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A Case Study on Optimization of Contractor's Financing through Allocation of Subcontractors

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Abstract**—**In many countries, the construction industry relies heavily on outsourcing models in executing their projects and expanding their businesses to fit in the diverse market. Such extensive integration of subcontractors is becoming an influential factor in contractor's cash flow management. Accordingly, subcontractors' financial terms are important phenomena and pivotal components for the well-being of the contractor's cash flow. The aim of this research is to study the contractor's cash flow with respect to the owner and subcontractor's payment management plans, considering variable advance payment, payment frequency, and lag and retention policies. The model is developed to provide contractors with a decision support tool that can assist in selecting the optimum subcontracting plan to minimize the contractor's financing limits and optimize the profit values. The model is built using Microsoft Excel VBA coding, and the genetic algorithm is utilized as the optimization tool. Three objective functions are investigated, which are minimizing the highest negative overdraft value, minimizing the net present worth of overdraft, and maximizing the project net profit. The model is validated on a full-scale project which includes both self-performed and subcontracted work packages. The results show potential outputs in optimizing the contractor's negative cash flow values and, in the meantime, assisting contractors in selecting suitable subcontractors to achieve the objective function.

Keywords**—**Cash flow optimization, payment plan, procurement management, subcontracting plan.

I. INTRODUCTION

CASH flow management is a crucial area of wide interest to contractors. In principle, contractors forecast their cash flow profile to calculate their financing requirements and secure credit limits for the project execution at the per-award and post-award phases. There are various factors that affect the contractors' forecasted cash flow values. One of the important parameters is the contractors' decision to subcontract the works which significantly affects the forecasted cash-out values [1], [2]. Subcontracting strategy is commonly adapted by contractors to either solve the problem of resource availability or if the contractor does not acquire the know-how of specialized work packages [3]. Reference [4] reported that subcontractors' involvement in the construction industry is up to 90% of construction projects and [5] recorded that subcontractors' participation contributes up to 80% to 85% of the construction works. Accordingly, it is essential to apprehend cash management across the project stakeholders and supply chain specialists, considering the contractors' perspective, the nexus of the cash flow chain. Contractors receive cash from the project owner for works executed and reimburses subcontractors and suppliers for works performed. Such payments are independently released based on payment conditions communicated with each party. Owner's payment terms are negotiated between the bidders at the per-award phase and signed off after the project award. Specialists' prices and payment conditions, on the other side, are discussed at the early stages of project mobilization to procure the necessary services and agree on sub-prices and unit rates to mitigate the risk of price fluctuations. At this stage, contractors are presented with several financial quotation each individually affecting the contractor's cash out which ensue variant financing requirements. Furthermore, mapping the subcontractors' schedule of payments and contractors' commitment to these schedules can be prolific to the project success. A survey in Hong Kong conducted among subcontractors and main contractor's staff pointed that committed payments and reasonable cash flow are the most influential factors that motivate the subcontractor's performance [6]. Specialists' companies are mostly small to medium-sized businesses that operate at low-profit margins. Subcontractors can get deterrent when they operate under financial losses and their progress can be disruptive and claim-based for compensations to balance their cash deficiencies. On the other side, if they are confident that they will be compensated timely and fairly for their work subcontractor's operation will show a proactive and cooperative manner which contributes to the project's success [6]. Accordingly, this paper aims to apply a decision support model, on a case study project, to optimize the contractor's cash flow financing requirements and increase its profitability through the selection of the optimum combination of the service providers' payment schedules based on their financial quotations.

This paper is organized in the following sequences: Section II presents the literature review on the research works conducted on contractor's cash flow optimization of financing requirements, Section III discusses the model development, Section VI illustrates the case study application, Section V shows the case study results, Section VI covers the subcontractor's advance payment optimization, and Section VII provides the conclusion.

