Research Article

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Time and finance optimization model for multiple construction projects using genetic algorithm

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Abstract: Construction contractors usually undertake multiple construction projects simultaneously. Such a situation involves sharing different types of resources, including monetary, equipment, and manpower, which may become a major challenge in many cases. In this study, the financial aspects of working on multiple projects at a time are addressed and investigated. The study considers dealing with financial shortages by proposing a multi-project scheduling optimization model for profit maximization, while minimizing the total project duration. Optimization genetic algorithm and finance-based scheduling are used to produce feasible schedules that balance the finance of activities at any time with the available funds. The model has been tested in multi scenarios, and the results are analyzed. The results show that negative cash flow is minimized from −693,784 to −634,514 in enterprise I and from −2,646,408 to −2,529,324 in enterprise II in the first scenario and also results show that negative cash flow is minimized to −612,768 with a profit of +200,116 in enterprise I and to −2,597,290 with a profit of +1,537,632 in enterprise II in the second scenario.

Keywords: optimization, multiple construction projects, cash flow, genetic algorithm

1 Introduction

The most critical resource for any project is cash, as companies fail more often due to lack of cash than due to lack of other resources. Over 60% of contractor failures are attributed to economic factors, according to [1]. In addition to conducting a financial feasibility analysis, there are two primary goals: the first step is to see if the contractor has enough money to complete the project. In the second step, the goal is to show how much of the investment has been used and how the payments have progressed throughout the project. Once the contractor has achieved these two goals, he can begin managing the cash flow of the project, which is referred to as cash flow management [2]. The importance of financial management in construction management has long been recognized. On the other hand, the construction industry has the highest rate of insolvency compared to other sectors of the economy. Due to poor financial management, many construction businesses fail, particularly due to lack of focus on cash flow forecasting. Lack of cash flow control has been a major contributor to the industry's high rate of insolvencies for years; as a result, it is a topic that all contractors should consider seriously. Contractors go out of business because they run out of cash, not because they do not have enough work. Cash flow is one of the most important tools for regulating an enterprise's cash flow by determining the cash in and cash out in a project and presenting the possible outcomes with a time effect [3]. Contractors used to face financial shocks when undertaking multiple construction projects concurrently. Despite any reasons behind that, they need to maneuver with their available resources, especially funds, to minimize time or cost overrun. Such optimum solutions are challenging and complicated without a comprehensive view of the whole situation in all the undertaken projects. A computerized system might be of great help in this sense.

2 Research methodology

This study's methodology is based on the premise that project financing costs and profits are affected by negative cash flow. Because of this, schedulers can use an optimization algorithm by a quantitative system design to devise schedules that maximize project profit, while minimizing negative cash flow to avoid a budget deficit

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without delaying project completion, allowing contractors to relieve financial pressure on activity execution. Hence, the maximum profit can be attained. This necessitates an appropriate cash flow management strategy; the following steps are performed in this research:

- Literature review: Investigating the state-of-art for modeling cash flow combination of multi construction projects.
- Data collection and analysis: Gathering factual data on multi construction projects' cash flow in some local major contracting enterprises.
- Building the optimization model: The model should provide for cash flow planning that assures profit maximization, while maintaining the total project duration using the optimization algorithm.

3 Literature review

Time-cost trade-off analysis and financing optimization are proposed as part of an integrated model. The optimization problem is solved using a hybrid GALP algorithm, which combines genetic algorithms (GA) with linear programming (LP). Using small and large networks, the proposed model is evaluated to see if it achieves optimal results in terms of financing costs and profits, to validate the model's performance and structure, and to confirm its practicality in large networks [4]. A practical method for solving the multi-objective optimization problem in construction project management to reduce the error probability that the optimized project will have in the actual project was proposed in [5]. Payments to subcontractors and suppliers, as well as financial arrangements with banks, are highlighted as the main payment conditions based on portfolio cash flow management. An optimization model that uses a GA is presented to assist construction enterprises in determining the optimum project schedules that minimize the total interest paid by a contractor for a portfolio of projects as well as minimize the maximum negative cash flow while accounting for various payment conditions between multiple parties [6]. A model that minimizes financing cost by integrating a line-of-credit and a long-term loan using a work schedule with normal activity durations is presented. The proposed model provides the optimum schedules of financing inflow (borrowed money) and outflow (repayments of principal and interest). The contractor benefits when the proposed model is used because the contractor: (1) pays less financing cost, (2) obtains higher profit, and (3) has more negotiating power with a lender because the contractor provides an optimal financing schedule when applying for a loan and/or credit line [7]. A model that minimizes financing costs by taking into account various financing options and a work schedule with typical activity durations is presented. There are several advantages in using a new financing model, such as a lower financing cost, avoiding a longer project duration, avoiding liquidated damages, and reducing the risk of a work schedule that includes more critical activities, over previous models [8]. An innovative multi-objective scheduling optimization model for multiple construction projects is developed in this study. Time, cost, profit, and resource fluctuations are among the goals of this project. Multi-objective scheduling optimization model for multiple construction projects was developed using the fast elitist non-dominated sorting genetic algorithm (NSGA-II) [9].

4 Scheduling using critical path method

In order to meet financial goals, a project's activities are shifted without affecting the project's deadline [6]. First, the Critical Path Method (CPM) was used to determine the time of the project's activities in order to schedule them. As an extension of the CPM approach, this study explores the effects of varying the start and end times of activities, as well as the total float and free float that can exist between them. Only the names of the activities, their predecessors, and the start date of the first activity in any project need to be entered into the model proposed in this article. Each activity's CPM will be calculated by the model. Each project's first activity must be set to begin on a specific date, even though the projects are being carried out at the same time. Changing the start dates of activities will only be possible within the free float of each activity, as each project has a set deadline. Consequently, each activity will have start and finish dates, along with deferred start and deferred finish dates, determined by the optimization model to meet the financial objectives of the contractor.

$$\text{Activity delayed start} = \text{Activity start date} + X, \quad (1)$$

where X = shifted days within free float determined by the optimization algorithm.

5 Cash flow in construction project

Cash flow has been extensively researched from the contractor's perspective. The financial terminology and equations used in [10] will be adapted for this study with some minor changes. In Figure 1, you can see a typical construction project's cash flow. Financial institutions such as banks, suppliers, and subcontractors all have an effect on a contractor's cash flow. It is important to keep in mind that how much money a contractor gets from the owner depends on the payment terms he has with that person. Bank financing costs, such as interest rates on loans, will have an impact on the contractor's cash outflow as a result of these terms. The financing costs that contractors incur while working on a project are sometimes referred to as interest payments, and they reduce their profits [11]. Terms like contractor-owner terms, such as advance payment, retention, and when to repay the retention percentage, have an impact on cash outflow as well. When a contractor has multiple projects going on at the same time, they are more likely to be able to negotiate better terms for subcontractors by offering them the opportunity to work on more projects. Contractual expenses (E_t), excluding interest or financing costs, include weekly payments to subcontractors, portions of activities executed by the contractor's own resources, and project-related indirect costs.

$$E_t = \text{Construction expenses during time period } (t) \text{ excluding financing costs.} \quad (2)$$

Cumulative cash flow before receiving the interim payment for $t \geq 1$ is [11]:

$$F_t = N_{t-1} + E_t, \quad (3)$$

where (N_{t-1}) the cumulative net cash flow from previous time periods up to time period ($t-1$). The cumulative net cash flow after receiving the interim payment is given by ref. [11]:

$$N_t = F_t + P_t, \quad (4)$$

where P_t is the interim payment received at the end of time (t). The following equation gives the profit for the project [11]:

$$G = \sum_{t=0}^{n} (P_t + E_t), \quad (5)$$

where G is the profit represented by a positive number, while the cost E_t is represented by a negative number. Because of the fact that N_t is negative in the early stages of the project and becomes positive towards the end of the project, contractors typically use bank loans to finance their projects and incur financing costs that are affected by a specific annual interest rate (i). As a result, the net cumulative cash flow before and after the payment (P_t) can be explained by Eqs. (6)–(8) [11]:

$$I_t = iN_{t-1}, \quad (6)$$

$$\hat{F}_t = F_t + \sum_{k=1}^{t} I_k (1+i)^{t-k}, \quad (7)$$

$$\hat{N}_t = \hat{F}_t + P_t. \quad (8)$$

Net cash flow ($\hat{N}_t$) during a project is the maximum value that the contractor will need to cover its financing at any given project. Enterprise-level equations will be used in this article instead of project-level formulae.

