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Research Article

Development of a Financing Optimization Framework Based on Risk Simulation in BOT Projects: A Case Study of the Waste-to-Energy Project

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Infrastructure projects that are mostly characterized by high uncertainty usually face various risks at all stages as timing risks, cost risks, and disruption in the executive processes (by the reason of unpredictable obstacles in financing risks, technology production, and so on). Owing to the complex nature of infrastructure projects, the build-operate-transfer (BOT) contract is usually concluded between the private and public sectors. Considering that the public sector transfers all or part of its financial risk to the private sector (contractors), in this type of contract, the distribution of risks is different from that of traditional contracts. Besides, project implementation methods and the lack of risk management might lead to the failure of the project. As the implementation of such projects, along with the risks of the projects that require a large amount of investment, it would be necessary to develop a proper financing schedule with consideration of the effect of repayment of various loans in the project to ensure the feasibility of the project. So, in this project, considering the effects of risks in a waste-to-energy infrastructure project, an optimal project financing framework is developed. In the current research, using Monte Carlo simulation, the impact of risks on the project is investigated during the construction period and the operation period. The results have shown that consideration of the impact of the risks on projects might have a significant effect on the increase of time and cost; nevertheless, the cost of optimal financing might reduce the project profit by 23%. The results indicate that choosing the appropriate financing solution guarantees the project's final profit. Besides, it can help project managers to make the best financing decisions based on realistic situations.

1. Introduction

Hundreds of contractors go bust annually for different reasons, certainly one of which would be high uncertainty in the construction industry. Although many different factors could lead to failure in the labor market, financing and budgeting factors are among the most important and common reasons [1]. Beyond 60% of contractors' failures stem from financing issues, the lack of financing leads to the failure of 77–95% of contractors [2]. Failure to establish a connection between the financing plan and the project schedule affects cash flow and produces an unrealistic schedule, and probably it would lead to the contractors' failure on the way of implementing their projects. The existence of financing problems not only affects the cash flow of the project but also causes high tension and disagreement among the project members; consequently, the conflicts among them [3] and contractors' claims [4] are increased, and thus contract terminations get presumable [2]. Incorporating both financing and scheduling aspects is crucial for the successful management of construction projects, and minimizing financing costs emerges as a significant factor in achieving this goal.

Contractors often experience imbalanced cash inflows and outflows throughout the project, leading to negative balances during certain periods. Consequently, they may need to utilize their own capital or seek external borrowing to address these financial fluctuations. In this case, the repayment of this amount necessitates paying an interest rate in addition to the principal amount. This issue, which is known as the cost of financing, shall be calculated in the projects' costs and profit calculation; otherwise, the calculations would be distant from reality.

Because of the different nature of BOT projects, these projects are implemented in a way that the contractor generally finances the project either with his capital or by borrowing from a third party and earns his profit during a certain period of project operation. So, the importance of financing, as well as the cost of financing in such projects, is more important than that in other projects.

Additionally, BOT projects are always characterized by high uncertainty. A BOT project faces different risks at all stages, such as timing risks, cost risks, and disruption in implementation processes because of financing risks and technological risks. Considering that in this type of contract, the public sector transfers all or part of its financial burden to the private sector (contractor); thus, risk management in these projects requires a more detailed investigation. Though the current complex situation cannot be addressed by the conventional risk evaluation method, finding a new approach is extremely important from a practical standpoint [5]. So, the identification of these risks and uncertainties from the outset and the consideration of their probability and impact through correct planning could help the success of these projects [6]. Examining different financing ways for such projects, and taking into account the impact of their risks, is vital for reducing project management costs and guaranteeing the contractor's final profit. The innovation and contribution of this study are as follows:

(i) Performing qualitative and quantitative risk analysis to evaluate the project risk probability and its impact on objectives (time and cost)

(ii) Using a more realistic duration and cost for project activities (considering risk impacts)