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II. LITERATURE REVIEW

Various researchers developed cash flow optimization modes, such as finance-based schedule optimization (FBS), time-cost-trade-off optimizations (TCTO), and supply chain payment and selection models. When developing cash flow forecasts, three payment parameters are widely utilized that characterize payment transactions made between the payer and the payee. Reference [7] outlined these as the payment lag which is the payment collection duration between the invoice submission date and payment receipt, payment frequency which is the agreed time interval of invoice submissions which can be weekly, bi-weekly, or monthly and the payment component which distinguishes the disbursed payments made under different cost categories such as material, labor, equipment, and subcontractors. Reference [8] developed a linear programming cash flow modelled as investment banking cash transactions to optimize project profit. The model presents the project cash transaction on an arc and node network where nodes are time points on the project time scale and arrows refer to cash transactions across time. It is developed on monthly payment frequency with compound monthly interest charges however, subcontracting variable payment parameters of works packages were not considered. Reference [9] developed an FBS model to optimize project finance with the trade-off in project duration. The model devises the project's optimum extension schedule to meet the credit limits and formulated the financing cost equations for the contractor's overdraft profiles. Reference [10] presented a multi-objective optimization FBS to optimize the total project duration and maximum credit limits using non-dominated sorting genetic algorithm. Reference [11] devised a project portfolio management for the maximization of the overall project profits by changing the activities' start dates in the portfolio to reduce the aggregate project financing requirements and costs. Reference [12] utilized FBS models to select the best-fit project financing plans for projects with fixed durations that reduce financing costs and increase profitability. Previous FBS models have considered line of credit as the financing plan, wherein [12] utilized long-term, short-term, and line of credit. The above-addressed FBS models considered owner payment terms, however did not account for the subcontractor's payment parameters in the modeling of contractor's cash-out graph. Reference [13] established a multi-objective FBS optimization to minimize negative overdraft and maximize profit for an enterprise of projects. The decision variables are the shift in the activity free floats and subcontractors' payment terms considering advance payment and retention mechanisms only. Researchers have also studied contractors' time-cost trade-off optimization problems. Reference [14] examined TCTO with discounted cash flow to minimize the project costs. The model dimension apprehends that activity cost along the project time span is not constant, especially when the project duration exceeds one year, thereof has accounted for the time value of money in its cost calculations. The cost optimization is made based on the allocation of construction methods and their duration. However, the developed cash-out did not account for crew payment terms. Reference [15] also presented a TCTO model with multi-objective optimization to minimize time and maximize profit, considering only monthly payment lags to selected crews. Their model solves for the optimum crew utilization and scheduling scheme that satisfies the objective functions. In addition to the discussed work herein, various other research has addressed different aspects of contractors' cash flow optimization; [16] conducted a critic literature review on cash flow optimization developments and addressed that in finance-based forecast model, most developed problems did not consider the contractor's procurement plan and payment arrangements with external stakeholder such as supplier and subcontractors which changes the forecasted values of the required capital.

Other researchers have addressed contractors' cost optimization by considering subcontractors' selection. Reference [3] proposed a multi-objective selection algorithm, utilizing ant colony optimization allocating subcontractors to project works to minimize cost and risk at a fixed project duration. Reference [17] emphasizes the importance of balancing cash flow among the project stakeholder and supply chain levels and addresses that traditional payment mechanisms such as unit price or lump sum are adversely affecting the stakeholder relationship and project success. Their research developed an IT system that models different payment mechanisms among the owner, contractors, and supply chain suppliers for off-site materials and provides the cash flow profiles generated under incentive-based payments, such as cost-reimbursement contracts. Reference [18] associated the selection of subcontractors with the optimization of cost, time, and quality of the project performance considering various work packages. The multi-objective optimization model assesses bidder cost and time quotations and provides Pareto-front solutions for subcontractor combinations based on the user's priority of the objective functions, either that of cost, time, or quality or an equal priority of each. However, the cost optimization of the bidders has not accounted for its payment parameters. Reference [19] introduced a linear optimization model to evaluate the impact of subletting units of work packages to subcontractors to predict the project profit. The optimization was built on the subcontractors' unit prices however, it did not consider its payment terms. The study developed a sensitivity analysis to emphasize the variations in sublet quantities of works on the profit slopes, which decision-makers can utilize to negotiate discounted rates in exchange for increased work units.