Many researchers' financial scheduling goals have been to maximize profits (G) or reduce total interest payments (I). In this article, a GA is used to reduce the portfolio's maximum cumulative negative net cash flow and maximize the portfolio's overall profit (G) using finance-based scheduling of multiple projects.

6 GA

This study's optimization engine uses GAs with heuristics. John Holland invented GAs in 1975. GA, a metaheuristic, simulates Darwin's theory of evolution and survival of the fittest. Changing organisms are thought to be the result of genetic mutation, reproduction, and gene

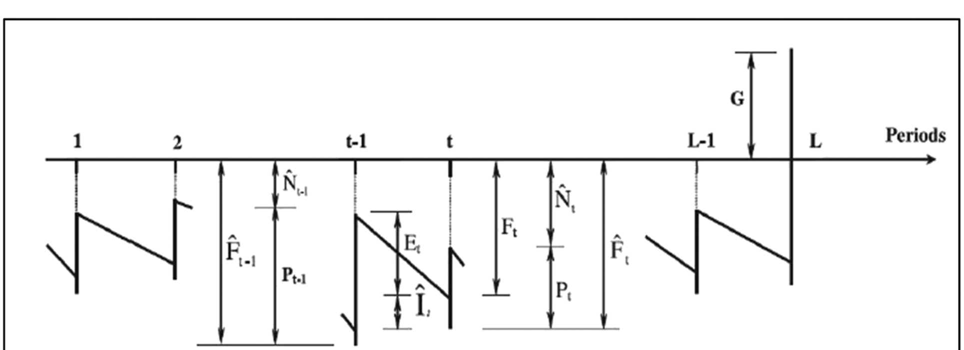


Figure 1: Typical cash flow profile for a construction project [11].

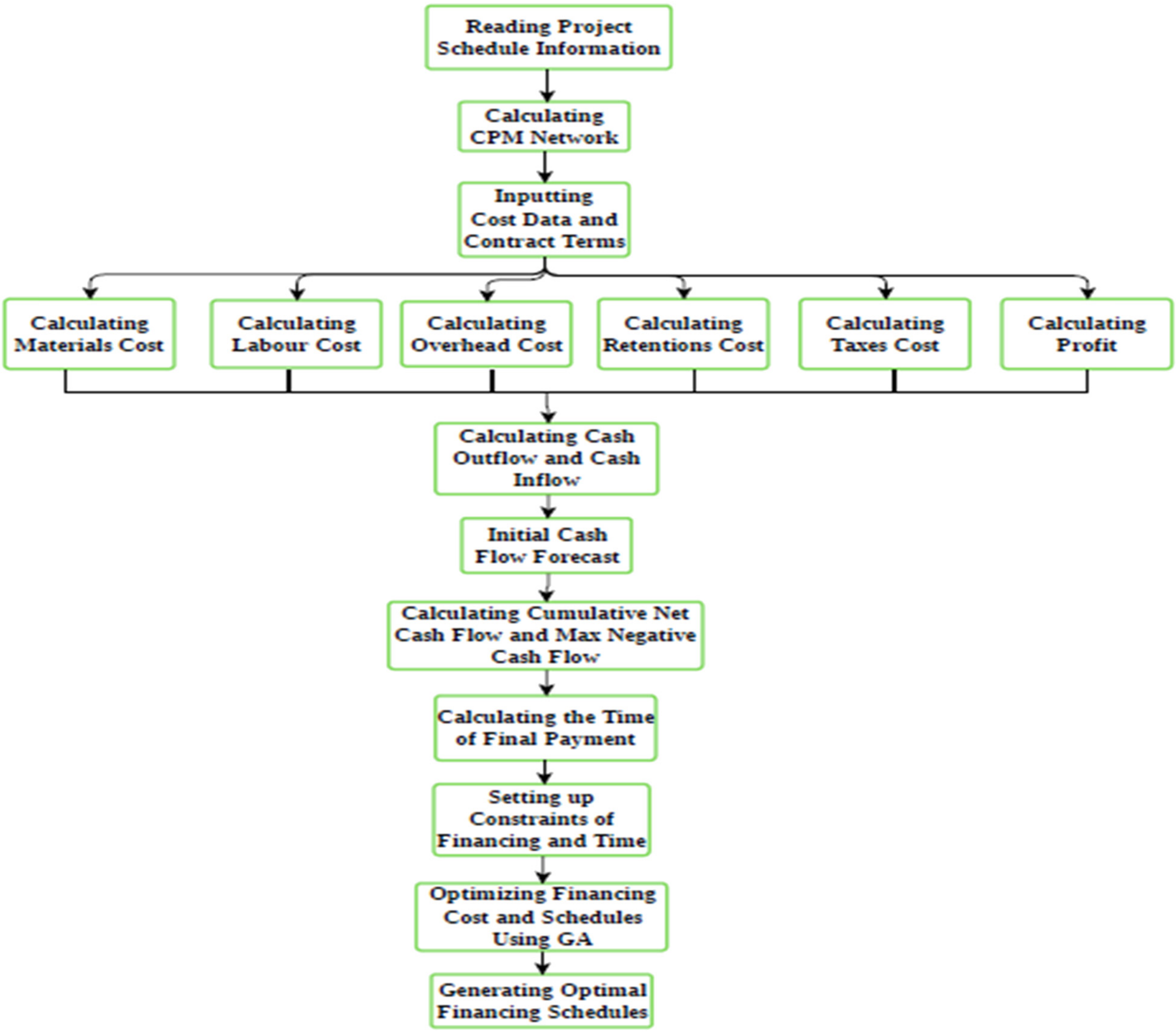


Figure 2: Chart for model development.

crossover [12]. The metaheuristic solves combinatorial optimization problems by random search. Using GA, the first generation's improvement becomes the basis for the next generation's random search. The first step in solving any combinatorial optimization problem using GAs is to create chromosomes. The parameters encoded are generated at random, and each gene offers a potential solution to the problem. Gene structure is a string of elements that corresponds to the start of each activity. Genes represent a possible timetable. Genes are evaluated based on expected contractor profit and negative cash flow at the end of the project. This study's goal is to find a project schedule that minimizes negative cash and maximizes project profit. Good chromosome individuals produce high values in maximization problems and low values in minimization problems [13]. The first chromosome generation creates many generations. The rest is discarded. Reproduction, crossover, and mutation from that generation are used to improve it. It is then applied to the next generation. The cycle repeats once the termination condition is met. A generation's best chromosomes are passed down through reproduction. Their role as parents to the next generation adds to the solution's bitterness. The least fit chromosomes are discarded to keep the population stable. Crossover is the process of mixing two chromosomes to see what happens. It is the main operation in GAs. Like in marriage, two-parent chromosomes are chosen at random to discuss the issue. The best chromosomes are more likely to be chosen at random. The phenomenon of "mutation" occurs when one or two offspring in a generation suddenly become geniuses. Mutations are used in evolution to ensure the best possible outcome for the next generation. No matter how many

Table 1: Projects of public and private enterprises

Projects	Enterprises	Work sector	Year
Bagaq Bridge in Nineveh Governorate	AL-Mutasim State Constructional Contracting Company	Public	2020–2021
Zghitun Bridge in Kirkuk Governorate	AL-Mutasim State Constructional Contracting Company	Public	2020–2021
Baladruz Road in Diyala Governorate	Ashur State Constructional Contracting Company	Public	2019–2020
Khanaqin-Naft Khana Road in Diyala Governorate	Ashur State Constructional Contracting Company	Public	2019–2020
Al-Fajr Al-Bdeir Road in Thi Qar Governorate	Ashur State Constructional Contracting Company	Public	2019–2020

recombination and crossovers occur, this data will always be lacking. To compensate, some chromosomes are silenced [14]. The procedure compares each generation's chromosome values to that of the previous generation, keeping only those that improve. The procedure must be repeated until an endpoint is reached.

