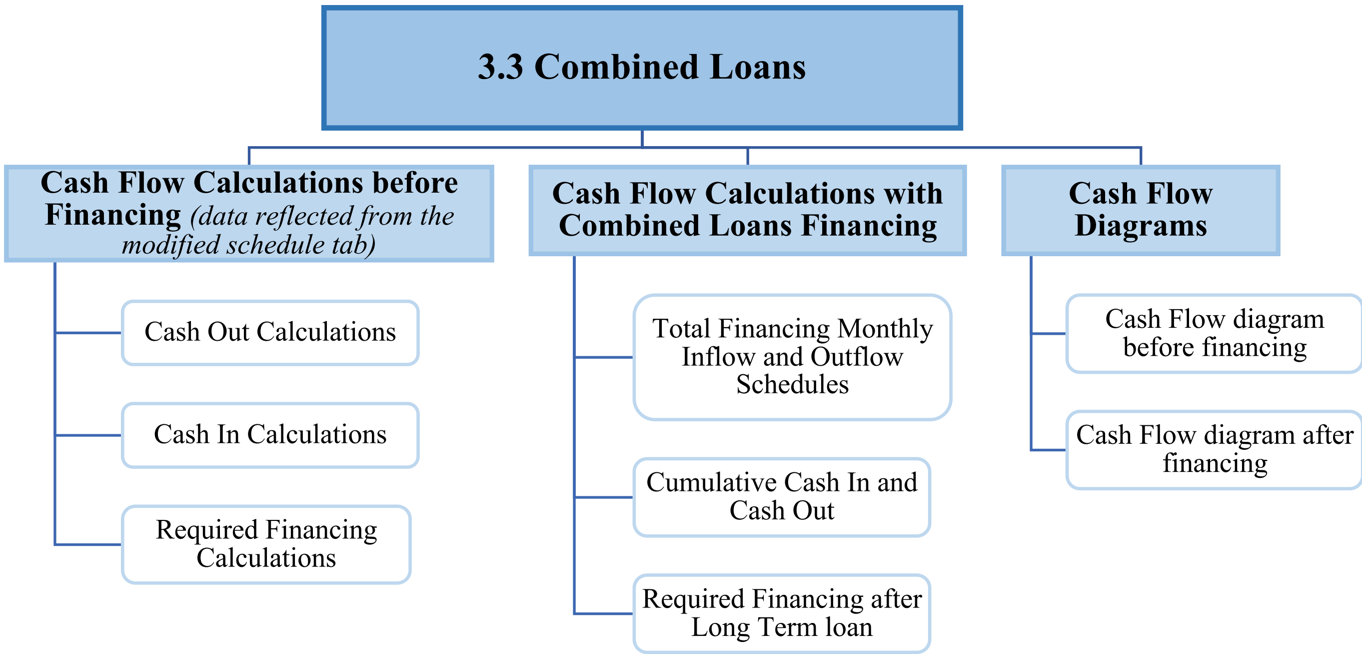


Figure 14: Combined Loans tab structure

Figure 14 summarizes the components of the combined loans tab. Refer to the below Figure 15, for the simple process of inputs required by the user.

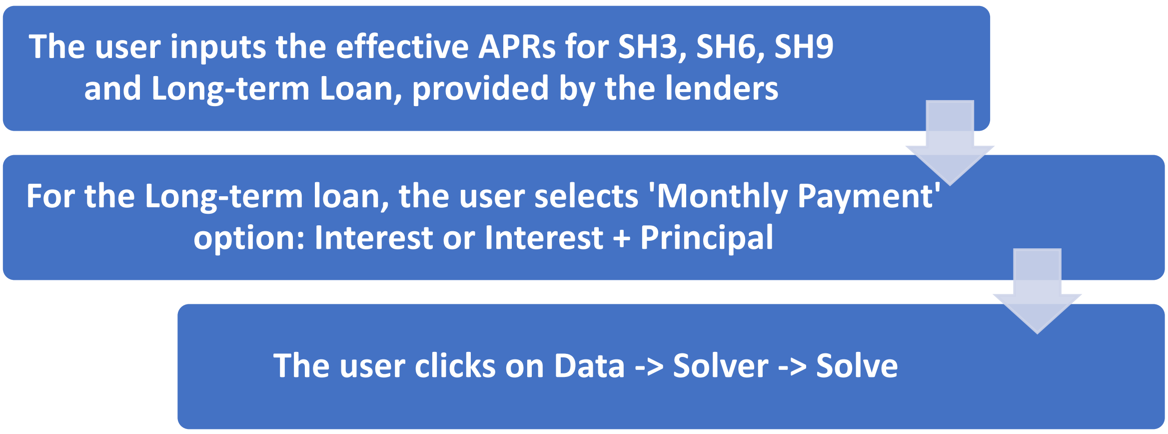


Figure 15: Combined Loans - User Inputs

Following the same methods followed in the long- and short-term loans; using the Solver Add-In, the model analyzes and determines the optimal multipliers every month, for each type of loan, if needed, which are then multiplied by the maximum financing required values. The maximum cumulative financing required throughout the project in case of the long-term loan, and the maximum values every 3, 6 or 9 months in the cases of short-term loans, are multiplied by the optimal multipliers determined by the solver, to get the loan values required to minimize the cash shortage with the least possible financing costs.

Below is an explanation of how the Solver Add-In is utilized in this part of the model to identify the optimum values for the series of different types of loans, which is the financing inflow, required to cover the cash deficit with the least financing cost. The Solver parameters consist of three main components:

1. **The Objective**
2. **The Changing Variable Cells**
3. **The Constraints**

- The Objective of this optimization is to minimize the ***'Total Financing Costs'***, which is the difference between the total financing inflows and total financing outflows, for the set of loans determined, and it represents the interest applied by the lenders for offering the required loans.

3. COMBINED OPTION	
Total borrowed amount	EGP 826,771.74
Financing Cost	EGP 54,444.17
Profit before Financing	EGP 943,750.00
Profit after Financing	EGP 889,305.83
Decrease in profit	5.77%

Figure 16: Combined Option summary table

- The Changing Variable Cells, is the ***'Multiplier'*** that shall be solved for by the Solver Add-in to determine the optimum loan values required to cover the cash shortage.
- The Constraints in this model are that:
    - The 'Multiplier' shall be greater than or equal to zero
    - All the values in the 'Cumulative Finance' column after financing shall be less than or equal zero; meaning that no further financing is required from the contractor after taking this loan.
    - The Multiplier value shall be less than or equal to 10; the model specifies a ceiling for the multiplier value.

The '*Solving Method'* selected in this model is the '*GRG Nonlinear'* since the problem in this model is considered smooth nonlinear. All of these parameters are already built-in in the model, all the user has to do is click on 'Data', 'Solver', then 'Solve'.

A set of calculations are carried out by the model to guide the user in analyzing this financing alternative; such as the total borrowed amount, the total financing costs, the profit before and after financing and consequent percentage decrease in profit, shown in Figure 16. Then the model develops a schedule that illustrates the corresponding optimum financing inflow and out flow on a monthly basis, for each type of loan and their subsequent total, as per Figure 17. The financing outflow calculations for the long- and short-term loans are following the same equations and concepts applied in the analysis of the previous separate alternatives, explained earlier. In the case of long-term loans, the user is given the option to choose the fixed monthly repayments to incorporate either interest charges only and the principal is paid off at the end of the loan duration, or interest and part of the principal. As for the short-term loans, the model assumes fixed monthly repayments of interest charges, and the principal amount is repaid at the end of the loan period.

OPTIMIZED FINANCING MONTHLY INFLOW SCHEDULE					
Months	SH3	SH6	SH9	L1	TOTAL
0	-	-	-	260,124.71	260,124.71
1	-	-	-	-	-
2	-	-	-	-	-
3	-	-	-	-	-
4	-	-	-	-	-
5	-	-	-	-	-
6	63,640.00	263,883.49	-	-	327,523.49
7	-	-	-	-	-
8	-	-	-	-	-
9	57,594.00	-	118,423.54	-	176,017.54
10	-	-	-	-	-
11	-	-	-	-	-
12	63,106.00	-	-	-	63,106.00
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-

OPTIMIZED FINANCING MONTHLY OUTFLOW SCHEDULE					
Months	SH3	SH6	SH9	L1	TOTAL
0	-	-	-	-	-
1	-	-	-	18,136.38	18,136.38
2	-	-	-	18,136.38	18,136.38
3	-	-	-	18,136.38	18,136.38
4	-	-	-	18,136.38	18,136.38
5	-	-	-	18,136.38	18,136.38
6	-	-	-	18,136.38	18,136.38
7	1,107.39	3,664.93	-	18,136.38	22,908.70
8	1,107.39	3,664.93	-	18,136.38	22,908.70
9	64,747.39	3,664.93	-	18,136.38	86,548.70
10	1,002.18	3,664.93	1,212.28	18,136.38	24,015.78
11	1,002.18	3,664.93	1,212.28	18,136.38	24,015.78
12	58,596.18	267,548.42	1,212.28	18,136.38	345,493.27
13	1,098.10	-	1,212.28	18,136.38	20,446.76
14	1,098.10	-	1,212.28	18,136.38	20,446.76
15	64,204.10	-	1,212.28	18,136.38	83,552.76
16	-	-	1,212.28	-	1,212.28
17	-	-	1,212.28	-	1,212.28
18	-	-	119,635.82	-	119,635.82

Figure 17: Optimum financing monthly schedule

The Cumulative Financing Inflow and Outflow are calculated for each month, by adding the value of the current month to the cumulative value as of the previous month, to track the total amount of loan borrowings and repayments throughout the project.

The **Cumulative Cash In** after financing is calculated by summing the total of the Cumulative Cash received from the client (as a result of the work done on site) and the financing inflow (which is the total value of borrowed loans). Likewise, **the Cumulative Cash Out** after financing value is calculated by adding the Cumulative Cash incurred on the project activities to the financing outflow amounts (interest charges and/or loan principal repayment). Hereafter, a complete Cash In and Cash Out schedules are produced; including the financing inflows and outflows, besides the associated financing costs. Ultimately, the Cumulative Finance column calculation is carried out by subtracting the Cumulative Cash In from the Cumulative Cash out (after financing values are added), which shall produce values less than or equal to zero. This designates that obtaining the determined set of loans attains the main objective of minimizing the cash deficiency throughout the project.

