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OPTIMIZING PRODUCTIVITY RATE TO MINIMIZE OVERDRAFT INTEREST PAYMENT IN INFRASTRUCTURE CONSTRUCTION PROJECTS

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Winning a bid is a good opportunity for contractors that includes risks. After winning a project, contractors typically receive payments after two-three months of work completion that leads to negative cash flow (overdraft) throughout the duration of a project. Hence, contractors borrow from banks and pay monthly interests on the amount of overdraft they owe. To solve this problem, a hybrid model utilizing Discrete Event Simulation using SIMPHONY software, a special purpose simulation tool developed by the University of Alberta, accompanied by Markov Chain prediction technique. The developed hybrid model allows contractors to test different scenarios in search of the optimum productivity rate and payment arrangement to minimize negative cash flow. A case study utilizing a typical road construction project is used to test and validate the developed model and its ability to determine the optimum scenario. Results revealed that markup percentage and initial investment are two crucial factors to deliver the project successfully. In the harsh market, increasing the amount of cash to invest without a reasonable markup (at least 10%) will no longer make a profit. But, if the markup percentage could be increased by more than 15%, it will offer a chance to the contractor to make a profit and successfully deliver the project with initial investment reasonably low; and save a flexible productivity rate to finish the project within the schedule.

Keywords: Discreet Event Simulation, SIMPHONY software, Negative cash flow, Markov Chain, Construction management, Decision making.

1 INTRODUCTION

The Construction industry is challenging because of uncertainty and difficulty in scheduling and budgeting. According to Russell (1991), 60% of construction failure is depending on the lack of finance i.e., the cash outflow is more than the cash inflow. That is negative cash flow which causes loans with a high-interest rate. The negative cash flow also happens when a contractor receives delayed payments. This makes the contractor deals with cash-constraint (Shiha and Hosny 2019). The authors explained that contractor-subcontractor payment and contractor-bank payment affect contractor cash liquidity. Then, the appropriate cash flow is essential to be successful in the construction industry. Moreover, multiple unpredictable factors, such as "change of progress payment, payment duration, the financial position of the contractor, project delays, and poor planning" can affect the cash flow (Zayed and Liu 2014). This paper presents a Discrete Event Simulation (DES) and Markov chain model to help decision-makers in a wide variety of choices to get a suitable competitive solution to minimize the overdraft percentage.

2 LITERATURE REVIEW

Different research is established to help contractors in the decision-making process, such as integrating the analytical hierarchy process with simulation to examine the effect of the aforementioned factors. For instance, Basha *et al.* (2016) implemented a genetic algorithm model to minimize the negative cash flow and optimize the contractor's profit. Moreover, Shiha and Hosny (2019) proposed a genetic algorithm model with restricted assumptions for the subcontracting option to manage cash flow. Another study, Lu *et al.* (2016), implemented a what-if scenario based on five-dimensional building information modeling to estimate accurate cash flow. In addition, many articles have been used fuzzy modeling to forecast accurate cash flow like Yu *et al.* (2017), Tabei *et al.* (2019). In addition, system dynamics is utilized to find a better financing option among different cash flow strategies that could be more beneficial (Cui *et al.* 2010). Besides, some researchers implemented a simulation method to manage cash flow and getting more profit for a contractor company, such as Huang (2013), Ock and Park (2016), Hussain (2019). Similarly, Andalib *et al.* (2018) implemented a stochastic simulation model to analyze how different owner-contractor payment methods could affect cash flow and profit.

3 METHODOLOGY

3.1 General

This paper develops a model, consists of 3 main components, to help decision-makers to test all available scenarios and choose the best suitable one for the running case. The first part is responsible for capturing project activities, quantities, and planned durations; the second part is responsible to capture the internal relations between project activities which is responsible to start and pause activities, add or remove crews, and check whether the activities will finish to the planned time. The third part is responsible to capture company financial status like cash flow, project cost, and the interactions between them. There are some assumptions and logical relations applied in this model: increasing productivity by increasing the number of working crews, the maximum number of working crews is depending on site conditions, the time delay required for hiring a new crew is ignored in the model, the model is initialized by planed time and quantities from the project schedule, and logical expressions are used to avoid negative deliverables.

To implement the simulation model, Simphony has been utilized which is a special purpose simulation tool that allows users to solve different problems using featured elements, software. One of those elements is an integrated calendar that makes it unique and sensitive for real-time. The more considerable elements that should be defined in the proposed model are Stock, Valve, and Watch. A Stock element is defined to represent the state of the variable. The valve element could be helpful to implement a gate in the model that shuts or open automatically after a certain condition. Finally, the Watch element, which is sensitive for Stock's state, can generate entities (AbouRizk *et al.* 2016a, AbouRizk *et al.* 2016b).

3.2 Model Layout

3.2.1 *Capture project activities*

In this step, project network diagram is partially captured as shown in Figure 1. The relations between activities are set to be either parallel or series. If the activity starts after the successor activity starts with lag then it is a parallel relation, but if it starts after the successor activity finish then it is a series relation; moreover, it sets the fixed lag durations between series activities.