7 Model development

Project financing costs and profit are impacted by negative cash flow, as discussed previously. When cash flow is properly managed, schedulers can devise plans that maximize project profitability. By reducing negative cash flow as much as possible, this quantitative system design seeks to avoid a budget shortage without delaying project completion. Because of this, you can make the most money possible and a cash flow management strategy is required. This model's development is illustrated in Figure 2.

The main goal of the problem can be stated as maximizing the project profit by:

- The project is initially scheduled based on input data, such as the relationships and duration of activities.
- The project's schedule is used to determine the maximum negative cash flow and profit.
- Optimization process using GA begins to search for the best possible scenario for a given project.

In this step, the available floats are used to generate multiple scenarios with activities starting at various times, and the resulting cash flow is calculated. GA processes, such as reproduction, crossover, and mutation, are used to create project scenarios. The best starting times are then determined by comparing each scenario to a predetermined objective function. In order to achieve this goal, a comprehensive model of various cash problems was constructed. For this, we will use two scenarios. The first scenario is used to find a solution to the problem of devising schedules that correspond to a minimum negative cash flow without reducing profit. The second scenario extends the time of the project and reduces the problem of negative cash flow while maintaining the maximum profit.

- The output data from the model are the selected scenario's optimized schedule, optimized cash flow, and net cash flow diagram. In the following section, a

Table 2: Items of work and other essential data of project I in enterprise I

Activity	Duration (day)	Predecessor	Cost of activity × 1,000 IQD	Lag	EST	EFT	LST	LFT	TF
A1000	60	—	47,400	0	90	149	90	149	0
A1010	46	—	83,149	0	90	135	139	184	49
A1020	40	A1000 and A1010	324,590	35	185	224	185	224	0
A1030	37	A1020	117,514	7	232	268	232	268	0
A1040	31	A1030	75,375	9	278	308	278	308	0
A1050	16	A1040	142,299	10	319	334	319	334	0
A1060	60	A1050	526,015	0	335	394	335	394	0
A1070	26	A1060	167,892	0	395	420	395	420	0
A1080	24	A1020	276,500	0	225	248	405	428	180
A1090	7	A1080	21,978	0	249	255	429	435	180
A1100	30	A1070 and A1090	533,345	15	436	465	436	465	0
A1120	21	A1100	71,890	0	466	486	466	486	0
A1130	10	A1100	6,162	0	466	475	477	486	11
A1110	10	A1101	52,014	0	466	475	477	486	11
A1140	6	A1120, A1130, and A1110	8,651	0	487	492	487	492	0

Table 3: Items of work and other essential data of project II in enterprise I

Activity	Duration (day)	Predecessor	Cost of activity × 1,000 IQD	Lag	EST	EFT	LST	LFT	TF
A1000	15	—	15,800	0	1	15	1	15	0
A1020	60	A1000	300,299	0	16	75	16	75	0
A1084	35	A1000	24,111	259	275	309	336	370	61
A1085	30	A1084	30,382	0	310	339	371	400	61
A1030	30	A1020	171,825	15	91	120	91	120	0
A1040	60	A1030	82,753	15	136	195	136	195	0
A1050	30	A1040	43,450	15	211	240	211	240	0
A1060	30	A1050	166,848	15	256	285	256	285	0
A1070	60	A1060	83,938	0	286	345	286	345	0
A1080	30	A1070 and A1085	54,053	15	361	390	361	390	0
A1090	20	A1080 and A1085	30,462	10	401	420	401	420	0
A1100	15	A1090	22,003	0	421	435	421	435	0
A1120	20	A1080	38,394	0	391	410	446	465	55
A1130	15	A1080	30,119	0	391	405	451	465	60
A1140	10	A1080	10,270	0	391	400	456	465	65
A1110	30	A1100	22,041	0	436	465	436	465	0
A1150	5	A1110, A1120, A1130, and A1140	8,279	0	466	470	466	470	0

Table 4: Items of work and other essential data of project I in enterprise II

Activity	Duration (day)	Predecessor	Cost of activity × 1,000 IQD	Lag	EST	EFT	LST	LFT	TF
A1000	60	—	171,000	0	1	60	1	60	0
A1005	80	A1000	1,125,000	0	61	140	61	140	0
A1010	60	A1000	300,000	0	61	120	101	160	40
A1015	60	A1000	12,000	0	61	120	81	140	20
A1020	80	A1010	777,150	0	121	200	161	240	40
A1025	90	A1005 and A1015	12,000	0	141	230	141	230	0
A1030	60	A1005	240,000	0	141	200	261	320	120
A1040	60	A1015	48,750	0	121	180	151	210	30
A1045	30	A1040	150,000	0	181	210	211	240	30
A1050	70	A1025, A1020, and A1045	2,250,000	10	241	310	241	310	0
A1060	60	A1050	1,764,000	10	321	380	321	380	0
A1090	50	A1030	120,000	5	206	255	336	385	130
A1095	60	A1030	450,000	5	206	265	326	385	120
A1100	35	A1060, A1090, and A1095	48,000	5	386	420	386	420	0
A1110	30	A1060, A1090, and A1095	240,000	5	386	415	391	420	5
A1120	25	A1100 and A1110	240,000	0	421	445	421	445	0

practical construction project is used to demonstrate the model's applicability.

8 Case study

The proposed model can be demonstrated using a sample of multiple construction projects from two public sector enterprises. Scenario analysis is based on a variety of constraints, such as project profitability and completion dates. Table 1 shows the maintenance and restoration projects for the roads and bridges involved.

The data needed to develop models are obtained from 5 projects completed in the period (2019–2021). Information is extracted from the records of the enterprises in the Ministry of Construction and Housing and Municipalities. The project is assigned to one main contractor and includes the following works: removing damaged items, installing new items, and maintaining some damaged items. Tables 2–6 show each item's work, duration, and direct cost, representing ten columns of input data. The first column, "Activity name," is used to identify the activities of the project; Second column, "Duration," is the activity duration in working days; Third column, "Predecessor," is used to define

Table 5: Items of work and other essential data of project II in enterprise II

Activity	Duration (day)	Predecessor	Cost of activity × 1,000 IQD	Lag	EST	EFT	LST	LFT	TF
A900	50	—	123,750	0	123	172	123	172	0
A1000	60	A900	585,975	0	173	232	173	232	0
A1010	30	A900	184,500	0	173	202	203	232	30
A1020	80	A1000 and A1010	306,000	0	233	312	248	327	15
A1030	90	A1000 and A1010	181,500	0	233	322	233	322	0
A1040	30	A1000 and A1010	9,000	0	233	262	298	327	65
A1050	80	A1030, A1040, and A1020	1,532,550	5	328	407	328	407	0
A1060	70	A1050	1,217,025	5	413	482	413	482	0
A1070	40	A1060	1,275,375	5	488	527	488	527	0
A1079	90	A1000 and A1010	105,000	0	233	322	443	532	210
A1080	30	A1070 and A1079	184,500	5	533	562	533	562	0
A1100	30	A1080	49,725	0	563	592	563	592	0
A1110	30	A1080	248,625	0	563	592	563	592	0
A1120	19	A1100 and A1110	18,750	0	593	612	593	612	0

Table 6: Items of work and other essential data of project III in enterprise II

Activity	Duration (day)	Predecessor	Cost of activity × 1,000 IQD	Lag	EST	EFT	LST	LFT	TF
A1000	60	—	19,614	0	184	243	184	243	0
A1005	70	A1000	28,133	0	244	313	244	313	0
A1010	30	A1000	16,164	0	244	273	284	313	40
A1020	60	A1005 and A1010	105,000	0	314	373	314	373	0
A1050	40	A1020	37,594	5	379	418	379	418	0
A1070	30	A1050 and A1080	486,000	5	424	453	424	453	0
A1080	30	A1020	222,833	5	379	408	394	423	15