Based on the above review of related research works and knowing that the optimization of contractors' financing requirements is a fundamental objective for contractors' cash flow. Limited research has been developed to associate the contractor's allocation of service providers considering their prices and financial terms, including, payment lag, frequency, advance payment, and retention, and its effect on the contractors' overdraft profile and financing requirements. Accordingly, this research presents an integrated cash flow model that optimizes the contractor's financing requirement with the collective evaluation of the subcontractor's financial terms and the selection of the optimal combinations. The model is validated on a full-scale project considering five subcontracted packages.

III. Model Development

Below is a brief of the model architecture and its schematic process which is explained in further detail in the work carried out by [9]. The model consists of three modules namely input, computation, and optimization. Each module is comprised of a number of interfaces as listed below.

The input modules consist of the following:

A. *Project Info:* This interface defines the project pricing parameter, as indirect, overhead percentages and owner payment terms.

B. *Activity Data:* Activities are initially scheduled on a CPM software and then this interface takes in the activity IDs, its start and finish dates and budget direct cost.

C. *Subcontractor Payment Plans:* The financial terms received from various bidders, who are distinguished by the contractors as technically qualified subcontractors to be awarded work packages, are defined in this section. Each bidder takes a subcontractor ID and its financial inputs namely, the bidder's price, advance payment percentage and its due interval, the payment lag and frequency and retention percentage, and its release intervals are defined.

The Computation Modules consist of the following:

A. *Subcontracted Activity Cost Matrix:* Bidders' prices are usually based on bill of quantity items and not activity-based. Hence, this cost matrix distributes the bidders' prices among the activities of each work package.

B. *Cost Disbursement Bar Chart of Scheduled Activities:* This bar chart maps the scheduled activities' start and finish dates and budget cost per unit time across the project time scale to calculate the forecasted budget direct cost of works scheduled at each time period (t).

C. *Cost Disbursement Bar Chart of Subcontractors' Payment:* This bar chart is built with a VBA user-defined function that outputs the subcontractor's payment schedule based on the subcontracted work package planned activities and the designated subcontractor ID from the optimization module.

D. *Cash-out, Cash-in and Overdraft Plots:* The contractor's cash out is plotted from the budget cost of self-performed packages and subcontractor payment schedules of subcontracted packages. Cash-in is plotted from the budget cost of scheduled works along with the owner payment terms defined in the project info interface. Cumulative cash-out and cash-in are calculated and the overdraft profile is plotted.

The optimization module is the final interface that defines the objective function and decision variables. The objective is to minimize (1) and (2) and maximize (3), each evaluated separately, and the optimum combination based on the net profit and financing cost parameters is suggested.

$$F_1(t) = \text{Min}\ (OD_t) \tag{1}$$

$$NPV = \sum_{t=1}^{W} \frac{OD_t}{(1+r)^t} \tag{2}$$

$$NP = PBF - \sum_{t=1}^{W} FC_t \tag{3}$$

wherein, 't' is the time interval, 'OD' is the overdraft at time t, 'NPV' is the net present worth of the contractor's overdraft at time t = 1, 'r' is the discounted interest rate either announced by the central bank of the project country or the discounted rates of the contractor's ledgers and 'W' is the project planned duration, 'NP' is the net profit, 'PBF' is profit before finance and 'FC_t' is financing cost at time t calculated at an interest rate agreed upon with the contractors and its lending agency.

IV. Case Study Application

The model is applied to a full-scale project with a total of 750 activities and a duration of 132 weeks, i.e., 2.5 years. Initially, the project payment terms and contract price parameters are collected from the signed contract between the owner and contractor. The total contract price is EGP 2,513,661,530 and the advance payment received by the contractor before the commencement date is 20% of the contract price. Payment application frequency is submitted at the end of each month on the 28th day (every 4 weeks) and payments are received after 56 days (8 weeks) from the submission of the contractor's invoice. Besides, the final payment is received after 84 days (12 weeks) from the contractor's submission of the final statement and 5% retention is deducted on each certified payment which is returned in full at the final payment certification. For the price parameters, the fixed and variable overhead percentages are 5% and 10% of the direct cost respectively and the markup is 15% of the project cost.