Finally, Cash In versus Cash Out cash flow diagrams are illustrated; where the cash flow profile before the series of combined loan financing is portrayed against the cash flow profile after the loans financing; to provide a comparison showing the difference in cash flow profiles, before and after tackling the cash flow financing problems.

3.4.5 Negotiable Bid

In this section, the model investigates another solution other than borrowing funds from a lending institution to overcome the cash overdraft. The advance payment plays a huge role in the cash flow improvement; as it reliefs the financial burden on the contractor, especially during the initial phase of the project (Hussin and Omran, 2009). Moreover, studies have proven that the advance payment is a reliable method to reduce the net negative cash flow, and increasing the advance payment may be one of the methods to improve the cash flow profile and support the contractor in carrying out the project more efficiently and effectively (Hussin and Omran, 2009; Al-Joburi et al., 2012).

Hence, this tool allows the user to calculate the increase in advance payment required to cover the net negative cash flow throughout the project and to keep the project financing itself, subject to the contract and payment terms. In order to carry out proper negotiations with the client, the contractor shall present an incentive for the increase in advance payment, which in this case would be decrease in profit, in terms of offering a discount on the total contract price.

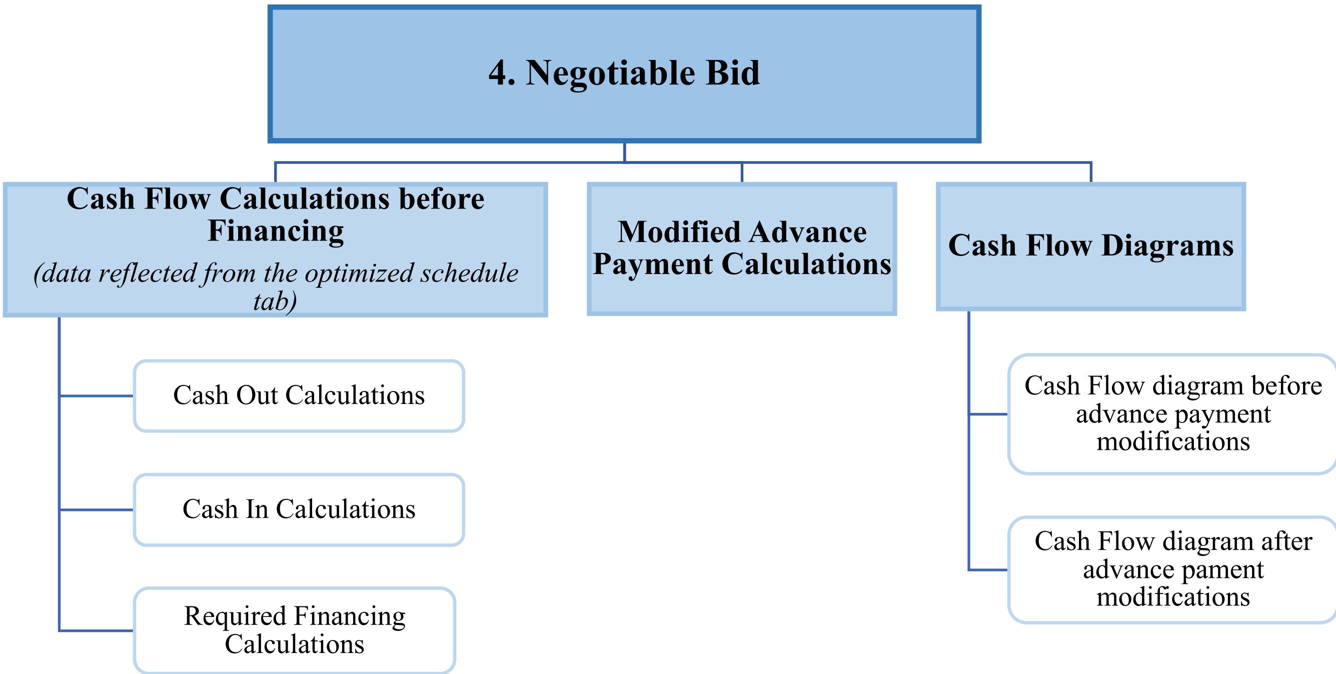


Figure 18: Negotiable Bid

The above Figure 18, simplifies the structure of this section of the model. The optimized schedule determined earlier in the model, and the corresponding cash flow calculations are reflected in this sheet, and accordingly the objective is to decrease the overdraft amount throughout the project to zero, by finding the optimum increase in advance payment and decrease in profit. After finding the optimum increase in advance payment, the model computes the Cash Flow Calculations based on the modified Advance Payment and Profit. Then, the cash flow diagrams before and after the advance payment modifications are illustrated to visualize the effect of increasing the advance payment on the cash flow profile.

The Modified Advance Payment calculations, as formerly mentioned, depend on increasing the advance payment percentage against, finding the suitable decrease in profit. This model considers the decrease in profit obtained from the four financing alternatives studied, as a result of the associated financing costs; and determines the minimum value of decrease in profit to be presented as the allowable decrease in profit that the contractor may offer. This method is applied in an attempt to find a better way of overcoming the cash shortage, without compromising more profit than in the cases of borrowing. If the contractor succeeds to obtain the desired increase in advance payment percentage, while offering the same decrease in profit associated with borrowing funds, this shall be a better option for the contractor to proceed with, to avoid all the hassle and the coordination related to borrowing funds.

Solver Add-In is applied in this part of the model as well to identify the optimum increase in advance payment, corresponding to the identified decrease in profit, that shall overcome the cash shortage throughout the project.

- The Objective of this optimization is to find the minimum increase in advance payment.
- The Changing Variable Cell, is the ***'Multiplier'*** that shall be solved for by the Solver Add-in to determine the optimum increase in advance payment shall meet the required objective.
- The Constraints in this model are that:
    - All the values in the 'Cumulative Finance' column after the advance payment modification shall be less than or equal zero; meaning that no financing is required from the contractor after increasing the advance payment.
    - The Multiplier value shall be greater than or equal to 1.

The output of this tool is summarized in the below Figure 19. The modified advance payment is calculated by multiplying the original advance payment percentage by the multiplier determined by solver to get the modified percentage. The decrease in profit as discussed earlier, is the minimum percentage from the four financing alternatives studied, and the modified markup percentage is calculated by multiplying the original markup value by the determined decrease in profit percentage. Finally, the decrease in profit amount is calculated, besides the corresponding discount percentage that the contractor can offer to the client against the increase in advance payment, and the resultant modified Total Contract Price.

Negotiable Bid Calculations	
Original Advance Payment (%)	20%
Multiplier	2.26
Modified Advance Payment (%)	45%
Increase in Advance Payment (%)	25%
Original Mark up (%)	10%
Decrease in profit (%)	5.77%
Modified Mark up (%)	9.42%
Modified Mark up Value (% of [DC+FOH+VOH])	EGP 889,305.83
Decrease in profit	EGP 54,444.17
Discount	-0.5244%
Modified Total Contract Price	EGP 10,326,805.83

Changing Variable

Figure 19: Negotiable Bid calculation

3.4.6 Model Calculations Summary

A model calculations summary tab is established; including the following components in Figure 20, to summarize all the model outputs and calculations.

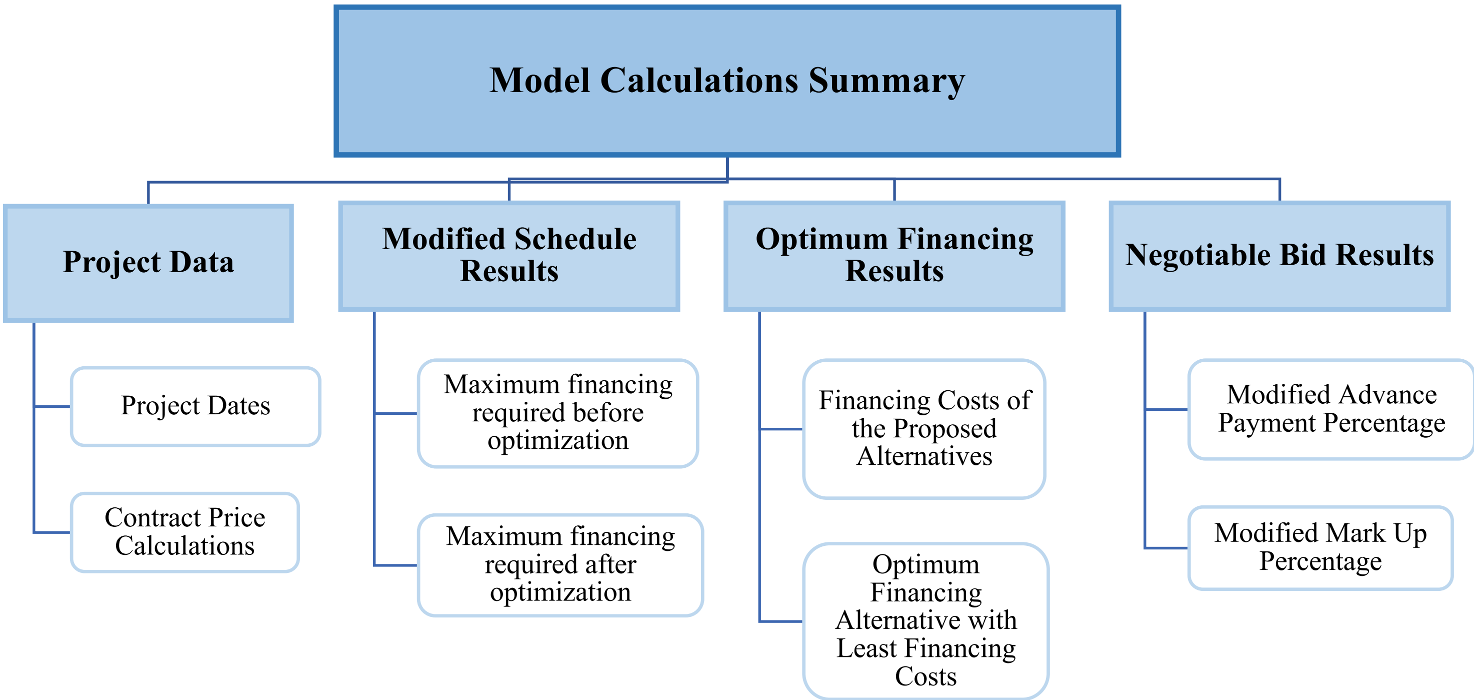


Figure 20: Model Calculations Summary

Chapter 4

4 Model Verification

In order to verify the viability of the model developed, a sensitivity analysis is conducted.