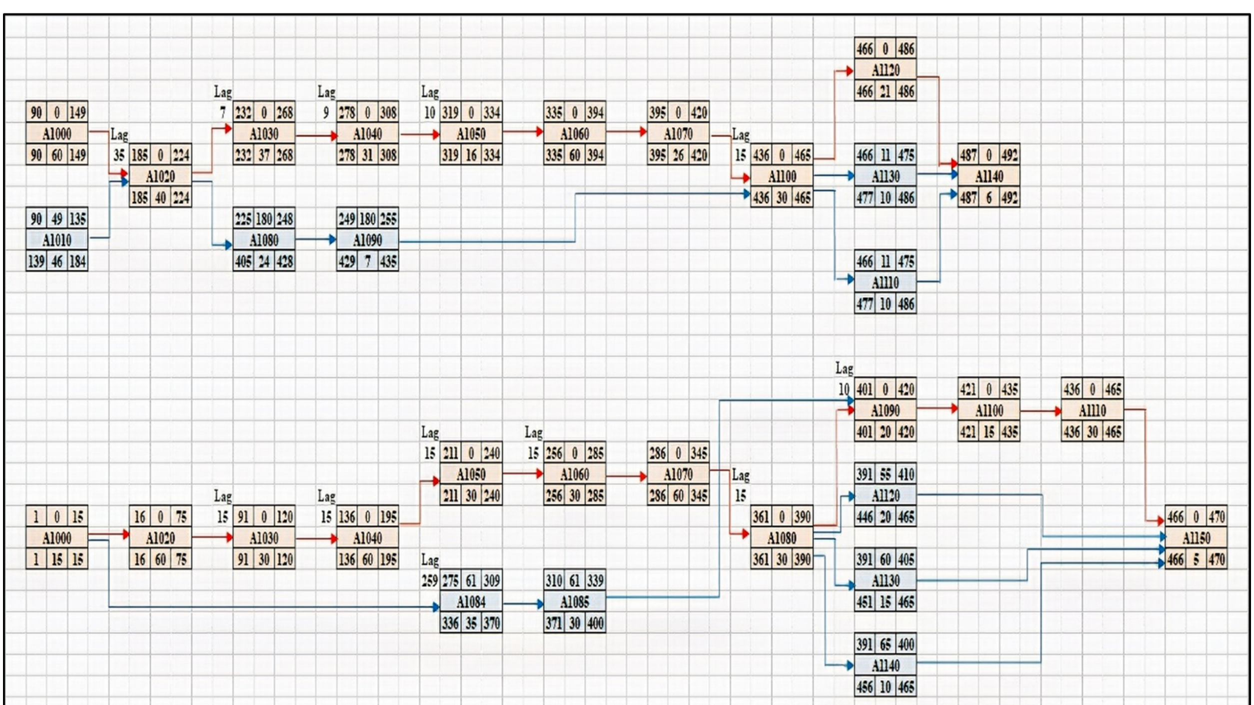


Figure 3: Planned activity network for enterprise I.

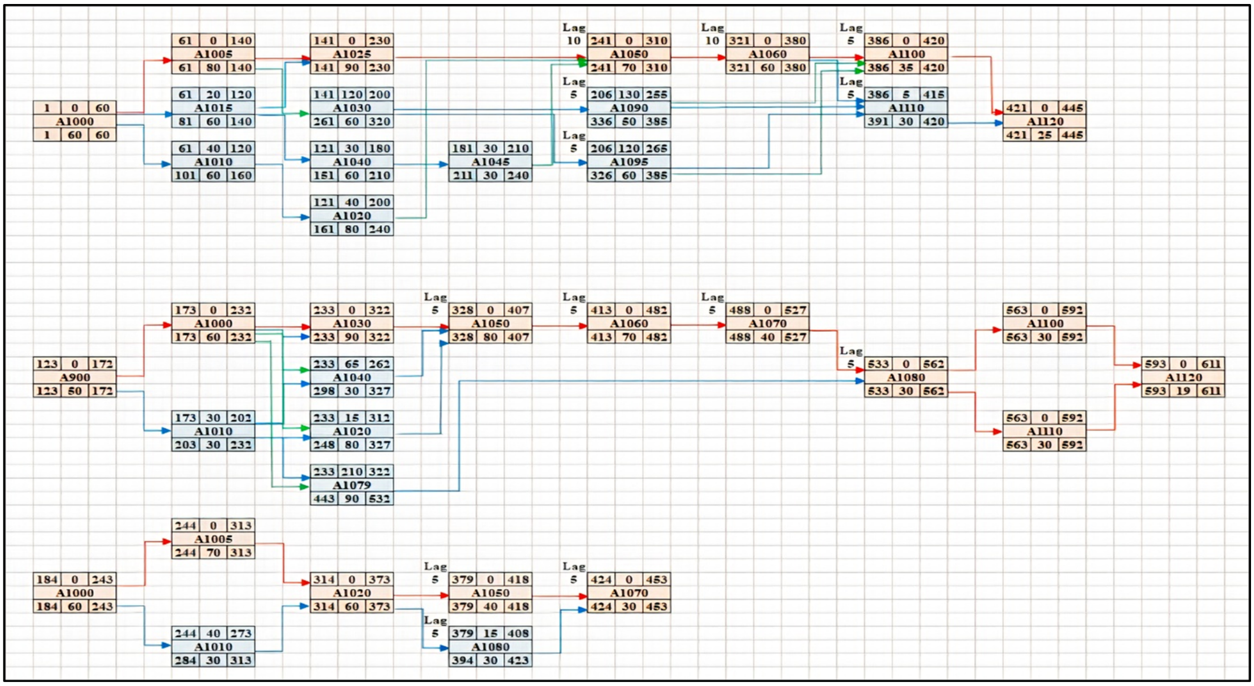
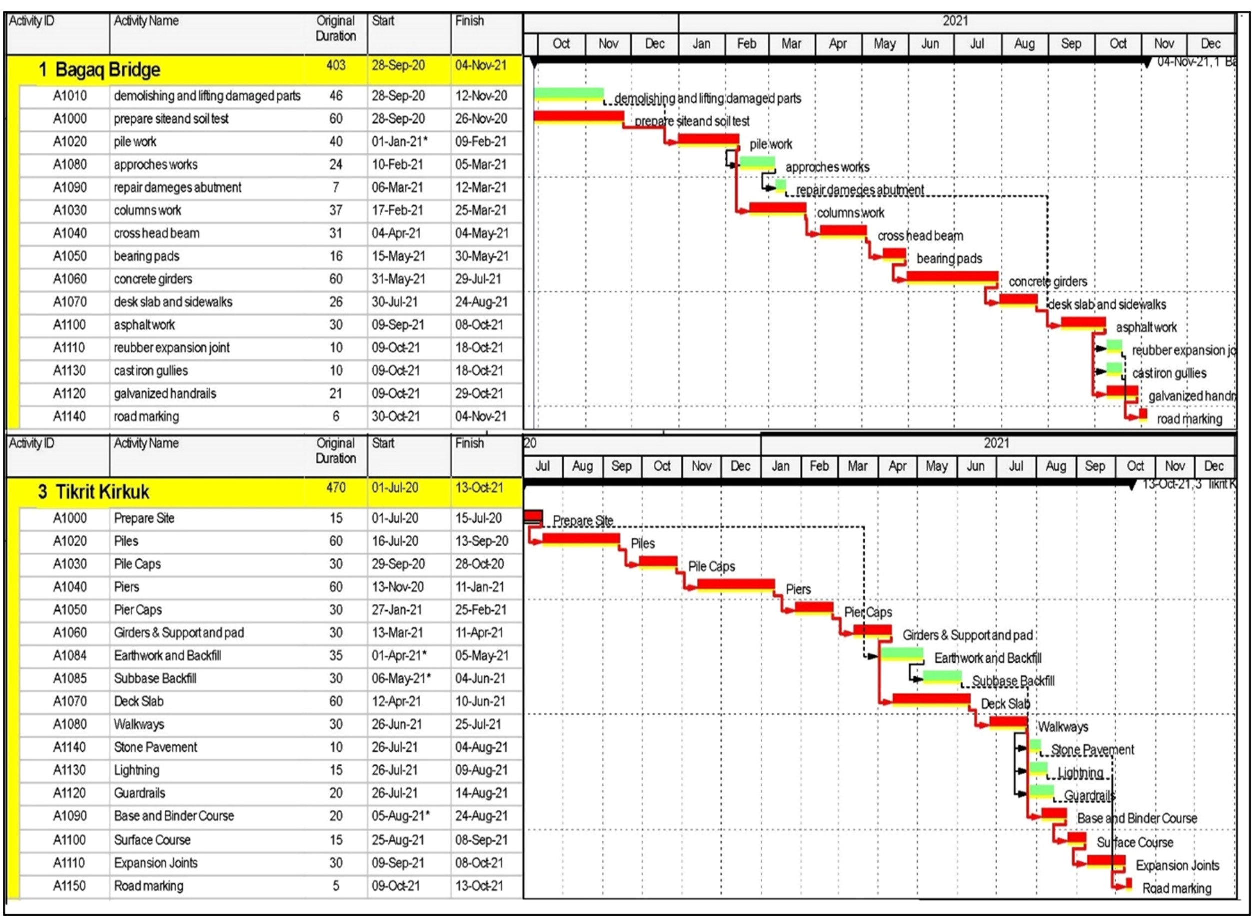


Figure 4: Planned activity network for enterprise II.