Crews are not assigned to activities unless the activity is in operation. Finally, the time constraint is added to activities. If the owner has a constraint to finish any or all project activities at a specific date, this constrain is applied and matched to activity.

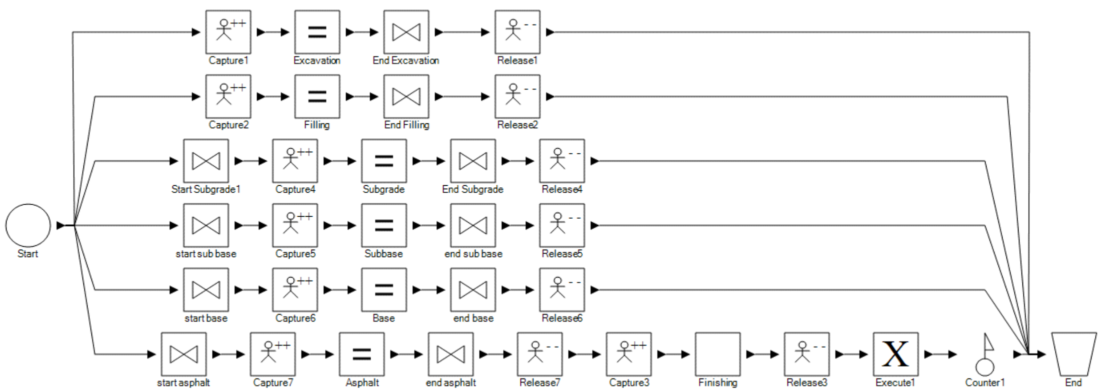

Figure 1. Activities relations.

At the start of the project, a signal of start operation of the activity will be sent to all activities. Not all the activities will respond immediately and start, but they will be delayed until the valve receives another signal from the technical relation subsystem to start this activity. After the two signals received by the activity then start to assign resources. At this point, the financial subsystem will check if the required amount of cash is available to hire this resource, then it's assigned. If there is no adequate available cash, then the activity will be delayed till the cash is available.

3.2.2 *Modeling technical relations*

In this stage, the technical relations between activities are modeled and integrated into the previous subsystem. The network diagram captures the relations using a time variable. For example, if two activities will work in parallel with lag or lead time between them. This time depends on quantity finished from the independent activity. This representation of relation captures the dynamic relation between activities. This relation is modeled by utilizing stocks to represent the accumulation of activities' finished quantities.

Figure 2 illustrates the mechanism of capturing technical relation between activities. The finished amount of any activity is represented in a stock. This amount is initiated by the value of zero and increases with the operation of the activity. This increment depends on the number of crews assigned and the productivity of the crew that depend on management style of the company using Markov chain. The numbers feed to Markov chain in this model are taken from the contractor based on his observations and work style. After the amount of the stock increased to the required limit, the depending activity is initiated by using the watch item that sends a signal to the dependent activity to start. Similarly, if the amount of work is less than the limit or the whole activity amount is achieved then a signal is sent to stop the progress regarding the dependent activity or the completed one.

3.2.3 *Financial monitoring*

In this part of the model, the cost of finished work is calculated. Then, it is linked to the company's financial status. This part focuses on organization cash liquidity. The initial value is the amount of cash available assigned by the company working on this project. Then gradually this amount is decreased because activates consume cash in their operations. After completing a portion of activities, the contractor makes a payment request. This request will take time until the contractor receives it. After receiving cash the amount of available cash will increase by this amount. There are various key variables in this process: time, mark-up size, production rate, and company initial investment. The company spends money on the project and received it with mark-up added and retainage subtracted. The retainage is subtracted to 50% of the project is finished and is given back to the contractor at the final payment request.

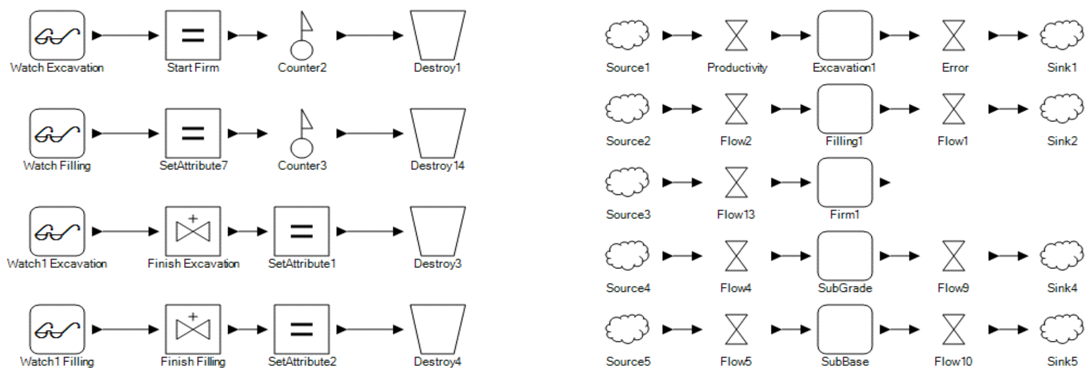

Figure 2. Capturing technical relations.