(iii) Developing a financing optimization to investigate the reduction of project profit

(iv) Applying as a framework to waste-to-energy BOT projects which is more complicated than common construction projects

(v) Finding optimized time, cost, and profit of a real BOT project (WTE) with more realistic inputs

Therefore, this study is structured as follows. In the literature review section, a review is conducted on the previous studies of risk management, cash flow, and financing. The gap in the research is suggested at the end of this section. The "Problem Statement" section demonstrates the framework steps and the mathematical approach in detail. The case study, results, and sensitivity analysis are explained in the "Results and Discussion" section. In the "Managerial Insights and Practical Implications" section, practical aspects of the results and framework are introduced. Eventually, in the "Conclusions" section, the study outcomes are summarized and concluded.

2. Literature Review

In this part of the article, the research and studies performed in the risk management of build-operate-transfer (BOT) contracts, their cash flow, and financing are discussed.

2.1. Risk Management. Risk management is a scientific approach for identifying, minimizing, and predicting the adverse effects of infrastructure projects [7]. Without effective management and decision-making, some conflicts might arise among stakeholders which could have serious consequences including rising disposal costs, financial loss, project cancellation, or project postponement [8]. So, to maintain the proper performance of risk management, the stakeholders are to continuously improve their knowledge of risks. According to Davies et al. [9], the necessity for effective risk management in projects is undeniable. Their research revealed that a substantial 37% of projects in Egypt experienced cost overruns, while an overwhelming 98% of Egyptian contractors delivered their projects with significant delays to clients. Numerous other studies in the literature mirror these findings, emphasizing the critical role of risk management, particularly in large-scale and infrastructure projects (Altoryman [10]; Taroun et al. [11]); besides, infrastructure projects are generally recognized as projects having high costs and long performance durations. Based on society's needs, the importance of succeeding in these projects is very important. So, to improve the risk management of these projects, the use of quantitative risk analysis techniques has been recommended in the literature; nevertheless, in infrastructure projects, lack of knowledge and implementation in terms of risk analysis is noticeable, empathetically in Iran.

The success of public-private partnerships (PPPs) depends on effectively managing risk, where one of the key problems would be estimating the likelihood of a risk and its impact on project goals [12]. Bing et al. [13] used a questionnaire to investigate risk allocation in UK construction projects. They suggested that project-specific risks are better to be left to the private sector. Burke and Demirag [14] reviewed and analyzed risk transfer and stakeholder relationships in public-private partnership contracts. Song et al. [15], using the fuzzy model and system dynamics, presented a model for estimating the operational time in an energy conversion project under a BOT contract. By using their model, they chose the most feasible option among eight alternatives. In their research, they stated that the developed model helps the public sector in better decision-making and choosing feasible options. However, there have been many limiting assumptions (such as merely focusing on the public sector, not considering risks, and responding to them during the project) that have not been considered in their research. Ma et al. [16] proposed a time and cost estimation model for the grant period of public-private partnership projects. By using the real-option analysis and risk allocation, they produced a decision-making model for the operational period; besides, they implemented their proposed model on a water treatment plant project in China. Digiesi et al. [17] proposed a model for reducing the exposure risk for employees performing repetitive manual tasks. Recently, Aladag and IsiK [18] evaluated design and construction risks in megatransportation projects with BOT contracts in their research.

Different approaches have been presented in quantitative risk analysis by different researchers. Sato et al. [19] delved into the risks associated with road projects in Japan, conducting a quantitative analysis using empirical data. Their research aimed to introduce risk management and implement quantitative risk analysis based on real project data. On a similar note, Platon and Constantinescu [20] explored the risks of investment projects utilizing Monte Carlo simulation. Their study emphasized the significance of risk assessment in investment projects to examine the probability of achieving favorable performance thresholds for metrics such as the internal rate of return (IRR) or net present value (NPV). In 2015, Leo conducted a study focusing on the variables that could substantially impact the success of quantitative risk analysis in large projects.