Activity ID	Activity Name	Original Duration	Start	Finish
1 Bagaq Bridge		403	28-Sep-20	04-Nov-21
A1010	demolishing and lifting damaged parts	46	28-Sep-20	12-Nov-20
A1000	prepare siteand soil test	60	28-Sep-20	26-Nov-20
A1020	pile work	40	01-Jan-21*	09-Feb-21
A1080	approches works	24	10-Feb-21	05-Mar-21
A1090	repair dameges abutment	7	06-Mar-21	12-Mar-21
A1030	columns work	37	17-Feb-21	25-Mar-21
A1040	cross head beam	31	04-Apr-21	04-May-21
A1050	bearing pads	16	15-May-21	30-May-21
A1060	concrete girders	60	31-May-21	29-Jul-21
A1070	desk slab and sidewalks	26	30-Jul-21	24-Aug-21
A1100	asphalt work	30	09-Sep-21	08-Oct-21
A1110	reubber expansion joint	10	09-Oct-21	18-Oct-21
A1130	cast iron gullies	10	09-Oct-21	18-Oct-21
A1120	galvanized handrails	21	09-Oct-21	29-Oct-21
A1140	road marking	6	30-Oct-21	04-Nov-21

Activity ID	Activity Name	Original Duration	Start	Finish
3 Tikrit Kirkuk		470	01-Jul-20	13-Oct-21
A1000	Prepare Site	15	01-Jul-20	15-Jul-20
A1020	Piles	60	16-Jul-20	13-Sep-20
A1030	Pile Caps	30	29-Sep-20	28-Oct-20
A1040	Piers	60	13-Nov-20	11-Jan-21
A1050	Pier Caps	30	27-Jan-21	25-Feb-21
A1060	Girders & Support and pad	30	13-Mar-21	11-Apr-21
A1084	Earthwork and Backfill	35	01-Apr-21*	05-May-21
A1085	Subbase Backfill	30	06-May-21*	04-Jun-21
A1070	Deck Slab	60	12-Apr-21	10-Jun-21
A1080	Walkways	30	26-Jun-21	25-Jul-21
A1140	Stone Pavement	10	26-Jul-21	04-Aug-21
A1130	Lightning	15	26-Jul-21	09-Aug-21
A1120	Guardrails	20	26-Jul-21	14-Aug-21
A1090	Base and Binder Course	20	05-Aug-21*	24-Aug-21
A1100	Surface Course	15	25-Aug-21	08-Sep-21
A1110	Expansion Joints	30	09-Sep-21	08-Oct-21
A1150	Road marking	5	09-Oct-21	13-Oct-21

Figure 5: Time schedule for enterprise I.

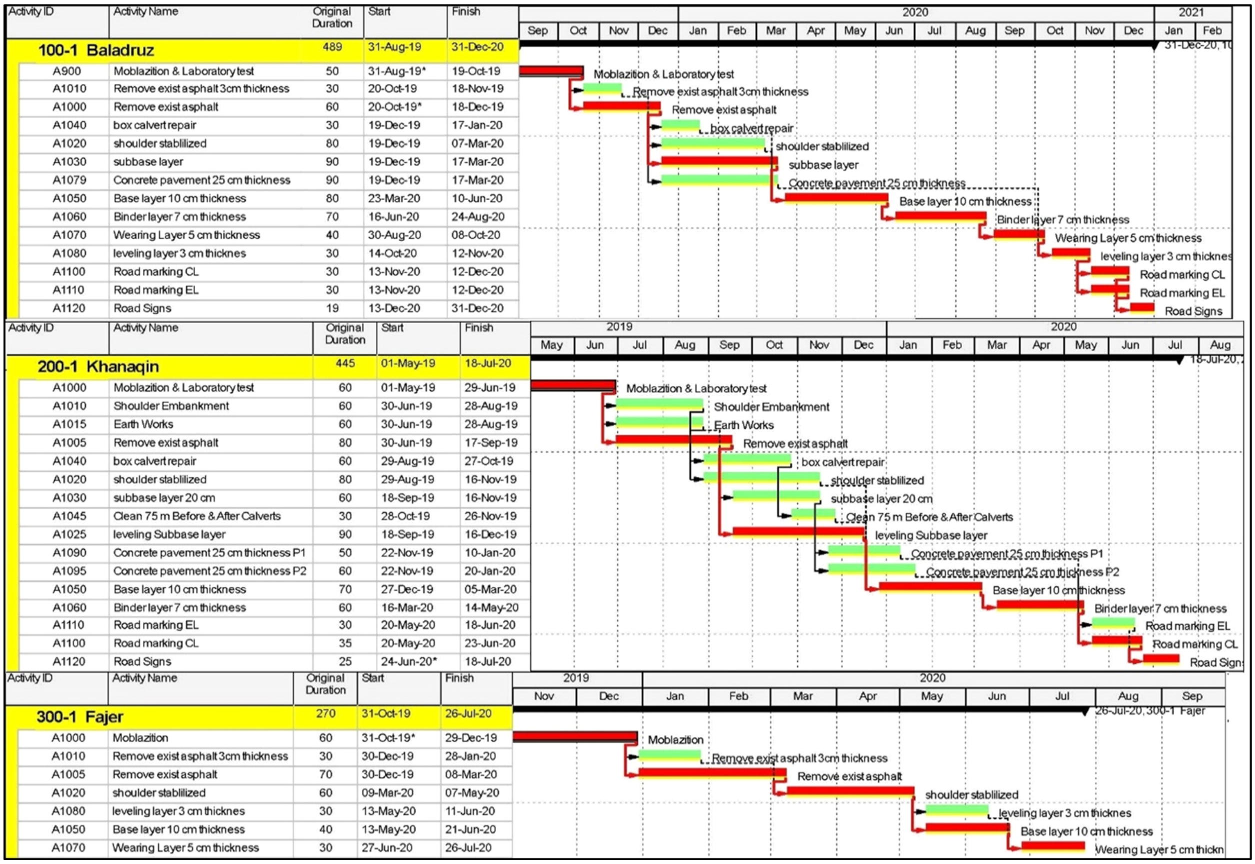


Figure 6: Time schedule for enterprise II.

