Egyptian Knowledge Bank

International Journal of Advances in Structural and Geotechnical Engineering

https://asge.journals.ekb.eg/

Print ISSN 2785-9509 Online ISSN 2812-5142

Special Issue for ICASGE'19

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ASGE Vol. 06 (02), pp. 131-141, 2022

International Conference on Advances in Structural and Geotechnical Engineering

ICASGE'21

29 March – 1 April 2021, Hurghada, Egypt

Optimizing Cash Flow of Construction Projects through Material Procurement Plans

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ABSTRACT

There is a widely held perception in many parts of the world today that the construction industry has long been a major component of the economies of the world industrialized nations. Admittedly, the issue of whether we should attempt to maximize contractor profit is certainly a contentious one. Cash flow management is an umbrella term that aims for achieving many objectives such as cash flow prediction, optimization, and monitoring and controlling. Reliable knowledge of project cash flow is essential for effective project management. Efficient planning of materials procurement and storage on construction sites can lead to significant improvements in construction productivity and project profitability. Nonetheless, researchers have proposed evolutionary-based algorithms for searching near-optimum solutions to overcome this source of trouble. In order to maximize contractor's profit, therefore, this research illustrates a significant optimizing model that nominates the optimum material procurement plans for contracting firm which makes the maximum monthly overdraft is minimum and furthermore, the cumulative expenses is minimum employing Genetic algorithm the magnificent artificial intelligence modeling technique.

Keywords: Construction projects, Cash Flow, Material Procurement, Optimization, Genetic Algorithm, Artificial Intelligence.

INTRODUCTION

Procurement is a key process in a construction project that creates and manages contacts. Procurement activities span from identification of requirements to project closeout, making it a perfect mode for integrating organizational strategic directions. Lately, the strategic importance of procurement has been widely acknowledged by academics as well as industry professionals. Construction procurement is a complex process with a large number of available options and directions(Ruparathna and Hewage 2013).The selection and management of appropriate procurement model are fundamental to the success of a large-scale construction project (LSCP)(Li and Gao 2010).

Materials constitute a large proportion of the total cost of construction. Proper management of the material flow may play a significant role in enhancing the effectiveness of a contractor (Polat, et al. 2006). According to statistics, construction materials generally consume about 40 percent to 60 percent of total budget of the project (Polat and Arditi, 2005).

Material procurement and storage on construction sites need to be properly planned and executed to avoid the negative impacts of material shortage or excessive material inventory on-site. Deficiencies in the supply and flow of construction material were often cited as major causes of productivity degradation and financial losses (Thomas et al. 2005).

Construction operations transform cash into physical work items which transform in turn into cash (Elazouni and Gab-Allah, 2004), and cash flow is cash in and cash out of a business. Cash flow at the project level comprises a complete history of all cash disbursements and earnings received as a result of project execution .Cash outflows on a construction project include expenses for completing a project, such as interest, materials and labor costs; cash inflows represent various payments received from the owner, such as bonuses.

LITERATURE REVIEW

Since long-term and high complexity during the construction period of a large scale construction project, the process of resource supply becomes instability, and the risk of out-of-stock on construction site is increasing. Therefore, Factors that influence decisions of procurement strategy in the supplier selection stage will be transformed because of unexpected events (such as natural disasters, social-political changes, terrorism, and economic disasters) (Li and Gao 2010).

Ordering smaller quantities of material more frequently minimizes the locked-up capital in material inventories; however, it increases the probability of material shortages and project delays. On the other hand, ordering larger quantities of material less frequently minimizes the probability of material shortage and project delays; however, it increases the cost of locked-up capital in large inventory buffers on-site(Said and El-Rayes 2010).

When a contractor considers a project for bidding, he/she needs to know the cost and time frame for this project (Mubarak 2005). In this context, the contractor must prepare a bid to be submitted to the owner based on the estimated costs and markup to build the project in accordance with the contract documents (Pratt 2003). Typically, a bid price is composed of direct costs, indirect costs and a bid markup (Dikmen et al. 2007).