2.2. Cash Flow and Financing. Cash flow is considered one of the most important parameters and financial influencing factors during the life of a project. During the project period, the complete history of all payments (cash outflows) and incomes (cash inflows) caused by the implementation of the project [21] is shown by that. The net difference between cash flow inputs and outputs represents the profit of the project [22]. Au and Hendrickson [23], modeling the liquidity of contractor income and expenses, presented a graph based on which the amount of expenses and incomes has been displayed in specific periods (weekly or monthly). Contractors need to evaluate and build their cash flow model based on the credit line of their accounts [24]. Elazouni and Metwally [25] presented a cash flow model that included various project revenues and costs (inputs and outputs) during the project period. Liu and Wang [26] presented a resource-constrained project planning model integrated with cash flow. Ahmed [27], using the Monte Carlo simulation technique, evaluated the sensitivity of activities to cash flow parameters.

The distinctive feature of liquidity is that it is used as a resource for proceeding with construction activities, and simultaneously the completed activities in the project produce this same resource (liquidity) and use that to finance the remaining activities. Therefore, by integrating the critical path method and the cash flow model, some researchers conducted in this field introduced the finance-based planning method.

Until 2004, the use of financing costs in scientific research was practically denied; Elazouni and Gab-Allah [28] introduced the finance-based scheduling method in their research.

This method involves integrating the scheduling and financing functions of a construction project, where the scheduling of construction activities is determined by considering both precedence relations and financing constraints. The goal of finance-based scheduling is to calculate a feasible schedule minimizing project delays while minimizing the cost of financing based on liquidity constraints. In case, the cumulative negative balance including financing costs surpassed the threshold, the start time of the activity is changed in the finance-based scheduling method based on the float of the entire activity, and if necessary, the project duration increases without exceeding the financial limit. The research of Elazouni [29] and Fathi and Afshar [30] is based on this method. Recently, Alavipour and Arditi [31] have presented a model that takes into account various financing options and a work schedule with typical activity durations to minimize financing costs. In another study, Alavipour and Arditi [32] have proposed a comprehensive model that analyses time-cost trade-offs and optimize financing; besides, Elghaish et al. [33] created a BIM-based methodology for integrated project delivery (IPD) cash flow analysis across all of its stages. Although the mentioned studies introduced an applied financing optimization model, their focus has been on projects with a small number of activities and a fixed duration, on which the effects of risk have not been observed.

2.3. Research Gap. The survey of the related works is presented in Table 1. As can be seen, the research studies carried out in the mentioned fields are very extensive. However, these studies have shortcomings that are briefly mentioned as follows.

Despite the review of the project scope, the mentioned models have not considered the simultaneous effects of project risks and their financing. The risk research related to the construction of waste-to-energy power plants (in the field of renewable and new energies) has been rarely carried out and has often been examined qualitatively. The effect of risk management processes and financial and quantitative analyses has been rarely seen in these studies. Generally, in international investigations, so far, no research has been performed in the field of developing financial optimization models based on the quantitative simulation of risks in the BOT contracts to examine all the existing situations that stem from risks, unlimited financing options, grant periods, the effects of the inflation rate, and responses to secondary risks and such issues.

Considering the novelty of the field of renewable energy and the mentioned cases, the research gap in this field is noticeable. Besides, the development of an optimization model that encompasses all the mentioned complex conditions and brings the simulation as close to reality as possible is recommended. This model, among varied options with appropriate precision, helps in finding the best solution for the private sector (contractor) and is useful for enabling project success in high-risk renewable and new energy projects.

Table 1: Survey of related works.