Table 7: Cash flow calculation according to time schedule in enterprise I

Month	Bill to owner	Retention	Taxes	Total receipts	Materials	Labor	Overhead	Total cost	Cumulative cash flow F_t	Net cash flow N_t
1					57,042	38,837	7,282	103,162	−103,162	−103,162
2	121,367	12,137	4,005	105,225	92,307	62,847	11,784	166,938	−270,100	−164,875
3	196,398	19,640	6,481	170,277	45,524	30,995	5,812	82,331	−247,206	−76,929
4	96,860	9,686	3,196	83,978	143,317	97,578	18,296	259,191	−336,120	−252,142
5	304,931	30,493	10,063	264,375	44,531	30,319	5,685	80,534	−332,677	−68,302
6	94,746	9,475	3,127	82,145	25,437	17,319	3,247	46,003	−114,305	−32,160
7	54,121	5,412	1,786	46,923	143,684	97,827	18,343	259,854	−292,014	−245,091
8	305,711	30,571	10,088	265,051	228,463	155,549	29,165	413,177	−658,268	−393,217
9	486,091	48,609	16,041	421,441	166,196	113,155	21,217	300,567	**−693,784**	−272,343
10	353,608	35,361	11,669	306,579	103,563	70,511	13,221	187,295	−459,638	−153,059
11	220,347	25,820	7,271	187,255	139,176	94,758	17,767	251,702	−404,761	−217,506
12	296,120		9,772	286,348	177,781	121,043	22,695	321,519	−539,025	−252,678
13	378,258		12,483	365,775	198,209	134,951	25,303	358,463	−611,141	−245,365
14	421,722		13,917	407,805	145,619	99,145	18,590	263,353	−508,718	−100,913
15	309,827		10,224	299,602	281,020	191,333	35,875	508,227	−609,141	−309,538
16	597,914		19,731	578,183	143,835	97,930	18,362	260,126	−569,665	8,519
17	306,031		10,099	295,932	—	—	—	—	8,519	**304,451**
Total	**4,544,051**	**227,203**	**149,954**	**4,166,894**	**2,135,704**	**1,454,096**	**272,643**	**3,862,443**		

Table 8: Cash flow calculation according to time schedule in enterprise II

Month	Bill to owner	Retention	Taxes	Total receipts	Materials	Labor	Overhead	Total cost	Cumulative cash flow F_t	Net cash flow N_t
1					53,010	35,340	9,424	97,774	−97,774	−97,774
2	117,800	11,780	3,887	102,133	61,148	40,765	10,871	112,783	−210,557	−108,425
3	135,883	13,588	4,484	117,811	358,283	238,855	63,695	660,832	−769,257	−651,446
4	796,183	79,618	26,274	690,291	367,871	245,247	65,399	678,517	−1,329,963	−639,672
5	817,491	81,749	26,977	708,765	411,196	274,131	73,102	758,429	−1,398,101	−689,336
6	913,769	91,377	30,154	792,238	425,542	283,695	75,652	784,888	−1,474,225	−681,987
7	945,649	94,565	31,206	819,877	513,811	342,541	91,344	947,696	−1,629,682	−809,805
8	1,141,802	114,180	37,679	989,942	451,146	300,764	80,204	832,114	−1,641,919	−651,976
9	1,002,547	100,255	33,084	869,208	852,199	568,133	151,502	1,571,834	−2,223,810	−1,354,602
10	1,893,776	189,378	62,495	1,641,904	688,224	458,816	122,351	1,269,390	−2,623,993	−982,089
11	1,529,386	152,939	50,470	1,325,978	556,730	371,153	98,974	1,026,857	−2,008,946	−682,969
12	1,237,177	62,937	40,827	1,133,412	905,524	603,683	160,982	1,670,188	−2,353,157	−1,219,744
13	2,012,275		66,405	1,945,870	773,493	515,662	137,510	1,426,664	**−2,646,409**	−700,539
14	1,718,873		56,723	1,662,150	516,807	344,538	91,877	953,221	−1,653,760	8,390
15	1,148,460		37,899	1,110,560	679,781	453,187	120,850	1,253,818	−1,245,428	−134,868
16	1,510,624		49,851	1,460,774	288,621	192,414	51,310	532,345	−667,213	793,561
17	641,379		21,166	620,214	573,919	382,613	102,030	1,058,561	−265,000	355,213
18	1,275,375		42,087	1,233,288	219,465	146,310	39,016	404,791	−49,578	1,183,710
19	487,700		16,094	471,606	151,686	101,124	26,966	279,776	903,934	1,375,539
20	337,080		11,124	325,956	82,854	55,236	14,730	152,820	1,222,720	1,548,676
21	184,120		6,076	178,044					1,548,676	**1,726,720**
Total	**19,847,349**	**992,366**	**654,963**	**18,200,020**	**8,931,307**	**5,954,205**	**1,587,788**	**16,473,300**		

the precedence relationships between activities; The Fourth column "Activity cost (materials and labor)," is the cost of each activity multiplied by 1,000 Iraq dinar; The Fifth column is the "Lag time," between activities; Sixth to Tenth columns are refers to dates not events: "Early start time, Early finish time, Late start time, Late finish time, and Total float."

Figures 3–6 illustrate the planned activities and time schedule of the projects. The application of the optimization method was put to use in three stages: setting a time schedule, calculating the cash flow for multiple construction projects, and finally optimizing the cash flow under various constraints. In order to achieve this goal,

Table 9: Cash flow calculation in the scenario I in enterprise I

Month	Bill to owner	Retention	Taxes	Total receipts	Materials	Labor	Overhead	Total cost	Cumulative cash flow F_t	Net cash flow N_t
1					57,042	38,837	7,282	103,162	−103,162	−103,162
2	121,367	12,137	4,005	105,225	92,307	62,847	11,784	166,938	−270,100	−164,875
3	196,398	19,640	6,481	170,277	46,934	31,955	5,992	84,881	−249,756	−79,479
4	99,860	9,986	3,295	86,579	109,980	74,880	14,040	198,900	−278,379	−191,800
5	234,000	23,400	7,722	202,878	59,252	40,342	7,564	107,158	−298,958	−96,080
6	126,068	12,607	4,160	109,301	42,644	29,034	5,444	77,121	−173,202	−63,901
7	90,731	9,073	2,994	78,664	162,995	110,975	20,808	294,778	−358,679	−280,015
8	346,798	34,680	11,444	300,674	115,083	78,354	14,691	208,128	−488,144	−187,470
9	244,857	24,486	8,080	212,291	247,189	168,299	31,556	447,045	**−634,514**	−422,223
10	525,935	52,594	17,356	455,986	107,212	72,996	13,687	193,894	−616,118	−160,132
11	228,111	22,811	7,528	197,772	132,938	90,511	16,971	240,419	−400,551	−202,779
12	282,846	5,790	9,334	267,722	183,411	124,876	23,414	331,701	−534,480	−266,757
13	390,236		12,878	377,358	190,559	129,742	24,327	344,628	−611,386	−234,028
14	405,445		13,380	392,065	134,352	91,474	17,151	242,978	−477,005	−84,940
15	285,856		9,433	276,423	277,099	188,663	35,374	501,137	−586,077	−309,654
16	589,573		19,456	570,117	176,706	120,310	22,558	319,575	−629,229	−59,111
17	375,970		12,407	363,562					−59,111	**304,451**
Total	**4,544,051**	**227,203**	**149,954**	**4,166,894**	**2,135,704**	**1,454,096**	**272,643**	**3,862,443**		

Table 10: Cash flow calculation in the scenario I in enterprise II

Month	Bill to owner	Retention	Taxes	Total receipts	Materials	Labor	Overhead	Total cost	Cumulative cash flow F_t	Net cash flow N_t
1					53,010	35,340	9,424	97,774	−97,774	−97,774
2	117,800	11,780	3,887	102,133	58,028	38,685	10,316	107,029	−204,803	−102,670
3	128,950	12,895	4,255	111,800	336,443	224,295	59,812	620,550	−723,219	−611,420
4	747,650	74,765	24,672	648,213	358,282	238,855	63,695	660,832	−1,272,252	−624,039
5	796,183	79,618	26,274	690,291	307,635	205,090	54,691	567,416	−1,191,455	−501,165
6	683,634	68,363	22,560	592,711	363,417	242,278	64,608	670,303	−1,171,468	−578,757
7	807,594	80,759	26,651	700,184	663,143	442,095	117,892	1,223,130	−1,801,887	−1,101,703
8	1,473,651	147,365	48,630	1,277,655	401,075	267,383	71,302	739,761	−1,841,464	−563,809
9	891,278	89,128	29,412	772,738	797,103	531,402	141,707	1,470,211	−2,034,020	−1,261,282
10	1,771,339	177,134	58,454	1,535,751	687,492	458,328	122,221	1,268,042	**−2,529,324**	−993,573
11	1,527,761	152,776	50,416	1,324,569	622,146	414,764	110,604	1,147,514	−2,141,087	−816,518
12	1,382,547	97,782	45,624	1,239,141	921,364	614,243	163,798	1,699,404	−2,515,922	−1,276,781
13	2,047,475		67,567	1,979,908	678,672	452,448	120,653	1,251,774	−2,528,555	−548,647
14	1,508,161		49,769	1,458,392	622,220	414,813	110,617	1,147,650	−1,696,297	−237,905
15	1,382,711		45,629	1,337,082	711,201	474,134	126,436	1,311,771	−1,549,676	−212,594
16	1,580,447		52,155	1,528,292	301,622	201,081	53,622	556,324	−768,919	759,374
17	670,270		22,119	648,151	575,319	383,546	102,279	1,061,143	−301,770	346,381
18	1,278,486		42,190	1,236,296	234,906	156,604	41,761	433,271	−86,889	1,149,407
19	522,013		17,226	504,787	149,409	99,606	26,562	275,577	873,830	1,378,617
20	332,020		10,957	321,063	88,821	59,214	15,790	163,825	1,214,792	1,535,855
21	197,379		6,514	190,866					1,535,855	**1,726,721**
Total	**19,847,349**	**992,366**	**654,963**	**18,200,021**	**8,931,307**	**5,954,205**	**1,587,788**	**16,473,300**		