4.1 Sensitivity Analysis

A sensitivity analysis is carried out to ensure that the model meets the main objectives specified, while changing the different parameters. One input parameter is changed whereas the rest of the parameters are fixed at the initial values (Zayed and Liu, 2014), to test the model's ability to react to different values of various factors. For the purpose of verifying the model; sensitivity analysis is carried out by changing parameters in the contract terms of the project, to explore the effects of contract terms on the total financing costs determined by the model. Three parameters were selected to conduct the sensitivity analysis on; namely:

- Retention percentage (initial fixed value: 5%)
- Advance Payment percentage (initial fixed value: 20%)
- Lag in paying the Payment Requests (initial fixed value: 1 month)

In addition, varying the financing parameters (i.e. the effective interest Annual Percentage Rate), is analyzed as well.

4.1.1 Retention Percentage

The values of the retention percentage were adjusted, to investigate the impact of changing the retained values on the required amounts to be financed by the contractor, which is the net negative cash flow, and hence on the amount of financing costs.

First, the retention percentage is explored against the maximum amount of financing required by the contractor throughout the project, according to the initial schedule and after the optimization conducted by the model. This is illustrated in Figure 21.

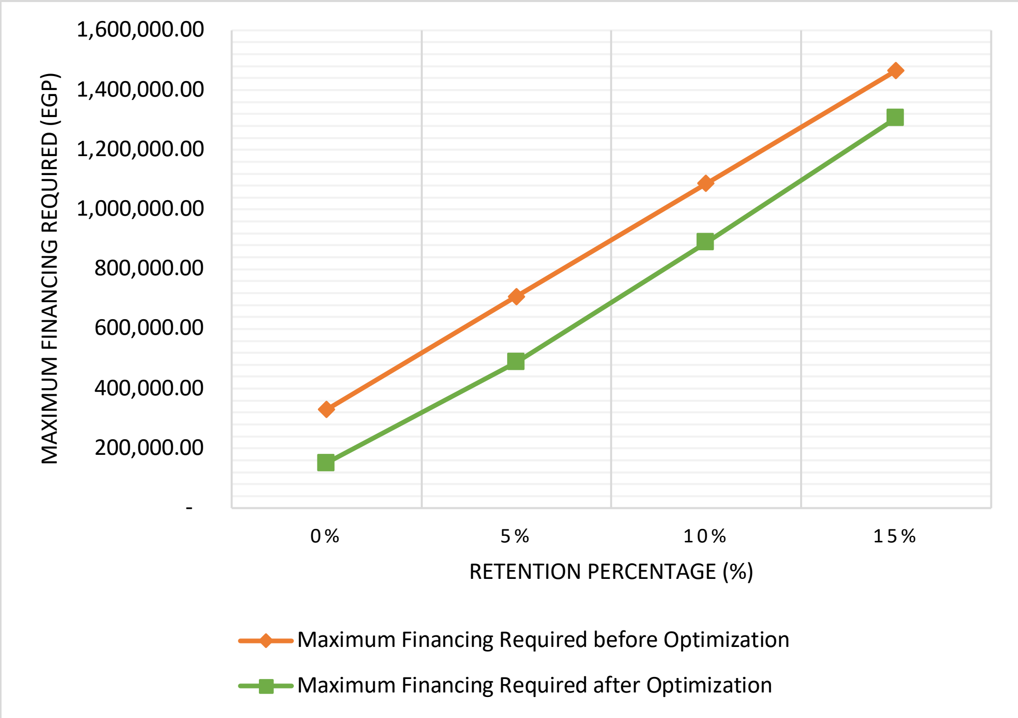


Figure 21: Retention versus Maximum Financing Required

Then, the effect of changing the retention percentage is explored on the optimum financing costs determined by the model. This is illustrated in Figure 22.

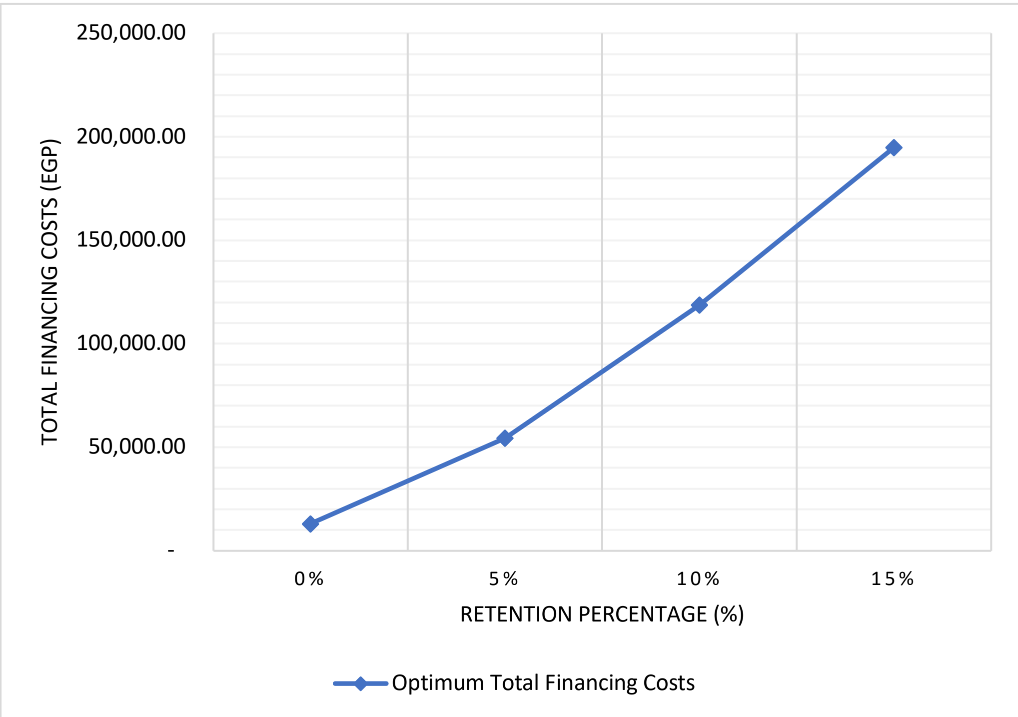


Figure 22: Retention versus Financing Costs

The results show a direct relationship between retention percentage and the amount of negative net cash flow, which is expected. Moreover, the maximum financing required amounts after optimization are less than the initial values, while changing the retention values, which ensures the optimization process is successful. The increase in the retained amounts from the monthly payments to the contractor, affect the amount of cash inflow, hence increases the net negative cash flow, and more funds are required to be financed by the contractor. Consequently, the amount of the total financing costs increase as the amount of retention increases as well, which explains the direct relationship shown in the above figure.

4.1.2 Advance Payment Percentage

The advance payment percentage values were altered, to inspect the effect of changing the amount of the advance payment paid in the beginning of the project, on the required amounts to be financed by the contractor, which is the net negative cash flow, and hence on the amount of financing costs.

First, the advance payment percentage is studied against the maximum amount of financing required by the contractor throughout the project, according to the initial schedule and after the optimization conducted by the model. This is illustrated in Figure 23.

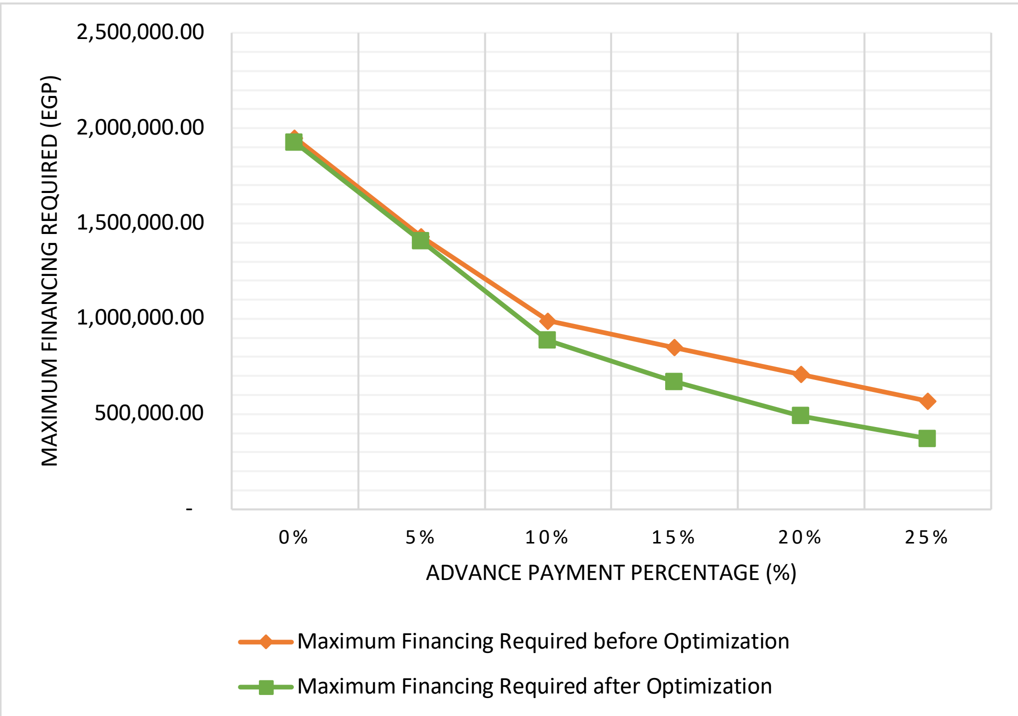


Figure 23: Advance Payment versus Maximum Financing Required

Then, the effect of changing the advance payment percentage is explored on the optimum financing costs determined by the model. This is illustrated in Figure 24.