The project activities are extracted from the cost-loaded baseline, developed on Primavera P6. The activity data inputs are the activity IDs (i), activity name, start and finish date, and activity total budget direct cost. The durations provided from P6 are in days which is converted to weeks to reduce the bar chart size. The budget direct cost per duration of activity is computed by dividing the total budget direct cost of each activity by its duration.

Next is establishing the subcontractor payment plan from the bidder's financial quotations. Five main subcontracting packages are selected, three are architecture packages (aluminum works, metal fabrication works, stone works) and two are electric packages (IP telephones works, and generators). The total package prices are 13% of the project's total price. For each package, the bidders' financial quotations are investigated, and their price and payment parameters are defined in the Subcontractor's Payment Plan interface. Table I shows the defined financial terms of technically qualified bidders.

The Cost Disbursement Bar chart of scheduled activities that allocated the budget direct cost of planned works and Cost Disbursement Bar chart of the subcontractor's payment that maps the subcontractor's payment schedule are both developed from the inputs introduced in the model interfaces. Consequent to the above, the cash-in, cash-out, and overdraft plots are developed. Figs. 1 and 2 show the cash plots and overdraft.

After completing the cash flow development, the optimization objective functions and decision variables are defined. $F_1(t)$ and NPV, NP are computed as provided in (1), (2) and (3). The financing costs in (3) are computed at a lending interest rate of 10.75% per year made with the contractor's borrowing agency. Since five work packages are optimized, five decision variables are created each with its respective constraints, detailed in Table II. The problem is formulated on evolver to solve the optimization using genetic algorithms.

TABLE I
SUBCONTRACTOR'S PAYMENT PLANS

PK. Name	Sub_ID	Total Price (EGP)	Advance Payment%	Advance Payment due weeks	Payment Frequency	Payment Lag	Retention %	Retention Release Date 1	Retention Release Date 2
Aluminum	1	103,352,986.7	35%	91	4	4	-	-	-
Aluminum	2	110,771,558.6	40%	91	4	3	10%	132	132
Aluminum	3	105,621,887.0	30%	91	4	3	5%	132	132
Aluminum	4	104,171,658.8	35%	91	4	3	-	-	-
Metal Fab.	5	28,928,339.0	30%	94	4	4	10%	132	132
Metal Fab.	6	25,147,076.0	35%	94	4	3	-	-	-
Metal Fab.	7	27,210,560.0	25%	94	4	3	5%	132	132
Stone works	8	31,444,836.9	30%	92	4	3	-	-	-
Stone works	9	34,189,487.7	25%	92	4	4	5%	132	132
Stone works	10	41,553,328.0	35%	92	4	4	5%	132	132
Stone works	11	32,760,085.2	10%	92	2	2	-	-	-
Active IP	12	48,459,929.8	35%	105	4	4	10%	132	132
Active IP	13	46,249,855.9	35%	105	4	3	-	-	-
Active IP	14	45,231,695.0	25%	105	4	3	-	-	-
Generators	15	17,333,664.8	35%	90	4	4	-	-	-
Generators	16	20,770,823.4	30%	90	4	4	5%	132	132
Generators	17	18,074,017.5	25%	90	4	3	-	-	-

TABLE II
OPTIMIZATION DECISION VARIABLES AND CONSTRAINTS

Decision Variable	Constraint 1	Constraint 2
V_1: Subcontractor ID for Aluminum works	Integer	$1 \leq V_1 \leq 4$
V_2: Subcontractor ID for Metal Fabrication works	Integer	$5 \leq V_2 \leq 7$
V_3: Subcontractor ID for Stone work	Integer	$8 \leq V_3 \leq 11$
V_4: Subcontractor ID for Active IP	Integer	$12 \leq V_4 \leq 14$
V_5: Subcontractor ID for Generator works	Integer	$15 \leq V_5 \leq 17$