GA is a stochastic search algorithm based on principles of natural competition between individuals for appropriating limited natural sources. Success of the winner normally depends on their genes, and reproduction by such individuals causes the spread of their genes. By successive selection of superior individuals and reproducing them, the population will be led to obtain more natural resources. The GA simulates this process and calculates the optimum of objective functions (Saeed G. 2013).

The population of chromosomes in the genetic algorithm (GA) represents the potential solutions to a problem. The chromosomes, which evolve through successive generations, comprise strings of values called genes. In order to exploit and explore other potential solutions for a problem, child chromosomes are generated by merging two parent chromosomes using a crossover operator and/or modifying the gene values of an existing chromosome using a mutation operator. Through successive generations, a predefined fitness function is used to evaluate the quality of the chromosomes in terms of introducing potential solutions to the problem. High-quality chromosomes will have higher probabilities of survival than the low-quality ones. Upon completing a considerable number of generations, the chromosomes may be closely identical in their fitness values, which represent the optimal or near-optimal solutions to the problem. Otherwise, a certain termination condition is applied to terminate the searching process (Alghazi et.al. 2012).

CONSTRUCTION CASH FLOW

Analysis of cash flow launches by aggregating activities with their cost. After that, project cumulative cost, revenue, expense, and income can be calculated. Typical cash flow profile embraces cumulative expense and income Fig. 1. The contractor can educate an approximate mean of his monthly expenses and the predestined monthly incomes. The cumulative expense curve (based on the project schedule and cost) predominating has an S-shape. Meanwhile, the income profile of the periodical payments received for performing the work occupies a ladder shape. Project expense is calculated from project cost. Income payments are calculated from revenue values considering payment delay period from the owner. Revenue values are calculated from cost values considering markup (M) percentage, i.e. revenue = cost / (1-M).

Part of cost may be paid immediately (immediate expense) while another part may be delayed or transferred to a later time period (transferred expense). Accordingly, expense values depend on the timing of the contractor payments to his/her suppliers and vendors. The variation between the two curves (expense and income) uncovers the amount of finance on which interest is charged. The variance between the contractor's expense and income symbolize the amount that the contractor needs to finance the project.

Financial charge (FC) represents the cost of financing this amount of money. Financial charge can be reduced by getting the expenses lower (through cheaper costs and/or credit from suppliers) and/or by getting the income profile higher (e.g., receiving an advanced payment).

Figure 2 illustrates monthly financial charges; for example, financial charge of the first month is calculated as the multiplication of monthly interest rate and the overdraft in this month. While in other months, it is the multiplication of monthly interest rate and all preceding monthly financial charge plus the overdraft of this month. It is also important to maintain maximum monthly overdraft (Omax). Minimizing Omax ensures optimization of cash flow.

Legend:
Ex is the cumulative expense amount
In is the cumulative income amount
O is the overdraft amount