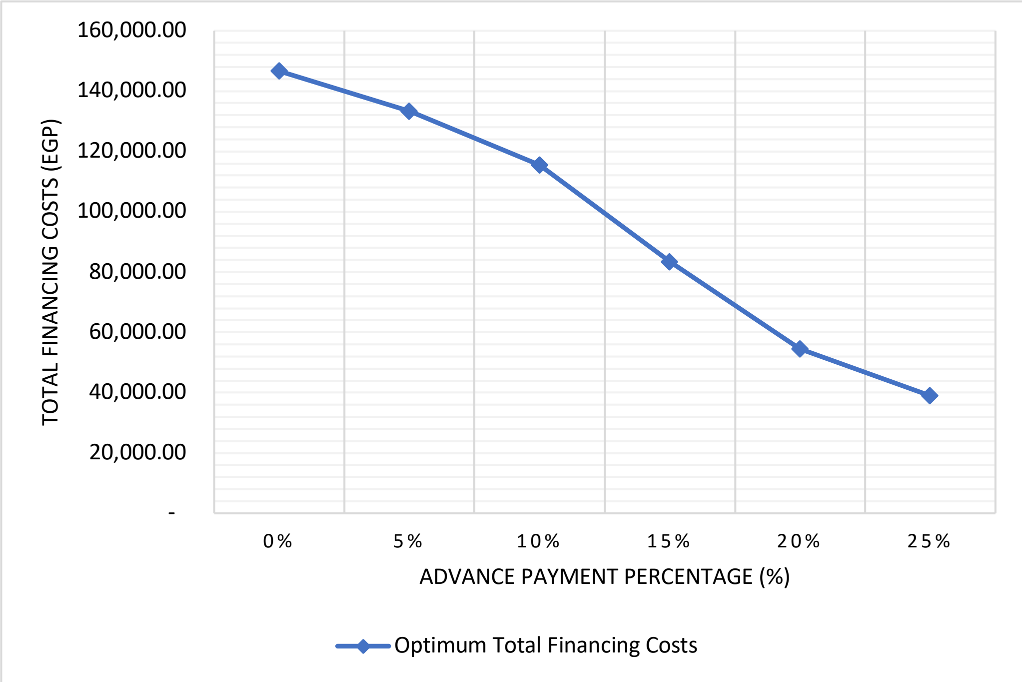


Figure 24: Advance Payment versus Financing Costs

The results show an inverse relationship between the advance payment percentage and the amount of negative net cash flow, which is normal. As previously explained, the increase in advance payment is one of the key factors that improve the cash flow of the contractor, since it provides the contractor with the initial financial boost and reduces the negative cash flow amounts throughout the project. Therefore, as the amount of advance payment increases, it reliefs the financial burden on the contractor more, by reducing the amount of overdraft and cash deficit that needs to be accounted for. Accordingly, the amount of the total financing costs decreases as the amount of advance payment percentage increases as well, since less amount of funds is required for financing, which explains the indirect relationship shown in the above figure. There is a considerable difference between the financing costs when there is no advance payment and when the advance payment is 20-25%, which emphasizes the importance of the advance payment on the cash flow of the contractor.

4.1.3 Lag in paying the Payment Requests

The lag in paying the payment requests were modified, to review its impact on the required amounts to be financed by the contractor, and on the amount of financing costs accordingly. First, the lag in paying the payment requests is analyzed against the maximum amount of financing required by the contractor throughout the project, according to the initial schedule and after the optimization conducted by the model. This is illustrated in Figure 25.

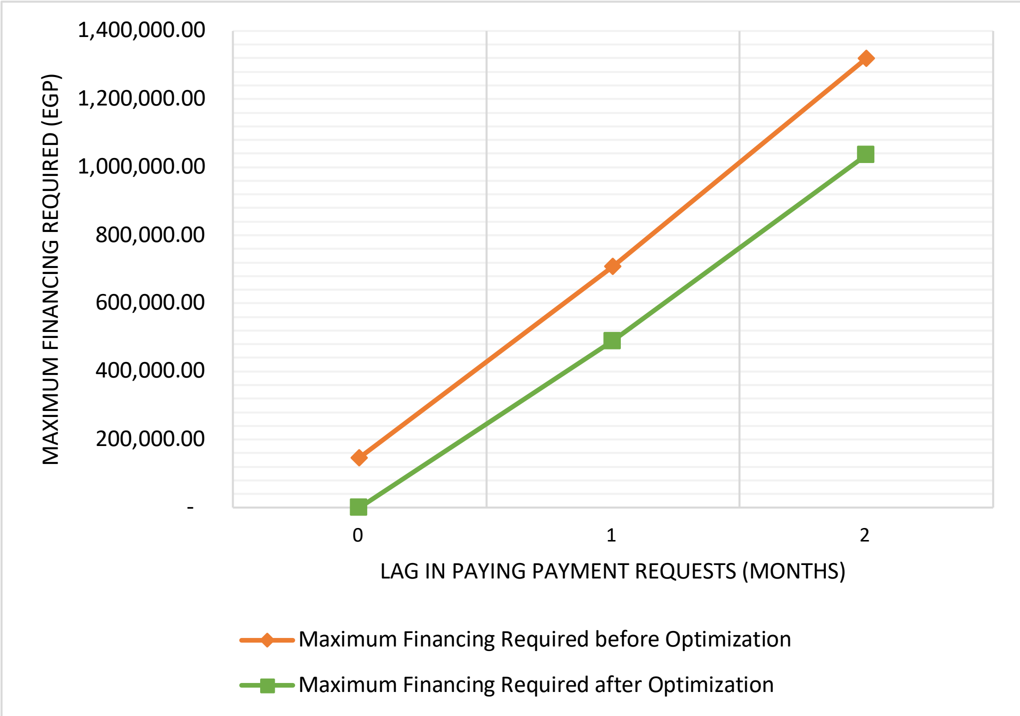


Figure 25: Lag in Payments versus Maximum Financing Required

Then, the impact of adjusting lag in paying the payment requests is investigated on the optimum financing costs determined by the model. This is illustrated in Figure 26.

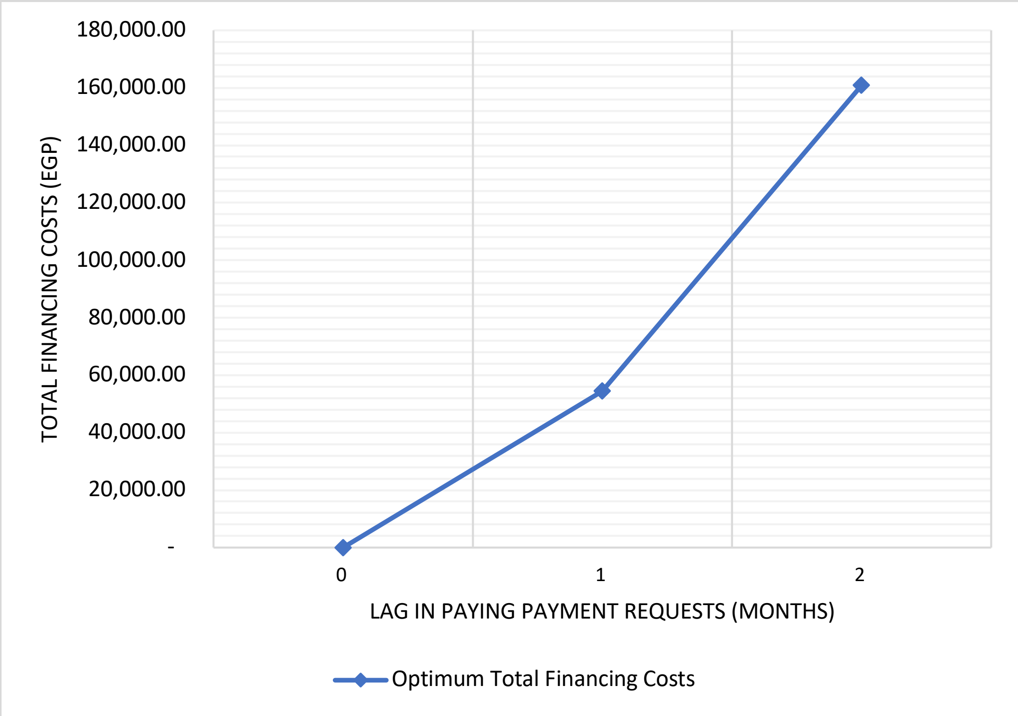


Figure 26: Lag in Payments versus Financing Costs

The results show a direct relationship between the time lag in paying the payment requests and the amount of negative net cash flow, which is common. As previously discussed, the time lag in paying the payment requests is one of the significant factors behind the contractor's overdraft, because the time lag between incurring the costs and receiving the payments, produce a gap between the cash in and cash out. This makes it inevitable for the contractor to bridge this gap by obtaining external financing from lending institutions. More time lag in paying the payment requests means greater gap between the cash in and cash out profiles, hence more overdraft and more financing required. Accordingly, the amount of the total financing costs increases as the time lag increases as well, since more amounts of funds are required for financing, which explains the direct relationship shown in the above figure. Furthermore, the results show that when there is no lag between payment requests and payment receipts, according to the initial schedule, slight financing was required, whereas after the schedule optimization conducted by the model, no financing was required.

4.1.4 The Annual Percentage Rates of the Long-term Loans

Apart from the contractual terms parameters were analyzed, another factor related to the financing costs is investigated; which is the interest rate denoted by the lending institutions, the effective APR. Long-term loans option was selected to conduct this analysis on.