V. CASE STUDY RESULTS

A. Optimization of Maximum Overdraft

The model is initially developed on the understanding that all works are self-performed by the contractor and financial terms are not accounted for in the contractor's cash-out plot. This induced a maximum overdraft limit of EGP (271,101,108) and the forecasted net profit is EGP 189,462,453. After optimizing $F_1(t)$, the financing requirement has decreased by 10%, and net profit increased by 7%. Table III shows the optimized values of $F_1(t)$. The optimum combination of subcontractors to achieve the least maximum overdraft value of EGP (243,447,015), with a net profit of EGP 203,058,168 are subcontractors 3, 7, 8, 14, and 15. Comparing the devised combination financial terms with other quotations in the same works package, the model during optimization considers the aggregate impact of the subcontractor's price and payment terms on the contractor's cash flow profile values and does not necessarily select the least price. The decision variables of V_1 and V_2 are subcontractors 3 and 7 where their financial quotations do not have the lowest prices but provide more lenient payment terms to another financial offer. For instance, comparing the payment terms of subcontractor 3 with 1 (having the lowest total price), it is noted that the prices of subcontractor 3 entail a 5% retention policy against no retention policy from subcontractor 1, and subcontractor 3 pricing is based on 30% advance payment against 35% for subcontractor 1. The same applies when comparing subcontractor 7 with 6, wherein, 7 based its prices on 25% advance and 5% retention policy while 6 quoted for 35% advance and no retention policy. The model thereto when optimizing the contractor's negative overdraft, considers all financial terms factors to devise the optimum combination for the contractor's financial benefits.

TABLE III
F_1(T) OPTIMIZATION VALUES AND VARIANCES

Objective Function and Profit Parameters	Without Subcontracting of Packages	$F_1(t)$ Values
Decision Variables	-	3,7,8,14,15
$F_1(t)$	EGP (271,101,108)	EGP (243,447,015)
NPV	EGP (1,983,443,334)	EGP (1,730,411,190)
Profit Before Financing Cost	EGP 196,721,337	EGP 209,430,004
Financing Cost	EGP (7,258,883)	EGP (6,371,835)
Profit after Financing Cost	EGP 189,462,453	EGP 203,058,168

B. NPV and Profit Optimization

Table IV shows the optimized values of the NPV function. The objective is to maximize the net present worth of the overdraft value to induce a profile with the least financing costs. This is devised by selecting subcontractors 1, 7, 11, 14 and 15 to perform the work. When comparing the results of the NPV with $F_1(t)$, subcontractors 1 and 11 are preferable, over 3 and 8 since the combined prices of packages 1 and 11 are less than the prices of 3 and 8, thus the derived cash flow requires relatively less financing. Accordingly, the NPV optimization increases the net project profit after finance from EGP 203,058,168 to

EGP 203,655,779. However, the least NPV solution requires a higher maximum overdraft of EGP (245,852,050).