3.2.4 *Validation and verification*

The model is validated by: first, reviewing the structure of the model, variables range, initial conditions, and its behavioral response from a case study. Second, by applying the model on a case of a contracting company deciding how much to invest in a road construction project and minimize its overdraft. In addition, a modified case of the project is applied by minimizing the scope of work for Excavation and Filing by excluding 90% of this major work. This makes them two projects with cost of 220,000,000$ and 40,000,000$.

3.3 Case Study

A case of road construction is applied to validate the model. The road is a double-free road with a total length of 24 km and a width of 47 m. The quantities and durations suggested by the owner are presented in Table 1. All activities of the project are suggested to operate in parallel with a lag time of four or five months between them.

Table 1. Project activities, quantities, and durations.

Item	Quantity	Duration
Excavation	12,000,000 m3	477 Day
Filling	22,000,000 m3	484 Day
Base 1	24 km	344 Day
Base 2	24 km	351 Day
Base 3	24 km	236 Day
Asphalt 1	24 km	229 Day

3.4 Scenarios

Different scenarios are tested to reduce the overdraft without changing project duration. Each scenario has five key parameters. Those parameters are markup percentage, initial cash available as a percentage of project cost, initial payment as a percentage of project cost, project productivity as a time-saving percentage, and retainage percentage. Also, it has two gages: overdraft and profit. The objective is to minimize overdraft and maximize profit. Profit and overdraft are measured as a percentage of the initial investment. First, the markup percentage is changed from 5 to 25 % of the project cost. Second, initial liquid cash available in the organization to invest varies from 1 to 20% of the project cost. Third, the initial payment of project owners varies from 0 to 5% of the project cost. Fourth, the retainage percent is assumed to be fixed at 10% as a recurrent value in most projects. Fifth, the productivity of the crew varies stochastically and based on the available time.

4 RESULTS AND ANALYSIS

Results indicate that at a markup percentage of 5%, the company will no longer be able to make any profit (Table 2). This means that reducing the markup percentage in order to have a highly competitive advantage will not help. Also, if the company could have an initial payment from the owner up to 5% of the project cost. The contractor can achieve zero losses at 8% markup. At this point of zero profit and with overdraft it will be considered losses. At a markup of 10%, the contractor will start to make a small profit related to the amount of cash invested. The company could reach from 6.7% up to 33.899% of the amount invested. But, this profit will not protect the contractor from the loans due to a huge overdraft that reaches up to 7 hundred times the initial investment at 2% of cash invested in project cost. The overdraft will reach zero point at 10% of cash invested. The initial payment will help at this stage to maintain more flexible productivity.

Table 2. Summary of applied scenarios and results.

Case	Mark-up	Cash invested	Initial payment	Overdraft	Profit
1	5-8%	1-10%	0-5%	0	-0.36
	10%	10%	0-5%	0	0.06
	15%	10%	0%	0	0.50
	20%	8%	0%	0	1.17
	20%	5%	5%	-13.11	1.88
	25%	10%	0%	0	1.17
2	20%	5%	0%	-41.99	2.29
	10%	10%	0%	-0.71	-0.34
	15%	10%	0%	0.00	0.15
	10%	5%	5%	-1.41	0.31
	15%	5%	5%	0.00	0.33
	10%	20%	5%	0.00	-1.34
	15%	20%	5%	0.00	0.18

At markup of 15%, the contractor could bid for the project with less than 10% of project cost and achieve profit up to 50% of the cash invested. But, if the contractor reduces the amount of cash invested to 6% he will have to face overdraft. This negative cash could reach up to 50 times of the available cash invested. If the contractor could have an initial payment from the owner, it will reduce the amount of overdraft but still face bad consequences from the loans. At 10% of cash invested the contractor will reach zero overdrafts and will reach a significant profit with respect to the initial investment. If the contractor raised the markup percentage to 20%, this will facilitate bidding to the project with a little amount of cash available (8% of project cost) and have zero overdrafts. But, this high percentage of markup could reduce the chances to win the tender. If the contractor increased the markup to 25% it will not secure competitiveness in a harsh market. In addition, it will not secure the company from overdraft but increase profit.

5 CONCLUSION AND FUTURE RECOMMENDATIONS

The decision process to set the markup percentage and amount of invested cash to minimize the overdraft and maintain a reasonable profit is very complex. Utilization of DES and Markov chain to solve this problem will be beneficial. Results revealed that markup percentage and initial investment are two crucial factors to deliver the project successfully. In the harsh market, increasing the amount of cash to invest without a reasonable markup (at least 10%) will no longer make a profit. But, if the markup percentage could be increased by more than 15%, it will offer a chance to the contractor to make a profit and successfully deliver the project with initial investment reasonably low. In addition, those decisions save a flexible productivity rate to finish the project within the schedule. On the other hand, this model exhibits limitations in assumptions, such as hiring new crews takes no time, and the limited tested scenarios.

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