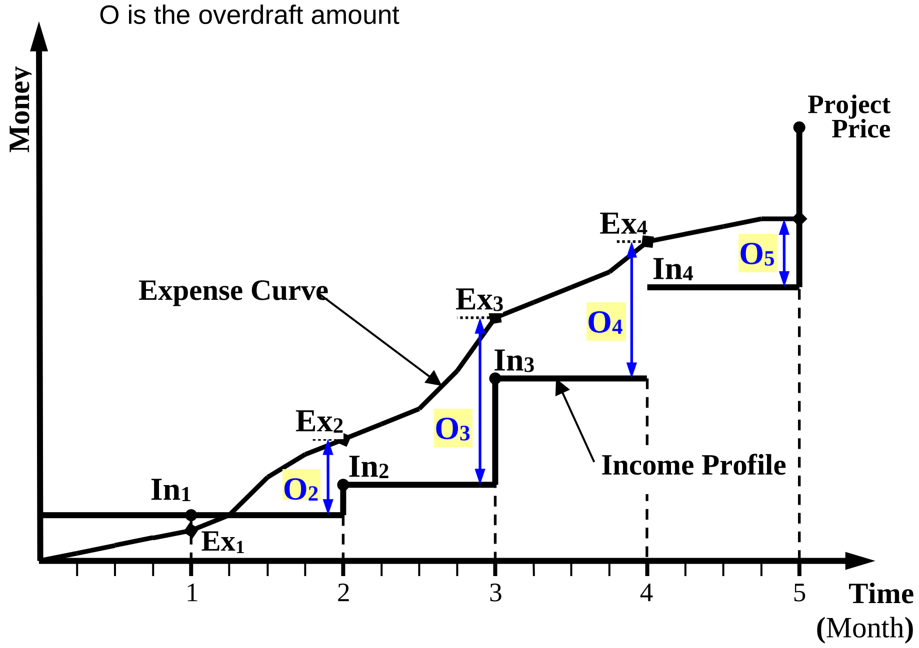

Fig. 1: Cash flow Curves (Sanad 2011)

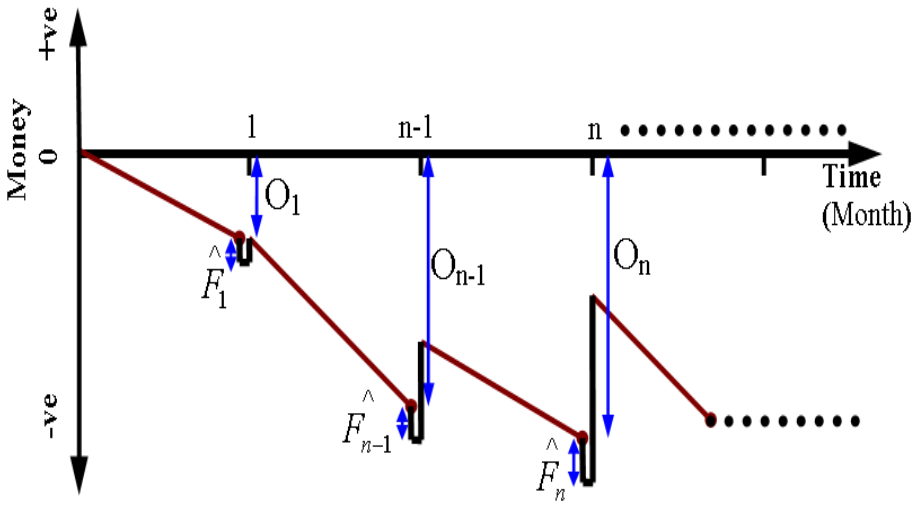

Fig.2: Generation of financial charge from overdrafts (Elazouny and Metwally 2005)

CASH FLOW MODELING

1- Optimization of Material Procurement plan

Price negotiation direct to pick out a convenient supplier of construction materials has long been renowned as a time exhaustion and costly procedure (Costantino and Di Gravio 2009; Huang et al. 2010; Lam et al. 2010; Shen et al. 2011; Yuan and Ma 2012). The provocation of construction material procurement negotiation engenders slightly because all negotiation team has particular acquaintance on their payoff assignment but is ignorant of the values and tactics of the contrary side. The mysterious and restricted supplier information as well as multiplex attachments among diverse factors impact supplier attitudes, making learning a supplier's negotiation strategy and determining the adequate offer price complicated for contractors. All procurement plans, including payment period, payment term, advance payment, and vendor price, displayed is Table 1.

Table1. Material procurement plans

Alternative	Payment period	Payment Term	Supplying Payment Ratio	Vendor Price
1	Monthly	Cash	0%	Mc
2	Monthly	day check-10%-60	10%	$0.1Mc + (0.9Mc \times \grave{i}_{A_2})$
3	Monthly	day check-10%-30	10%	$0.1Mc + (0.9Mc \times \grave{i}_{A_1})$
4	Monthly	day check-25%-60	25%	$0.25Mc + (0.75Mc \times \grave{i}_{A_2})$
5	Monthly	day check-25%-30	25%	$0.25Mc + (0.75Mc \times \grave{i}_{A_1})$
6	Monthly	day check-33%-60	33%	$0.33Mc + (0.67Mc \times \grave{i}_{A_2})$
7	Monthly	day check-33%-30	33%	$0.33Mc + (0.67Mc \times \grave{i}_{A_1})$
8	Monthly	day check-50%-60	50%	$0.5Mc + (0.5Mc \times \grave{i}_{A_2})$
9	Monthly	day check-50%-30	50%	$0.5Mc + (0.5Mc \times \grave{i}_{A_1})$