Ref	Risk		Objectives	Uncertainty in variables	Financing	Method	Case study
	Qualitative	Quantitative					
Davies et al. [9]	*	—	Identifying factors of risk	—	—	Logistic regression analysis	Sewer's structural condition
Bing et al. [13]	*	—	Risk allocation	—	—	Questionnaire	UK construction projects
Song et al. [15]	*	—	Operation period	*	—	Fuzzy model + system dynamics	Waste-to-energy project
Ma et al. [16]	*	—	Operation period	—	—	Real-option analysis	Water treatment plant project
Digiesi et al. [17]	*	—	Reducing the exposure risk	—	—	MINLP model	NE
Aladag and IsiK [18]	*	—	Evaluating construction risks	*	—	Fuzzy analytical hierarchy process	A transportation project
Sato et al. [19]	—	*	Quantitative risk analysis	*	—	Monte Carlo simulation	Road projects in Japan
Platon and Constantinescu [20]	—	*	Internal rate or the return	*	—	Monte Carlo simulation	An investment project
Au and Hendrickson [23]	—	—	Profit	—	Included	A rational framework	NE
Elazouni and Metwally [25]	—	—	Profit	—	Included	An improved GA	NE
Ahmed [27]	—	—	Cash flow model	*	Included	Monte Carlo simulation	NE
Elazouni and Gab-Allah [28]	—	—	Finance-based scheduling	—	Included	Integer programming	Small NE
Alavipour and Arditi [31]	—	—	Financing cost	—	Included	LP	Small NE
Alavipour and Arditi [32]	—	—	Time-cost trade-off	*	Included	Hybrid GALP	Small NE
Elghaish et al. [33]	—	—	Cost estimation	*	—	Monte Carlo simulation	A real construction project
This research	*	*	Financing cost considering risk impacts	*	Included	Monte Carlo simulation + hybrid GA-SFL	Real waste-to-energy project

Considering the existing gap in this field, this article aims to investigate the effect of project financing on the final profit of the contractor and to develop a financing schedule based on the simulation of project risks via different financing options in a BOT project. In this research, the effects of project risks of the construction and operation period have been considered on the time, cost, and income of a waste-to-energy power plant construction project, and based on that, the best project financing option is calculated. The main innovation of the current research is addressing an unexplored issue that has not been previously discussed in existing studies. This topic helps the project planners to familiarize themselves with the conditions that cause the occurrence of the project risks and their time and cost impact, as well as the financing conditions of the project and its cash flow during different periods. Also, considering the length of the operation period, the planners could take the necessary arrangements to finance and ensure profit.

3. Problem Statement

In this section, the methodology of the current research is introduced and discussed. The foundation of the finance-based optimization model of this research is to identify different financing conditions of the project at different times based on schedule, to minimize the repayment costs of these financing options, and as a result to increase the profit of the project. Furthermore, by identifying and ranking risks, the effect of their occurrence on the project and project goals could be checked. Considering that project financing is very important and common in BOT projects, the optimization of project financing to minimize the costs of project financing (such as the cost of repaying various types of loans, credit lines, and renting or depreciation of purchased machinery) would be very important. To better understand the methodology and purpose of this research, Figure 1 displays the concept of the framework and Figure 2 shows the implementation steps and the workflow of the research methodology. In the rest of this section, the concepts specified in Figure 2 are examined and introduced.

3.1. Project Risk. To achieve the main goal of this part of the research, the process introduced in this part is presented. In general, the project risk stages of this research include the three main stages of risk identification, qualitative analysis, and quantitative analysis of risks.

3.1.1. Risk Identification. The main purpose of this section is to identify and rank the risks of waste-to-energy projects that are implemented using BOT contracts. To successfully implement this process, it has been tried to involve stakeholders as much as possible in carrying out and verifying the steps and results of this stage. The process of identifying risks includes the following:

(i) Determining the project risk exposure

(ii) Identifying risks related to the project

(iii) Prioritizing project goals (including time, cost, and quality)

3.1.2. Qualitative Risk Analysis. This process aims to analyze risks qualitatively and prioritize them because it allows spending resources to increase opportunities and reduce threats to the most possible extent. This process is repetitive, and if new risks appear, they will be identified and analyzed. As qualitative analysis is dependent on descriptive and linguistic perceptions, and as the perceptions of different people differ with regard to the importance of risks, it would be only suitable for the initial stages of the project, when accurate information is not enough for a detailed evaluation.