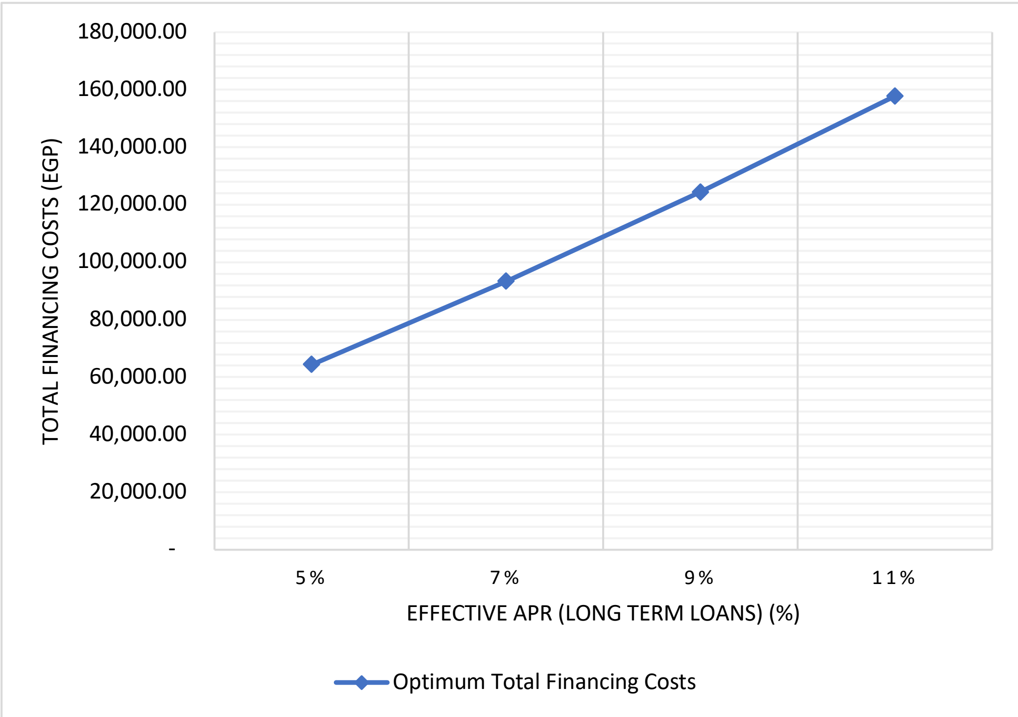


Figure 27: Effective APR versus Financing Costs

The results in Figure 27, show a direct relationship between the interest rate and the financing costs required, which is logical, since the financing costs are calculated using the interest rates provided by the lenders.

In conclusion; this analysis emphasizes on the significance of three contractual terms parameters on the cash flow performance. It proves that not only the financing input factors (i.e. interest rates), affect the amount of financing costs, but also the contractual terms may have a substantial effect on the amount of financing required and hence the financing costs associated. Thus, negotiating the contractual terms, and especially these three parameters with the client, and agreeing on the appropriate and feasible values, is of extreme importance as it may hugely affect the contractor's cash flow profile throughout the project.

Chapter 5

5 Model Validation (Testing the Model)

The model validation is conducted by testing the model and applying it on an example project similar to the one considered in a previous research (Alavipour and Arditi, 2018b). The project data inputs were used with some modifications to match the proposed model in this study, in order to take into consideration, the cash-out payment terms, advance payment and the negotiable bid option; which were not applied in the previous model by Alavipour and Arditi.

The purpose of testing the model is to demonstrate the processes and calculations carried out by the model, formerly explained.

5.1 Example Project from previous research (with some modifications)

The below Figures 28 and 29, illustrate the project data and contract terms required to be input by the user:

Project Data	
Project Name	1
Project Start	1-Jan-18
Monthly Fixed Overheads (FOH)	15%
Variable Overhead percentage of DC	10%
Mark up % of (DC+FOH+VOH)	10%

Contract Terms	
Advance Payment	20%
Retention	5%
Time for Payment *(in months after invoice submission)*	1
Repayment of Retention *(how many months after project completion)*	1

1. LONG TERM LOAN	
Effective Annual Percentage Rate (APR)	7%

2.1 SHORT TERM LOAN (SH3)	
Effective Annual Percentage Rate (APR)	23%

2.2 SHORT TERM LOAN (SH6)	
Effective Annual Percentage Rate (APR)	18%

2.3 SHORT TERM LOAN (SH9)	
Effective Annual Percentage Rate (APR)	13%

Figure 28: Model Inputs

Project Activities								Cash-Out Payment Terms		
Activity Description	Activity Code	Predecessor 1	Predecessor 2	Predecessor 3	Duration (Months)	Direct Cost (EGP)		Activity Code	Advance Payment Percentage (%)	Delayed Payment After how many months from the start of the activity?
	Start				0	-		Start	0%	0
	A	Start			2	500,000.00		A	10%	0
	B	Start			2	600,000.00		B	10%	0
	C	Start			3	720,000.00		C	10%	0
	D	A			1	240,000.00		D	10%	0
	E	B			1	120,000.00		E	10%	0
	F	B	C		1	450,000.00		F	10%	0
	G	D	E	F	1	100,000.00		G	10%	0
	H	E			2	240,000.00		H	10%	0
	I	F			2	420,000.00		I	10%	0
	J	G	H		2	540,000.00		J	10%	0
	K	F	H		2	500,000.00		K	10%	0
	L	I	K		2	540,000.00		L	10%	0
	M	J	K		2	320,000.00		M	10%	0
	N	K			2	350,000.00		N	10%	0
	O	L	M	N	1	280,000.00		O	10%	0
	P	M			2	540,000.00		P	10%	0
	Q	O			2	420,000.00		Q	10%	0
	R	L	O		1	250,000.00		R	10%	0
	S	P	Q	R	3	420,000.00		S	10%	0
	Finish	S			0	-		Finish		0

Figure 29: Model Inputs

The following project data are read in the first tab of the model '1. Project Schedule & Cash Flow', and are utilized to carry out the CPM calculations and produce the schedule data as per Figure 30, and the Contract Price calculations displayed in Figure 31.

CPM CALCULATIONS							
Project Schedule							
Early Start	Early Finish	Late Start	Late Finish	Free Float	Normal Total Float	Critical Activities	Direct Cost per Month (EGP)
0	0	0	0	0	0	Start	
0	2	1	3	0	1		250,000.00
0	2	0	2	0	0	B	300,000.00
0	3	0	3	0	0	C	240,000.00
2	3	3	4	1	1		240,000.00
2	3	2	3	0	0	E	120,000.00
3	4	3	4	0	0	F	450,000.00
4	5	4	5	0	0	G	100,000.00
3	5	3	5	0	0	H	120,000.00
4	6	5	7	1	1		210,000.00
5	7	5	7	0	0	J	270,000.00
5	7	5	7	0	0	K	250,000.00
7	9	7	9	0	0	L	270,000.00
7	9	7	9	0	0	M	160,000.00
7	9	7	9	0	0	N	175,000.00
9	10	9	10	0	0	O	280,000.00
9	11	10	12	1	1		270,000.00
10	12	10	12	0	0	Q	210,000.00
10	11	11	12	1	1		250,000.00
12	15	12	15	0	0	S	140,000.00
15	15	15	15	0	0	Finish	

Figure 30: CPM Calculations

The model calculates and displays the total project duration; which is 15 months in this example.

Contract Price Calculation	
Monthly Fixed Overheads (FOH)	EGP 75,500.00
Project Direct Cost (DC)	EGP 7,550,000.00
Fixed Overheads (FOH)	EGP 1,132,500.00
Variable Overhead (VOH)	EGP 755,000.00
Mark up % of (DC+FOH+VOH)	EGP 943,750.00
Total Contract Price	**EGP 10,381,250.00**

Figure 31: Contract Price Calculations

Then the project cash flow forecast and the corresponding maximum financing amount required by the contractor are demonstrated using the equations and formulas discussed earlier in the Model Development chapter, and the results for this example are displayed in the below Figure 32.

CASH FLOW CALCULATIONS

	Month	Date
Project Start Date	0	01-Jan-18
Project Completion Date	15	01-Apr-19

Maximum Financing Required	
Month	Value (EGP)
Nov-18	708,362.50

				CASH OUT		CASH IN (Invoice)							REQUIRED FINANCING CALCULATIONS				
Date	Month	Cost of Work done (EGP)	Invoice Sumbission Date	Monthly Expenses (EGP)	Cumulative Cash Out	Price of Work done (EGP)	Advance Payment	Retention Deduction	Advance Payment Deduction	Payment of Retention	Payment due date	Net Cash In	Date	Cumulative Cash In	Cumulative Cash Out	Cumulative Finance	Monthly Finance
1-Jan-2018	0			182,000.00	182,000.00		2,076,250.00				01-Jan-18	2,076,250.00	Jan-18	2,076,250.00	182,000.00	-1,894,250.00	-1,894,250.00
January-18	1	944,500.00	01-Feb-18	865,500.00	1,047,500.00	1,038,950.00	-	51,947.50	207,790.00	-	01-Mar-18	779,212.50	Feb-18	2,076,250.00	1,949,000.00	-127,250.00	1,767,000.00
February-18	2	944,500.00	01-Mar-18	901,500.00	1,949,000.00	1,038,950.00	-	51,947.50	207,790.00	-	01-Apr-18	779,212.50	Mar-18	2,855,462.50	2,693,500.00	-161,962.50	-34,712.50
March-18	3	735,500.00	01-Apr-18	744,500.00	2,693,500.00	809,050.00	-	40,452.50	161,810.00	-	01-May-18	606,787.50	Apr-18	3,634,675.00	3,391,000.00	-243,675.00	-81,712.50
April-18	4	702,500.00	01-May-18	697,500.00	3,391,000.00	772,750.00	-	38,637.50	154,550.00	-	01-Jun-18	579,562.50	May-18	4,241,462.50	4,000,500.00	-240,962.50	2,712.50
May-18	5	548,500.00	01-Jun-18	609,500.00	4,000,500.00	603,350.00	-	30,167.50	120,670.00	-	01-Jul-18	452,512.50	Jun-18	4,821,025.00	4,806,000.00	-15,025.00	225,937.50
June-18	6	878,500.00	01-Jul-18	805,500.00	4,806,000.00	966,350.00	-	48,317.50	193,270.00	-	01-Aug-18	724,762.50	Jul-18	5,273,537.50	5,522,500.00	248,962.50	263,987.50
July-18	7	647,500.00	01-Aug-18	716,500.00	5,522,500.00	712,250.00	-	35,612.50	142,450.00	-	01-Sep-18	534,187.50	Aug-18	5,998,300.00	6,203,000.00	204,700.00	-44,262.50
August-18	8	741,000.00	01-Sep-18	680,500.00	6,203,000.00	815,100.00	-	40,755.00	163,020.00	-	01-Oct-18	611,325.00	Sep-18	6,532,487.50	6,965,500.00	433,012.50	228,312.50
September-18	9	741,000.00	01-Oct-18	762,500.00	6,965,500.00	815,100.00	-	40,755.00	163,020.00	-	01-Nov-18	611,325.00	Oct-18	7,143,812.50	7,658,000.00	514,187.50	81,175.00
October-18	10	680,500.00	01-Nov-18	692,500.00	7,658,000.00	748,550.00	-	37,427.50	149,710.00	-	01-Dec-18	561,412.50	Nov-18	7,755,137.50	8,463,500.00	708,362.50	194,175.00
November-18	11	878,500.00	01-Dec-18	805,500.00	8,463,500.00	966,350.00	-	48,317.50	193,270.00	-	01-Jan-19	724,762.50	Dec-18	8,316,550.00	8,791,000.00	474,450.00	-233,912.50
December-18	12	306,500.00	01-Jan-19	327,500.00	8,791,000.00	337,150.00	-	16,857.50	67,430.00	-	01-Feb-19	252,862.50	Jan-19	9,041,312.50	9,006,500.00	-34,812.50	-509,262.50
January-19	13	229,500.00	01-Feb-19	215,500.00	9,006,500.00	252,450.00	-	12,622.50	50,490.00	-	01-Mar-19	189,337.50	Feb-19	9,294,175.00	9,222,000.00	-72,175.00	-37,362.50
February-19	14	229,500.00	01-Mar-19	215,500.00	9,222,000.00	252,450.00	-	12,622.50	50,490.00	-	01-Apr-19	189,337.50	Mar-19	9,483,512.50	9,437,500.00	-46,012.50	26,162.50
March-19	15	229,500.00	01-Apr-19	215,500.00	9,437,500.00	252,450.00	-	12,622.50	50,490.00	519,062.50	01-May-19	708,400.00	Apr-19	9,672,850.00	9,437,500.00	-235,350.00	-189,337.50
April-19	16		01-May-19	-	9,437,500.00		-			-	01-Jun-19	-	May-19	10,381,250.00	9,437,500.00	-943,750.00	-708,400.00