2- CASH FLOW OPTIMIZATION USING GENETIC ALGORITHM

A is a meta-heuristic that mimics Darwin's theory of evolution and the survival of the fittest. Evolution as a theory suggested that living things offspring and upgrades through reproduction, mutation, and crossover of patrimonial genes (Deb et al. 2002).The meta-heuristic adopts haphazardly navigable study to detect cosmopolitan optimum values for combinatorial optimization snag. The fundamental precept of GA is to transform the unsystematic search operation into non-random ones so that the refinement exists in the premier generation of the solution turn out the basis for the following one.

MODEL METHODOLGY

Firstly, it is vital that optimization objective, variables and constraints are comprehensible. Therefore, objective is monthly overdraft being minimum with assistance of variables which are various material procurement plans. Nonetheless, the project deadline is a constraint.

As outlined before, negative cash flow affects project financing costs, ultimate profit. Therefore, control of the negative cash flow enables schedulers to devise material procurement plans and financial items that maximize project profit. This system is a quantitative system design and attempts to minimize negative cash to avoid a budget deficit without delaying project completion, thereby helping contractors release financial pressures on activity execution. This is done by attempting minimizing cash overdrafts in case of borrowing. This necessitates an appropriate cash flow management strategy. Fig. 3 shows a flowchart of model methodology.