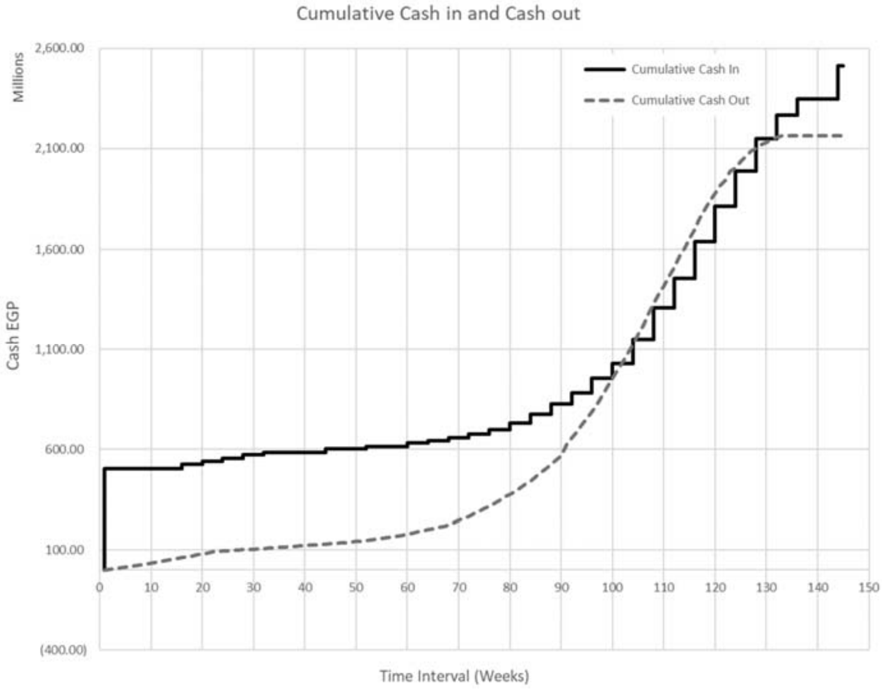

Fig. 1 Cumulative Cash in and Cash out

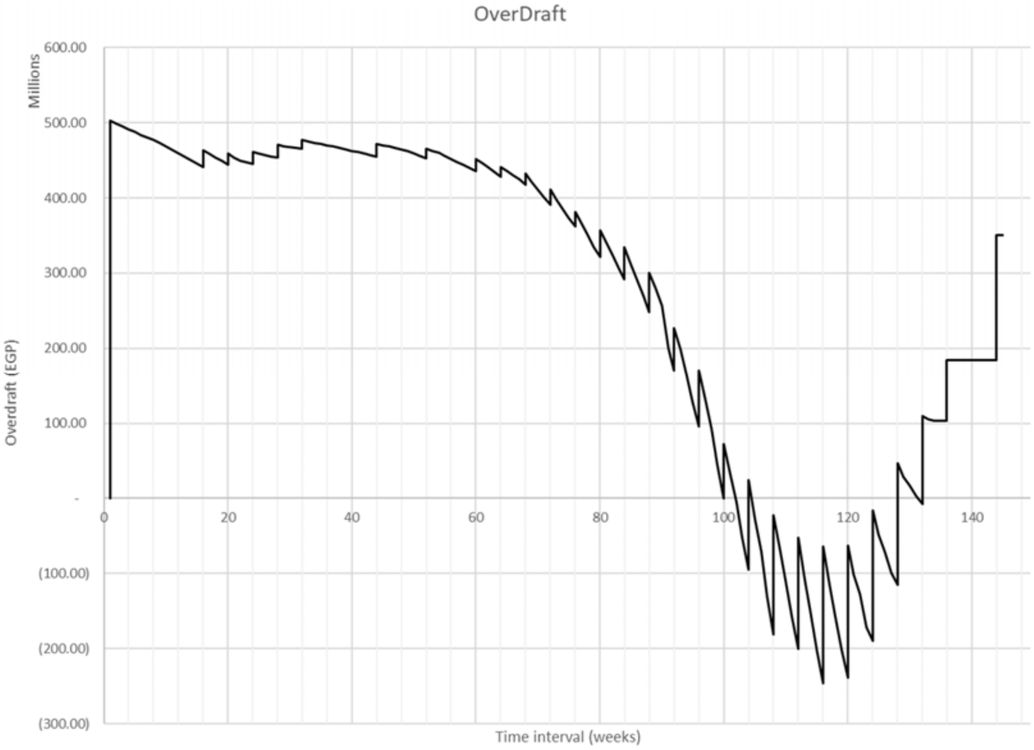

Fig. 2 Overdraft Profile

The third optimization dimension is the net profit utilized to allocate the selection based on maximizing the project net profit values. The selected subcontractors are packages 1, 6, 8, 14, and 15 which have the lowest prices and yield a net profit of EGP 204,351,755, with a higher financing requirement of EGP 247,075,189 compared to solutions of $F_1(t)$ and NPV. It is common that contractors may tend to prioritize project profit over other objects, so in case the contractor's financing capabilities cover the maximum overdraft limit, then the solution devised from the profit maximization can be a better option. However, if the contractors' priority is to reduce the financing requirements without forsaking the profit objective, then the combination devised from the NPV is an alternative option to secure a relatively high profit with lower financing requirements. Finally, if the contractor's main objective is to reduce the financing requirement, then the combination developed from $F_1(t)$ optimization secures the contractor with the lowest credit limits.