Figure 32: Cash Flow Calculations

Next, in order to determine the most feasible project schedule that minimizes the cash deficit, the solver is run and the enhanced schedule is obtained, by finding the ideal start times of the non-critical activities, as per Figure 33. Besides, a GANTT chart for the optimized project schedule is illustrated as well, refer to Figure 34.

Optimized Schedule								
Lag	Early Start	Early Finish	Late Start	Late Finish	Free Float	Total Float	Critical Activities	Direct Cost per Month
0	0	0	0	0	0	0	Start	-
0	0	2	1	3	0	1		250,000.00
0	0	2	0	2	0	0	B	300,000.00
0	0	3	0	3	0	0	C	240,000.00
0	2	3	3	4	1	1		240,000.00
0	2	3	2	3	0	0	E	120,000.00
0	3	4	3	4	0	0	F	450,000.00
0	4	5	4	5	0	0	G	100,000.00
0	3	5	3	5	0	0	H	120,000.00
1	5	7	5	7	0	0	I	210,000.00
0	5	7	5	7	0	0	J	270,000.00
0	5	7	5	7	0	0	K	250,000.00
0	7	9	7	9	0	0	L	270,000.00
0	7	9	7	9	0	0	M	160,000.00
0	7	9	7	9	0	0	N	175,000.00
0	9	10	9	10	0	0	O	280,000.00
0	9	11	10	12	1	1		270,000.00
0	10	12	10	12	0	0	Q	210,000.00
1	11	12	11	12	0	0	R	250,000.00
0	12	15	12	15	0	0	S	140,000.00
0	15	15	15	15	0	0	Finish	

Figure 33: Optimized Schedule Calculations

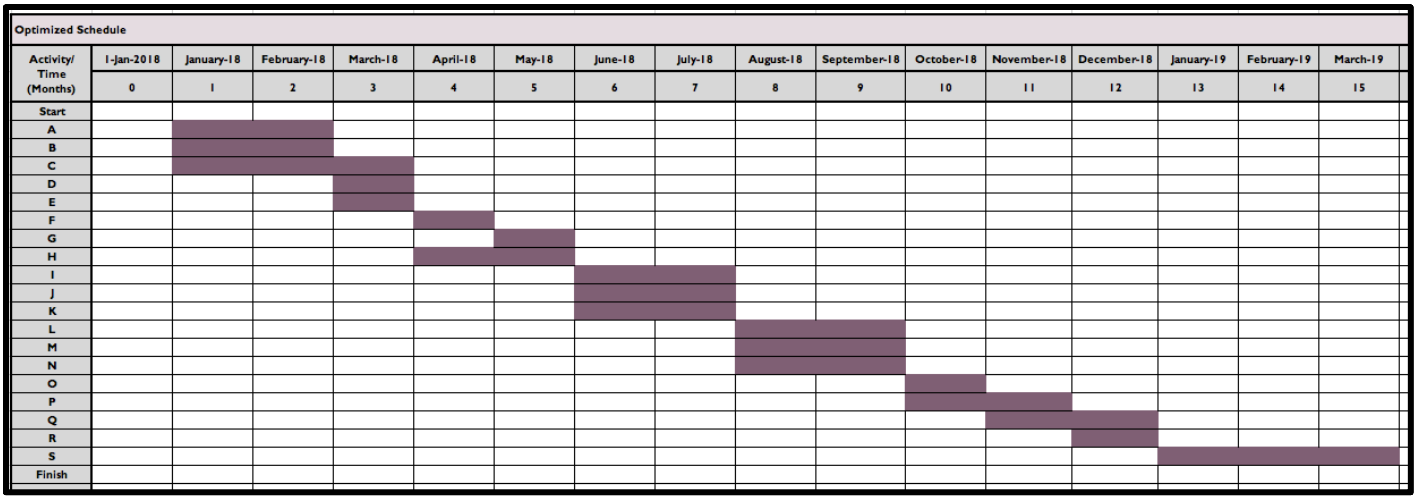


Figure 34: Optimized Schedule GANTT Chart

In this example, as per Figure 35, the maximum financing required by the contractor decreased from **EGP 708,362.25** to **EGP 489,187.50**, corresponding to **31%** decrease, as a result of the schedule optimization conducted by the model. Then, the corresponding cash flow calculations are determined as well.

Maximum Financing Required before Optimization	
Month	Value (EGP)
Nov-18	708,362.50

Maximum Financing Required after Optimization	
Month	Value (EGP)
Oct-18	489,187.50

Figure 35: Maximum Financing Amount Required

Based on the cash flow calculations after the schedule optimization, the financing alternatives are analyzed. The interest rates input by the user in the beginning of the model are reflected and used in determining the financing costs for each alternative. The model is run for each financing alternative: the long-term loan, short-terms loans every 3, 6 and 9 months, and finally for the combined option.

Optimum Financing Results		
Financing Costs of the Proposed Alternatives	**Effective APR (%)**	**Financing Costs (EGP)**
1. LONG TERM LOAN	7%	EGP 93,294.59
2.1 SHORT TERM LOAN (SH3)	23%	EGP 63,000.89
2.2 SHORT TERM LOAN (SH6)	18%	EGP 62,085.86
2.3 SHORT TERM LOAN (SH9)	13%	EGP 92,525.67
3. COMBINED OPTION		EGP 54,444.17
Optimum Financing Alternative with Least Financing Costs		
Optimum Financing Alternative		3. COMBINED OPTION
Corresponding Financing Cost		EGP 54,444.17
Profit before Financing		EGP 943,750.00
Profit after Financing		EGP 889,305.83
Decrease in profit		5.77%
(Please refer to "3. COMBINED OPTION" tab for all the calculations and Financing Schedule)		

Figure 36: Optimum Financing Results

Finally, a summary of the optimum financing costs results is displayed in a table, according to the above Figure 36. This shows the financing costs corresponding to each financing alternative analyzed, and picks the best alternative, which requires the least financing costs. In this example, obtaining a combined set of loans proved to be the best financing alternative, with the least financing costs of **EGP 54,444**, that could cover the cash deficit throughout the project duration. In addition, the decrease in profit as a result of the financing cost anticipated is calculated as well, which is in this case **5.77%.** If the user wants to access the comprehensive schedule of monthly financing inflows and outflows, refer to the combined option tab in the model, clarified in Figure 37.

In this example, it is assumed that the long- and short-term loan repayments are monthly fixed payments. For the long-term loan, the monthly payments represent interest and part of the principal, whereas the short-term loan monthly payments represent interest only, and the principal is paid off once at the end of the loan duration.

OPTIMIZED FINANCING MONTHLY INFLOW SCHEDULE					
Months	SH3	SH6	SH9	LI	TOTAL
0	-	-	-	260,124.12	260,124.12
1	-	-	-	-	-
2	-	-	-	-	-
3	-	-	-	-	-
4	-	-	-	-	-
5	-	-	-	-	-
6	63,640.00	263,883.76	-	-	327,523.76
7	-	-	-	-	-
8	-	-	-	-	-
9	57,594.00	-	118,423.65	-	176,017.65
10	-	-	-	-	-
11	-	-	-	-	-
12	63,106.00	-	-	-	63,106.00
13	-	-	-	-	-
14	-	-	-	-	-
15	-	-	-	-	-
16	-	-	-	-	-
17	-	-	-	-	-
18	-	-	-	-	-

OPTIMIZED FINANCING MONTHLY OUTFLOW SCHEDULE					
Months	SH3	SH6	SH9	LI	TOTAL
0	-	-	-	-	-
1	-	-	-	18,136.34	18,136.34
2	-	-	-	18,136.34	18,136.34
3	-	-	-	18,136.34	18,136.34
4	-	-	-	18,136.34	18,136.34
5	-	-	-	18,136.34	18,136.34
6	-	-	-	18,136.34	18,136.34
7	1,107.39	3,664.93	-	18,136.34	22,908.66
8	1,107.39	3,664.93	-	18,136.34	22,908.66
9	64,747.39	3,664.93	-	18,136.34	86,548.66
10	1,002.18	3,664.93	1,212.28	18,136.34	24,015.74
11	1,002.18	3,664.93	1,212.28	18,136.34	24,015.74
12	58,596.18	267,548.69	1,212.28	18,136.34	345,493.50
13	1,098.10	-	1,212.28	18,136.34	20,446.72
14	1,098.10	-	1,212.28	18,136.34	20,446.72
15	64,204.10	-	1,212.28	18,136.34	83,552.72
16	-	-	1,212.28	-	1,212.28
17	-	-	1,212.28	-	1,212.28
18	-	-	119,635.93	-	119,635.93

Figure 37: Optimized Financing Monthly Schedule

The financing costs inflows and outflows are integrated with the project cash flow values to obtain an accurate estimation of the cash flow profile for the whole project, incorporating all the possible financing costs incurred by the contractor.