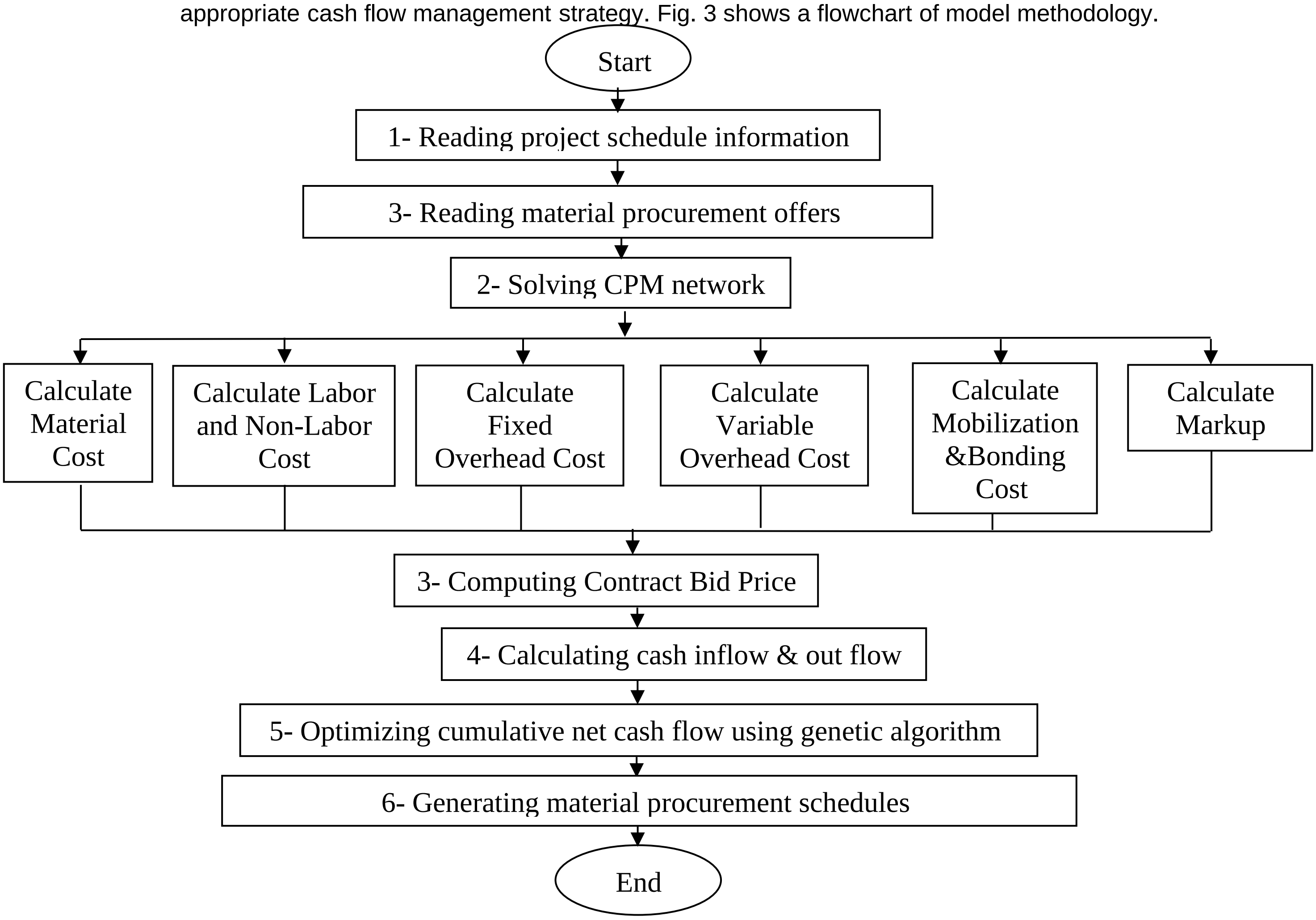

Fig.3: Flowchart of Model Methodology

In solving a problem with multiple objectives, different methods can be employed but in this model, approach is used to find the Pareto optimal solution set. The objective of the Pareto front concept is to find the set of optimum solutions (Pareto Front). Then the preferred solution, the one most desirable to the designer or Decision Maker (DM), is selected from this set. A solution belongs to the Pareto set (set of non-dominated solutions) if there is no other solution that can improve at least one of the objectives without degradation of any other objective. Fig.6 shows the concept of Pareto-optimality considering two objectives (Expense and Net cash flow). The feasible region is the region represents all feasible solutions for all objective functions of the system. These solutions satisfy the system constraints, but the optimal solutions lie on the outer most lower-left edge of the feasible region (in case of minimization). The set of Pareto-optimal solutions are generally called Pareto Front Fig.4.

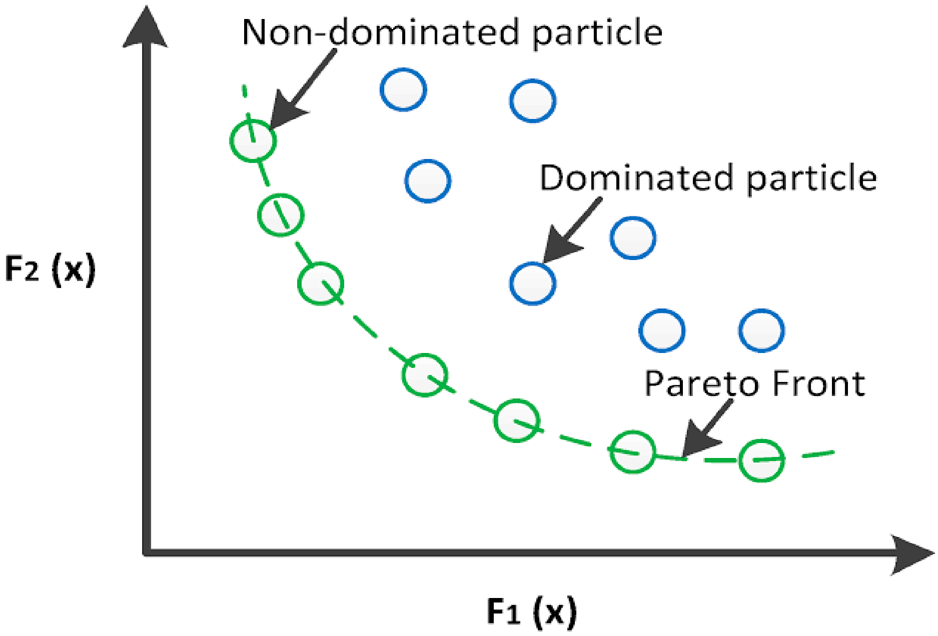

Fig. 4: Concept of Pareto-Optimality (Mahesh, et al. 2016)