TABLE IV
NPV AND PROFIT OPTIMIZATION VALUES

Parameters	$F_1(t)$ Values	NPV Values	Profit Maximization
Decision Variables	3,7,8,14,15	1,7,11,14,15	1,6,11,14,15
$F_1(t)$*	(243,447,015)	(245,852,050)	(247,075,189)
NPV*	(1,730,411,190)	(1,715,102,117)	(1,739,023,709)
PBF*	209,430,004	210,002,195	210,773,616
FC*	(6,371,835)	(6,345,416)	(6,421,860)
NP*	203,058,168	203,655,779	204,351,755

*Values in EGP.

VI. SUBCONTRACTOR'S ADVANCE PAYMENT OPTIMIZATION

This model can further be formulated to find the optimum advance payment to its subcontractors to meet the contractor's available financing requirements. In the first stage of optimization, the contractor has the luxury to select the optimal combination based on the contractor's financial capacities and its objective function prioritization. However, this is not usually the case, since contractors in some instances, are faced with nominated specialists from the client or they may assign some of the project work packages to known subcontractors based on previous experiences or long-term dealings without conducting a financial comparison with other market competitors. Thus, agreeing on the advance payment of designated subcontractors is another dimension for optimizing the contractor's financing requirements when the forecasted finance exceeds the procured limits. The optimization problem can be formulated such that the subcontractors' advance payments are the decision variables to limit the maximum overdraft to meet the available credit. Table V shows the optimization problem definition.

TABLE V
OPTIMIZATION OBJECTIVE, DECISION VARIABLES, AND CONSTRAINTS

Objective Function	Min (NPV)
Decision Variable	AP_n
Constraint 1	$10\% \leq AP_n \leq 40\%$
Constraint 2	$F_1(t) \leq CL$

CL: credit limits, AP_n: advance payment of subcontractor n.

In Table V, n is the subcontractor ID, AP is the advance payment, CL is the available credit limit and the values of constraint 1 depend on the contractor's company policy with the allowable down payment percentages. The objective is to search for the optimal advance payment configuration that reduces the NPV of the contractor's overdraft to ensure minimum financing costs and increase the profit values. The CL was constrained to EGP (235,000,000) and the negotiable advance payment percentages suggested are shown in Table VI. Thus, decision-makers can make use of the model negotiation limits during their financial discussions with nominated subcontractors. However, this optimization problem assumes that the subcontractor will not change its prices if the advance payment percentage is reduced. Otherwise, if the subcontractors placed a counteroffer with revised prices in response to the contractor's negotiation, then decision-makers may need to re-evaluate their financial values based on the revised offer or may need to consider its designated subcontractor position with other market competitors.

TABLE VI
NEGOTIABLE ADVANCE PAYMENT PERCENTAGES

Decision Variable	Maximum Negotiable Percentage
AP_1	≤ 10%
AP_2	≤ 28%
AP_3	≤22%
AP_4	≤ 23%
AP_5	≤ 22%

VII. CONCLUSION

This research has investigated the interrelationship between the subcontractor's financial terms and the contractor's cash flow values. The model provides an easy-to-use decision tool that can equally evaluate different payment conditions as advance payment percentage, payment frequencies, payment lags, and retention mechanisms. The optimization tool provides the user with three optimization objectives, namely minimizing the maximum overdraft, minimizing the net present worth, and maximizing the project profit. The decision-maker is presented with three combinations and the selection among the best fitted one depends on the contractor's secured financial requirements and prioritization of objective functions. Finally, another optimization dimension of subcontractor advance payment is presented in cases when the subcontracting option is already defined, either by nomination or previous mass company dealing with its service provider. Contractors at the negotiation stage can discuss lower advance payment percentages to reduce the financial burden on their cash flow. This model assumes that the bidder will perform the work based on the contractor's baseline schedule and does not account for the subcontractors' resource availability. The model can be further adjusted to account for the bidder time schedules, where provided in their technical quotations, and optimize for time and financing requirements.

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