The model also, illustrates the cash flow diagrams before and after the schedule optimization, and before and after the financing alternatives, shown in Figures 38, 39 and 40.

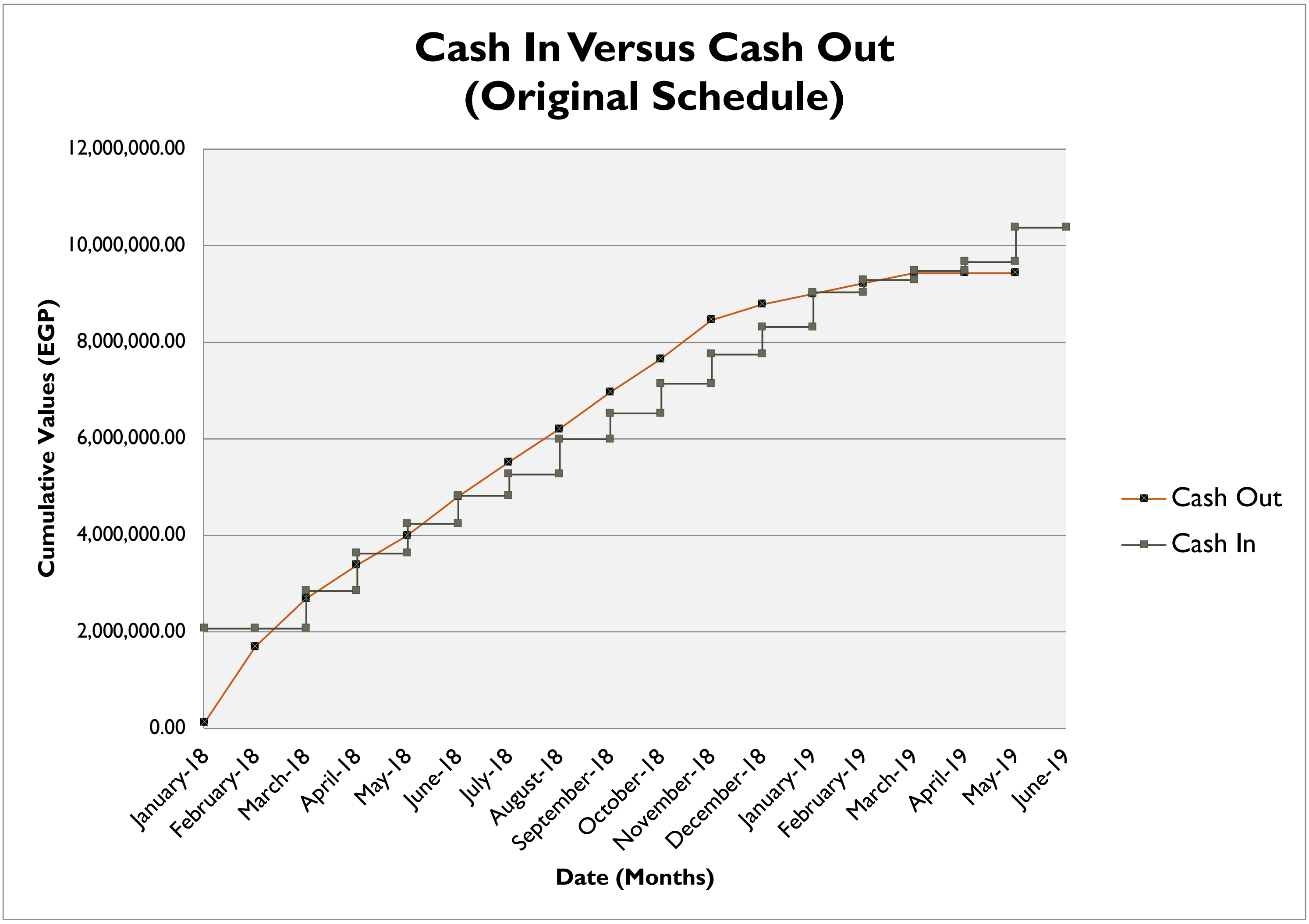


Figure 38: Cash In versus Cash Out (Original Schedule)

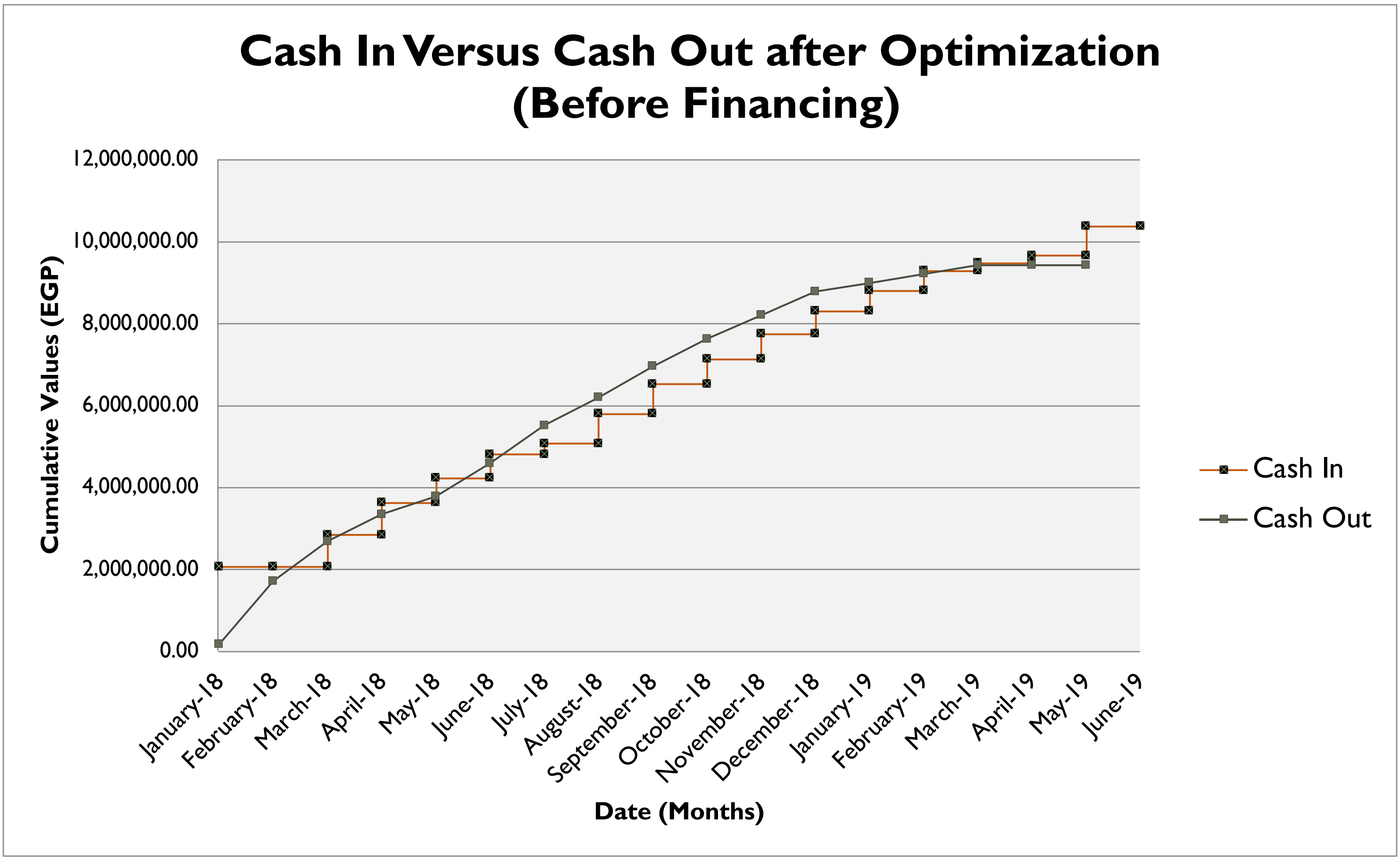


Figure 39: Cash In versus Cash Out after Optimization (Before Financing)