MODEL IMPLEMENTATION

The implementation media of optimization model is a computerized system comprised spreadsheet software. Which has played a vital role in performing formula based arithmetic and calculations, and other activities that may require mathematical calculations.

Another major contributing factor is that an optimization engine is essential to execute discrete arithmetical optimization rapidly and in a professional track. SolveXL is an add-in for Microsoft Excel that adds the possibility to use genetic algorithms to solve various optimization problems. To be able to work with this add-in user is required to have only basic knowledge of Microsoft Excel to enter appropriate formulas that represent given problem. Some basic knowledge of genetic algorithms is also essential in order to configure the algorithm properly to obtain best.

The optimization model is coded employed the Visual Basic for applications macro programming language to automate the optimization model.

The steps to use the computerized model are summarized as follows:

Step 1: MS-Excel Interface

When user turns on the MS-Excel program, the major MS-Excel interface is obvious. It involves numerous columns and rows for data feeding.

Steps 2 and 3: Schedule Data

User inserts schedule data in MS-Excel, in an excel sheet named "PROBLEM".

Steps 4 and 5: Material cost estimation Data

The cost estimation distribution of each activity is inserted by user.

Steps 6 and 7: Material procurement Data

User illustrates bargains among vendors and contractor.

Steps 10 and 11: Cash Flow Data

User input data on the subject of cash flow.

Steps 12, 13 and 14: Optimization

In this stride, the user is asked to specify optimization type, population size, number of generations and crossover type. Then the automated system starts to generate random solutions in first iteration and calculates objective function(s), then updating these solutions. This process continues until interchange position is reached.

Case Study

1-Project Data

The project has been divided into 10 activities. Descriptions, durations and direct costs of activities and logical dependencies between activities are given by (AbuElnasr 2021).The project start date is set to 1/1/2021. The project is planned to finish on 15/4/2021.Markup is assumed as 25% According to the contract conditions, The retention is 5%, no advanced payment, The mobilization is 3% of direct cost (DC),The indirect cost (IDC) is assumed to be the sum of fixed overhead costs (FOC) and variable overhead costs (VOC),Bonding cost is assumed to be 1.5% of price, Profit and risk and financial charge (FC) are assumed to be 7and 2 and 1.6 5 of cost respectively, and no incentive in case of early completion. The initial schedule is as shown in Fig. 5 and Table.2.

Table 2. Cash flow data.

Mobilization	3	% DC + VOC
V.O.C	3	% DC
Profit	7	% cost
Risk	2	% cost
F.c	1.6	% cost
Bonding Cost	1.5	% DC + IDC + MOB + MP
Markup	25	% DC + IDC + MOB
1 + M	1.25	
I monthly	1	%
Retention	5	%

Activity ID	DESCRIPTION	Budget COST	material cost	payment term	material cost payment	PLANNED START 1/1/21	PLANNED FINISH 4/15/21
Project							
Substructure							
Soil works							
A1000	Excavation	106,800.0	42,720.0	Cash	Cash	1/Jan/21	20/Jan/21
A1010	Backfilling UP TO S.O.G Level	418,800.0	167,520.0	Cash	Cash	5/Apr/21	15/Apr/21
Concrete works							
PC Works							
A1020	Formwork of PC works	87,360.0	34,944.0	Cash	Cash	21/Jan/21	31/Jan/21
A1030	Pouring PC works	177,450.0	70,980.0	30-day check-10%	Cash	1/Feb/21	3/Feb/21
A1040	Strip formwork PC works	8,190.0	3,276.0	60-day check-10%	Cash	4/Feb/21	7/Feb/21
RC Works							
A1050	Form work RC Footing and Tie beams	158,400.0	63,360.0	60-day check-25%	Cash	8/Feb/21	23/Feb/21
A1060	Steel Fixing RC Footing and Tie beams	462,000.0	184,800.0	60-day check-25%	Cash	24/Feb/21	11/Mar/21
A1070	Pouring RC Footing and Tie beams	26,400.0	10,560.0	Cash	Cash	12/Mar/21	14/Mar/21
A1100	Strip formwork RC Foundation	92,400.0	36,960.0	60-day check-10%	Cash	15/Mar/21	18/Mar/21
Insulation works							
A1110	3 layers of Cold bitumen of Footing	112,000.0	44,800.0	60-day check-10%	Cash	24/Mar/21	31/Mar/21
Total Planned Cost		1,649,800					