Table 11: Cash flow calculation in the scenario II in enterprise I

Month	Bill to owner	Retention	Taxes	Total receipts	Materials	Labor	Overhead	Total cost	Cumulative cash flow F_t	Net cash flow N_t
1					27,266	18,564	3,481	49,311	−49,311	−49,311
2	58,013	5,801	1,914	50,297	92,307	62,847	11,784	166,938	−216,249	−165,952
3	196,398	19,640	6,481	170,277	69,896	47,589	8,923	126,408	−292,360	−122,083
4	148,715	14,872	4,908	128,936	34,108	23,223	4,354	61,685	−183,768	−54,832
5	72,571	7,257	2,395	62,919	143,300	97,566	18,294	259,159	−313,991	−251,072
6	304,893	30,489	10,061	264,342	14,204	9,671	1,813	25,689	−276,761	−12,419
7	30,222	3,022	997	26,202	160,615	109,355	20,504	290,473	−302,892	−276,689
8	341,733	34,173	11,277	296,283	74,269	50,566	9,481	134,316	−411,005	−114,723
9	158,019	15,802	5,215	137,002	74,948	51,028	9,568	135,544	−250,266	−113,264
10	159,463	15,946	5,262	138,254	199,426	135,779	25,459	360,664	−473,927	−335,673
11	424,310	42,431	14,002	367,877	136,624	93,020	17,441	247,086	−582,759	−214,882
12	290,689	29,069	9,593	252,027	111,677	76,036	14,257	201,969	−416,851	−164,824
13	237,611	8,700	7,841	221,070	184,059	125,316	23,497	332,872	−497,696	−276,626
14	391,614		12,923	378,691	185,867	126,548	23,728	336,142	**−612,768**	−234,077
15	395,461		13,050	382,411	114,106	77,689	14,567	206,362	−440,439	−58,028
16	242,779		8,012	234,767	74,273	50,569	9,482	134,324	−192,352	42,415
17	158,028		5,215	152,813	329,776	224,528	42,099	596,403	−553,988	−401,175
18	701,651		23,154	678,497	102,747	69,956	13,117	185,819	−586,995	91,502
	218,611		7,214	211,397	6,237	4,246	796	11,280	80,222	**200,116**
Total	**4,544,041**	**227,203**	**149,953**	**3,807,172**	**2,135,699**	**1,454,093**	**272,642**	**3,862,435**		

Table 12: Cash flow calculation in the scenario II in enterprise II

Month	Bill to owner	Retention	Taxes	Total receipts	Materials	Labor	Overhead	Total cost	Cumulative cash flow F_t	Net cash flow N_t
1					53,010	35,340	9,424	97,774	−97,774	−97,774
2	117,800	11,780	3,887	102,133	58,148	38,765	10,337	107,250	−205,024	−−102,892
3	129,217	12,922	4,264	112,031	319,283	212,855	56,761	588,899	−691,791	−579,759
4	709,517	70,952	23,414	615,151	359,385	239,590	63,891	662,865	−1,242,625	−627,474
5	798,633	79,863	26,355	692,415	331,967	221,312	59,016	612,295	−1,239,769	−547,354
6	737,705	73,771	24,344	639,590	405,477	270,318	72,085	747,880	−1,295,234	−655,644
7	901,060	90,106	29,735	781,219	567,945	378,630	100,968	1,047,544	−1,703,187	−921,968
8	1,262,101	126,210	41,649	1,094,242	473,681	315,788	84,210	873,679	−1,795,647	−701,406
9	1,052,625	105,263	34,737	912,626	813,362	542,242	144,598	1,500,202	−2,201,607	−1,288,981
10	1,807,472	180,747	59,647	1,567,078	709,324	472,883	126,102	1,308,308	**−2,597,290**	−1,030,211
11	1,576,275	157,628	52,017	1,366,630	572,032	381,355	101,695	1,055,081	−2,085,293	−718,662
12	1,271,182	83,125	41,949	1,146,108	905,524	603,683	160,982	1,670,188	−2,388,850	−1,242,742
13	2,012,275		66,405	1,945,870	707,503	471,668	125,778	1,304,949	−2,547,692	−601,822
14	1,572,228		51,884	1,520,344	446,864	297,909	79,442	824,215	−1,426,037	94,308
15	993,030		32,770	960,260	566,968	377,978	100,794	1,045,740	−951,432	8,828
16	1,259,928		41,578	1,218,350	593,782	395,855	105,561	1,095,197	−1,086,370	131,981
17	1,319,515		43,544	1,275,971	573,919	382,613	102,030	1,058,561	−926,581	349,390
18	1,275,375		42,087	1,233,288	234,905	156,603	41,761	433,269	−83,879	1,149,409
19	522,011		17,226	504,785	149,409	99,606	26,562	275,577	873,832	1,378,617
20	332,020		10,957	321,063	77,571	51,714	13,790	143,075	1,235,542	1,556,605
21	172,380		5,689	166,691	11,250	7,500	2,000	20,750	1,535,855	1,702,546
22	25,000		825	24,175					1,702,546	**1,537,632**
Total	**19,847,349**	**992,366**	**654,963**	**18,200,021**	**8,931,307**	**5,954,205**	**1,587,788**	**16,473,300**		

a complete model of multiple cash issues is used. For this, the previously mentioned two scenarios are used.

9 Calculation of cash flows

Table 7 shows the total cash-in and cash-out values for the first enterprise and the other financial parameters' values and the total duration of projects. The maximum negative cash flow is −693,784 at the end of the 9th month, and the profit of the projects is +304,451 in enterprise I. On the other hand, Table 8 shows the total cash-in and cash-out values for the second enterprise and values of the other financial parameters along with the total duration of projects. The maximum negative cash flow is −2,646,408 at the end of the 13th month, and the profit of the projects is +1,726,720 in enterprise II. The GA system can then be used to search for optimum schedules that minimize maximum negative cash flow and optimize project profit. Explanation of calculation of cash flows:

- Bill to owner: The value of progress payment to the contractor without discounts of retention and taxes.
- Total receipts: Total progress payment to the contractor subtracted from the discounts of retention and taxes.
- Total cost: The total costs incurred by the contractor in each month (materials, labor, and overhead).
- Cumulative cash flow (F_t): The cumulative cash flow for each month (−103, 162−166, 938 = −270,100) (net cash flow in month 1+ total cost in month 2).
- Net cash flow (N_t): The net cash flow for each month (−270, 100 + 105, 255 = −164,875) (cumulative cash flow in month 2+ total receipts in month 2).