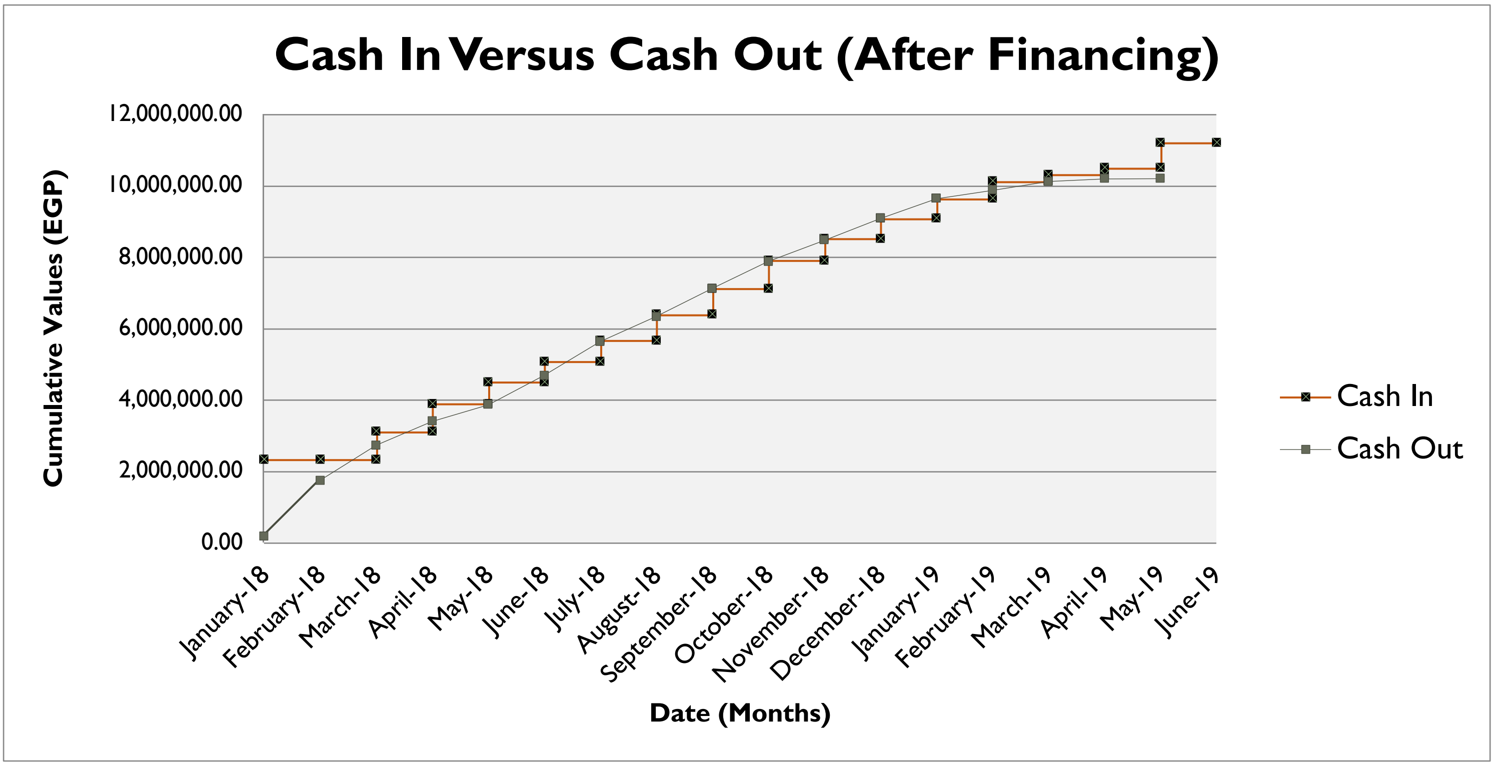


Figure 40: Cash In versus Cash Out after Optimization (After Financing)

Ultimately, when running the solver in the negotiable bid tab, the model calculates the ideal advance payment percentage that shall bridge the gap in cash flow instead of borrowing funds. In this case the project requires an advance payment of 45% instead of 20%, against offering a decrease in profit of 5.77%, and 0.5% overall discount on the Contract Price, as shown in Figure 41. Practically, this is not feasible as the required increase in advance payment percentage is significant compared to the offered discount, however in other cases this might be of great use to the contractor, as a powerful negotiation tool.

Negotiable Bid Results	
Original Advance Payment (%)	20.00%
Original Mark up (%)	10.00%
Modified Advance Payment (%)	45.27%
Modified Mark up (%)	9.42%
Modified Mark up Value (% of [DC+FOH+VOH])	EGP 889,305.83
Decrease in profit	EGP 54,444.17
Discount	-0.524%
Modified Total Contract Price	EGP 10,326,805.83
(Please refer to "Negotiable Bid" tab for all the detailed calculations)	

Figure 41: Negotiable Bid Results

5.2 Example Project from previous research (without modifications)

In the previous section, the example from Alavipour and Arditi’s paper was applied with some modifications to match the proposed model’s functions. However, in this section, the model is run again without any modifications to the previous model by Alavipour and Arditi, in order to compare the results of the proposed model to the results achieved by the previous model. The outcome of this comparison is summarized in Figure 42, where the financing costs determined by the proposed model were less than the financing costs generated by the previous model, which ensures the viability of the proposed model.

	Proposed Model	Alavipour and Arditi, 2018 *(Long and short term loans and line of credit)*	Alavipour and Arditi, 2018 *(Short term loans and line of credit)*
Financing Costs	115,867	120,202	147,314
Decrease in Financing Costs		4%	21%

Figure 42: Proposed Model versus Previous Model results

Chapter 6

6 Conclusion, Limitations and Recommendations

6.1 Conclusion

This objective of this study is to propose an integrated multi-objective finance-based model to minimize the contractor's negative cash flow, besides determining the best financing option and taking into consideration the financing costs. Several studies were conducted to forecast project cash flow profiles, to optimize the project schedule, and to explore the best financing alternative with the least financing costs. However, none of these studies integrated all these models in one tool. This model is developed using Microsoft Excel, and the Solver Add-In is the optimization tool utilized, hence this model is accessible, user-friendly and easy to use.

The established model in this thesis, is a simple yet integrated tool that:

1. Requires the user to input the project data, contract terms and cash-out payment terms; to be taken into consideration to produce a proper cash flow estimate.
2. Estimates the project cash flow using CPM Calculations, hence determines the contractor's negative net cumulative values during the whole project.
3. Establishes an enhanced schedule by utilizing the non-critical activities' free floats, without affecting the total project duration, to minimize the cash shortage.
4. Illustrates project schedule GANTT charts before and after schedule optimization.
5. Portrays Cash Flow Diagrams before and after schedule optimization, for the user to visualize the difference in the cash flow profile.
6. Explores different financing options: Long Term Loan, Short Term loans every 3, 6 and 9 months, separately and determines the best monthly financing inflow and outflow schedules for each option.
7. Allows the user to explore different financing alternatives, including analyzing a combination of a set of different types of loans, and determines the ideal combination of monthly financing inflow and outflow schedules.
8. Portrays Cash Flow Diagrams before and after each financing alternative proposed, for the user to visualize the difference in the cash flow profile.

9. Selects the best alternative with the minimum financing costs to satisfy the project financial requirements.
10. Provides the user with the monthly financing inflow and outflow schedules of the best financing alternative, which empowers the contractor in the negotiations with the lending institutions.
11. Provides the user with a negotiable bid tool that suggests another alternative to overcome the cash shortage, without borrowing funds. This alternative determines the optimum increase in advanced payment, against the suitable decrease in profit to be offered to the client as a discount on the total contract price. If the contractor succeeds to negotiate this alternative, borrowing funds would not be required anymore as the project will be financing itself.
12. Produces 'Model Calculations Summary' tab, to summarize the outcomes of running the model. This includes:
    - Main Project Data
    - Enhanced Project Schedule results
    - Best Financing Alternative results
    - Negotiable Bid results

Figure 43 below, highlights the differences between the proposed model in this study and the previous financing cost optimization models. The improvements proposed by the model in this study include:

- Taking into consideration the cash-out payment terms to suppliers and subcontractors, including advance payment and delayed payments, if any.
- Integrating the concept of finding the most feasible schedule that minimizes the cash deficit, and finding the best financing alternative in one tool.
- Introducing a negotiable bid option as an alternative to borrowing funds.
- However, the Line of Credit financing option which was analyzed in previous studies, is not incorporated in this study.

	Proposed Model	Previous Optimum Financing Models
Cash-Out Payment Terms	✓	✗
Enhanced Project Schedule	✓	✗
Line of Credit	✗	✓
Negotiable Bid	✓	✗

Figure 43: Proposed Model versus Previous Studies

Moreover, a sensitivity analysis was conducted to verify the results, and it provided a better understanding of the relationships between the different project parameters. This analysis highlighted the importance of three contract terms parameters on the cash flow profile; namely the retention percentage, advance payment percentage and the lag between the payment requests and payment receipts. The results of this analysis show that increasing the advance payment percentage enhances the cash flow profile and reduces the amount of financing requires, whereas increasing the retention percentage and/or the lag between payment requests and payment receipts adversely affect the cash flow profile. The outcome of this analysis is that besides the financing input factors (i.e. interest rates), the contractual terms may have a significant effect on the amount of financing required and therefore the financing costs associated. Hence, negotiating the contractual terms is of extreme importance as it may tremendously affect the contractor's cash flow performance.

Furthermore, the developed model was validated and tested using a case study, where the objectives were satisfied and the results were logical and coherent. In this example; the model reduced the amount of maximum financing required by 31% after the project schedule optimization conducted by Solver. In addition, the model determined the best financing alternative, which is a combined set of long- and short-term loans, that resulted in 5.77% decrease in profit corresponding to the financing costs incurred. The financing costs inflows and outflows are integrated with the project cash flow values to obtain an accurate estimation of the cash flow profile for the whole project, incorporating the financing costs. Therefore, this tool allows the contractor to build the proper total contract bid price.

6.2 Model Limitations and Recommendations

This study proposes an integrated multi-objective model that aims to forecast and enhance the contractor's cash flow, besides determining the best financing alternative and associated with the least financing costs, to ensure the highest possible profitability. However, this model has some limitations that shall be accounted for in future studies.

- One of the inevitable aspects in any construction project, is the variation orders. This model does not account for any costs incurred as a result of any changes in scope or variation orders.
- Construction projects are of a risky nature and the contractor has to endure the risks related to the project execution (Görög, 2009). However, any costs that may be incurred due to these risks is not accounted for in this model.
- The maximum allowable number of activities in this model is 100 activities, and three predecessors per activity. This may be increased in future research.
- The relationship between the activities is Finish-to-Start, other relationships are not incorporated in this model.
- This model is based on a single-project analysis, and assumes that there is no source of cash inflows or outflows other than the costs related to one project contract. However, construction contractors usually run more than one project concurrently, thus this may be an area of future improvement to this model.
- The model assumes equal direct costs per duration for each activity, for simplicity, but material costs and subcontractors' payments may require a different schedule of payments based on the procurement plan (Alavipour and Arditi, 2018b). However, this might be enhanced for better accuracy of cash outflows.
- The model does not explore the line of credit financing option. This might be added in future studies.

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