Fig. 5: Project Schedule

2. Cash Flow Optimization

The original schedule with the direct cost listed by (AbuElnasr 2021) has a total direct cost of 1,649,800 LE. Also, it has a maximum monthly overdraft of 1,104,685 LE. The original schedule has a cumulative expense of 1,986,840 LE. On the other hand, the optimized schedule has a cumulative expense of 1,998,729 LE. But, the maximum monthly overdraft is 942,879 LE. Consequently, the financial charge is developed from .604% to .401% as shown in Fig. 6 to Fig. 7 and Tables 3 to 4.

Table 3 to 4 .Original financial charge and optimized financial charge.

F.C (after material procurement)		
A Income	9610431.94	
A Expense	10408545.88	
A net	798113.939	
F.C	7981.13939	
F.C	0.401700069	%
MAX CASH REQURIED		-942879.8562
month		3

F.C		
A Income	9610431.94	
A Expense	10811829.6	
A net	1201397.658	
F.C	12013.97658	
F.C	0.604677475	%
MAX CASH REQURIED		-1104658.093
month		3

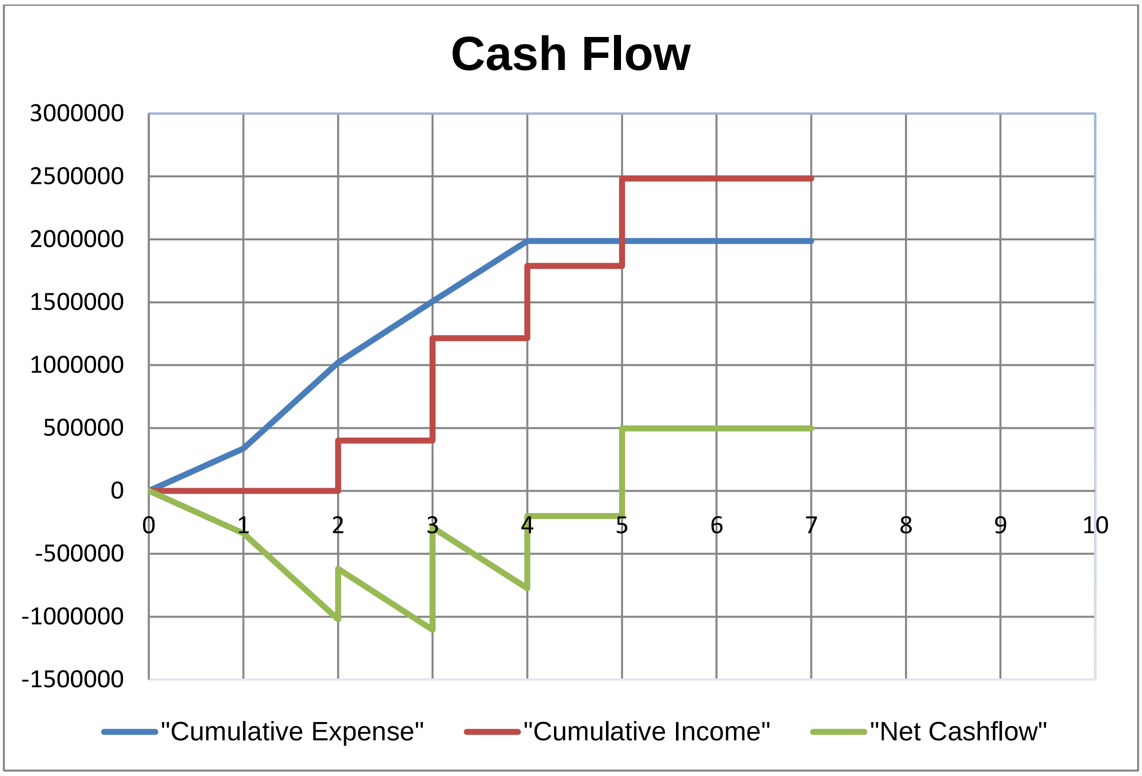

Fig. 6: Original Cash Flow

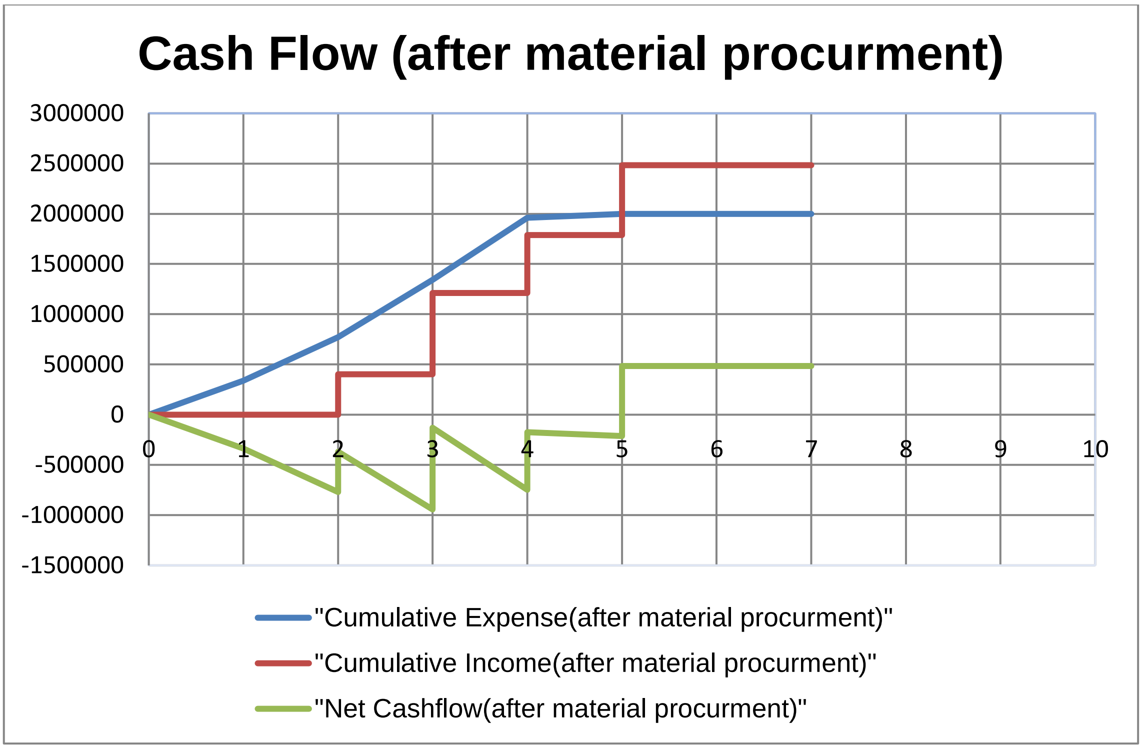

Fig. 7: Optimized Cash Flow

CONCLUSIONS

In this paper, an optimization model for cash flow of construction project was developed. The developed model can be used to optimize construction material procurement plans based on multiple objectives. Some remarks were concluded and listed below:

1- The results of the cash flow model can be used to make crucial decisions, such as: perfect material procurement plan.
2- Minimized level of monthly overdrafts reduces financial aspects of the project.
3- A case study was presented to validate the proposed model and to illustrate its use.

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