10 Optimization model

The main objective is developing a tool that will help contractors maximize their profits. In order to achieve this goal, a comprehensive model of various cash problems was constructed. For this, we will use two scenarios. The complete GA procedure is coded in MATLAB and then used to find an optimal time schedule for the problem at hand for the purposes of implementation

Scenario I: Maximizing profits while minimizing negative cash flow using a GA technique, we can find a solution to the problem of creating schedules that have the minimizing negative cash flow. The following are the objective function and constraints for the two enterprises involved in this scenario:

Table 13: Initial schedule and optimized schedule for scenarios in enterprise I

Activity	Original schedule start time	Optimized schedule start time for scenario I	Optimized schedule start time for scenario II
Project I			
A1000	90	90	90
A1010	90	124	109
A1020	185	185	188
A1030	232	232	241
A1040	278	278	291
A1050	319	319	342
A1060	335	335	368
A1070	395	395	438
A1080	225	240	283
A1090	249	292	438
A1100	436	436	491
A1120	466	466	521
A1130	466	472	532
A1110	466	466	530
A1140	487	487	542
Project II			
A1000	1	1	1
A1020	16	16	26
A1084	275	298	306
A1085	310	344	382
A1030	91	91	123
A1040	136	136	169
A1050	211	211	256
A1060	256	256	301
A1070	286	286	336
A1080	361	361	415
A1090	401	401	464
A1100	421	421	498
A1120	391	439	517
A1130	391	402	453
A1140	391	440	507
A1110	436	436	515
A1150	466	466	545
Max negative cash flow	**−693,784**	**−634,514**	**−612,768**
Profit	**304,451**	**304,451**	**200,116**

Table 14: Initial schedule and optimized schedule for scenarios in enterprise II

Activity	Original schedule start time	Optimized schedule start time for scenario I	Optimized schedule start time for scenario II
Project I			
A1000	1	1	1
A1005	61	61	61
A1010	61	69	75
A1015	61	69	61
A1020	121	138	143
A1025	141	141	141
A1030	141	161	141
A1040	121	134	121
A1045	181	183	195
A1050	241	241	241
A1060	321	321	321
A1090	206	298	280
A1095	206	206	206
A1100	386	386	386
A1110	386	391	386
A1120	421	421	451
Project II			
A900	123	123	123
A1000	173	173	173
A1010	173	182	173
A1020	233	248	233
A1030	233	233	233
A1040	233	298	283
A1050	328	328	328
A1060	413	413	413
A1070	488	488	488
A1079	233	401	371
A1080	533	533	533
A1100	563	563	563
A1110	563	563	563
A1120	593	593	620
Project III			
A1000	184	184	184
A1005	244	244	244
A1010	244	284	244
A1020	314	314	314
A1050	379	379	379
A1070	424	424	450
A1080	379	394	419
Max negative cash flow	**−2,646,408**	**−2,529,324**	**−2,597,290**
Profit	**1,726,721**	**1,726,721**	**1,537,632**

$$\text{Minimize:} F_t, \tag{9}$$

$$E_{\text{st}} \leq A_{\text{st}} \leq L_{\text{st}}, \tag{10}$$

where F_t is the maximum cumulative cash flow, E_{st} is the early start time for activity according to time schedule, A_{st} is the activity start data in the project, and L_{st} is the late start time for activity according to time schedule.

To generate schedules, critical path activities are started early and non-critical activities are started at random while maintaining a link between them. These random schedules generate corresponding cash requirement profiles. The GA procedure then looks for a schedule that generates the minimizing negative cumulative cash flow while keeps maximizing profit. Tables 9 and 10 show the optimized cash flow calculation in the scenario I in two enterprises.

Scenario II: Maximizing profit by extending the project and reducing the problem of negative cash flow while maintaining maximum profit.

$$\text{Maximize}{:}G. \tag{11}$$

Random activity start times are used to generate new time schedules while maintaining dependency between activities. It is possible to see how much cash each of these random schedules requires. Afterwards, the GA procedure looks for a schedule that generates the maximum profit, while also generating the minimum of cumulatively negative cash flow possible. Tables 11 and 12 show the optimized cash flow calculation in the scenario II in two enterprises.

Tables 13 and 14 show comparison between the initial schedule and the optimized schedule with activities' new start dates in enterprises. The first scenario is to minimize negative cash flow and keep or maximize the profit. The results show that negative cash flow minimized from −693,784 to −634,514 in enterprise I and from −2,646,408 to −2,529,324 in enterprise II with keeping the profit. On the other hand, the optimized schedule of the project in noncritical activities' start times have changed to reach the optimum schedule with the minimum negative cash flow and optimum profit. As well as the second scenario is maximizing profit by extending the project and reducing the problem of negative cash flow. The results show that negative cash flow is minimized to −612,768 with a profit of +200,116 in enterprise I and to −2,597,290 with a profit of +1,537,632 in enterprise II. On the other hand, the optimized schedule of the project in critical and noncritical activities start times have changed to reach the optimum schedule with the minimum negative cash flow and optimum profit.

11 Conclusion

This study uses GA to develop a new profit optimization model for enterprise project scheduling problems and conducts periodic financial auditing on behalf of the contractor. To assess the financial feasibility of a project, this work establishes a time schedule and incorporates cash flow and financial data into the model. The analysis employs an example of five projects in two public sector enterprises, and the optimal schedule is developed to minimize negative cash flow, while maximizing profit. Additionally, the scenario includes practical constraints such as a due date and initial negative cash and profit. The model can smooth financial pressure by shifting activities' schedules without delaying or extending the time of the project (delaying completion time). The results show that negative cash flow is minimized from −693,784 to −634,514 in enterprise I and −2,646,408 to −2,529,324 in enterprise II in the first scenario and also results show that negative cash flow is minimized to −612,768 with a profit of +200,116 in enterprise I and to −2,597,290 with a profit of +1,537,632 in enterprise II in the second scenario. Because of this, the model's proposed solution helps contractors meet their financial obligations when faced with scheduling problems.

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References

[1] Park HK, Han SH, Russell JS. Cash flow forecasting model for general contractors using moving weights of cost categories. J Manag Eng. 2005 Oct;21(4):164–72.

[2] Ahuja HN, Dozzi SP, Abourizk SM. Project management: techniques in planning and controlling construction projects. Hoboken (NJ), US: John Wiley & Sons; 2014.

[3] Melik S. Cash flow analysis of construction projects using fuzzy set theory [dissertation]. Ankara: Middle East Technical University; 2010.

[4] Alavipour SR, Arditi D. Time-cost tradeoff analysis with minimized project financing cost. Autom Constr. 2019 Feb 1;98:110–21.

[5] He W, Shi Y, Kong D. Optimization model calculation of construction cost and time based on genetic algorithm. IOP Conf Ser: Earth Environ Sci. 2019;242(6):062044.

[6] Shiha A, Hosny O. A multi-objective model for enterprise cash flow management. CSCE Annual Conference; 2019 Jun 12–15; Laval, Canada. CSCE; 2019.

[7] Alavipour SR, Arditi D. Optimizing financing cost using a line-of-credit and a long-term loan. 13th International Project Management Conference ARCOM Conference; 2018 Jan 28–29; Teheran, Iran.

[8] Alavipour SR, Arditi D. Optimizing financing cost in construction projects with fixed project duration. J Constr Eng Manag. 2018 Apr 1;144(4):04018012.

[9] El-Abbasy MS, Elazouni A, Zayed T. Generic scheduling optimization model for multiple construction projects. J Comput Civ Eng. 2017 Jul 1;31(4):04017003.

[10] Au T, Hendrickson C. Profit measures for construction projects. J Constr Eng Manag. 1986 Jun;112(2):273–86.

[11] Elazouni A, Abido M. Multiobjective evolutionary finance-based scheduling: Individual projects within a portfolio. Autom Constr. 2011 Nov 1;20(7):755–66.

[12] Deb K. Genetic algorithm in search and optimization: the technique and applications. In Proceedings of International Workshop on Soft Computing and Intelligent Systems, ISI, Calcutta, India; 1998. p. 58–87.

[13] Sastry K, Goldberg D, Kendall G. Genetic algorithms. In Search methodologies. Boston, MA: Springer; 2005. p. 97–125.

[14] Basha IM, Ibrahim AH, Abd El-Azim AN. Profitability optimization of construction project using genetic algorithm cash flow model. Am J Civ Eng Arch. 2016 Jan 11;4(1):17–27.