In this section, the occurrence probability and the impact of risk on the project goals are the main factors of the identified risks, and their ranking is represented in Tables 2 and 3.

3.1.3. Risk Ranking Based on Optimistic and Pessimistic Approach. After identifying the probability and effect of risks, it would be possible to rank them based on the optimistic and pessimistic approaches. The approach of the Project Management Institute (PMI), by which the risk factor is equal to the product of its probability and its impact, is an optimistic view of risk analysis; that is, in the interval between zero and one, the risk factor will always be lower than its probability and impact. In this approach, the calculation of the risk factor is shown in equation (1). This approach means that the organization has chosen a risk-seeking strategy and has a greater desire for accepting risk.

$$RF_{R_k}^{O} = P_{R_k} \times I_{R_k}. \quad (1)$$

According to this equation, the total amount of risk factor is always smaller than the smallest value of P and I or equal to that. It could be concluded that in this case, the smallest value of P and I determines the severity of the risk.

Cooper et al. [34] introduced a pessimistic approach to risk analysis, which means in the range of zero and one, the risk factor is always greater than the probability of its occurrence and impact. In this approach, the risk factor calculation is shown in equation (2). This approach means that the organization has chosen a risk-averse strategy and is less willing to accept risk.

$$RF_{R_k}^{P} = P_{R_k} + I_{R_k} - P_{R_k} \times I_{R_k}. \quad (2)$$

3.2. Qualitative Risk Analysis. The Monte Carlo method, which can negatively influence a project and support scheduling or budgeting reserves, is suggested by the Project Management Institute (PMI) as a way to evaluate risks. The application of Monte Carlo in quantitative risk analysis offers several advantages. Its utilization in cost and time management primarily involves quantifying the risk level

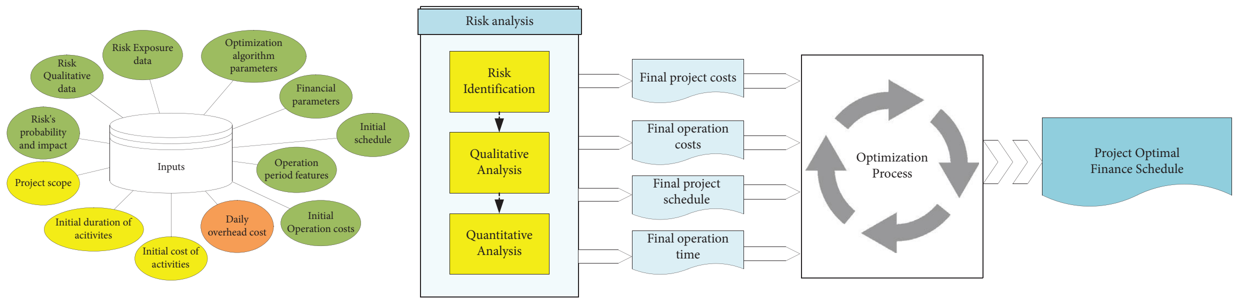


Figure 1: Framework of finance scheduling optimization.

associated with budgetary or completion periods [35]. The Monte Carlo method proves valuable in assessing the certainty of meeting a target completion date during schedule development. Modeling project schedules using Monte Carlo simulations is a fundamental aspect of quantitative risk analysis. In real-world scenarios, Monte Carlo simulations have proven to be effective tools for evaluating scheduling risk [36]. Project managers can employ the Monte Carlo method to incorporate uncertainty into their schedules and networks, thereby ensuring reasonable duration and cost expectations. Subsequently, contingency decisions can be confidently made based on the results of Monte Carlo simulations.

With a given level of confidence, Monte Carlo simulations can aid in revealing the chance of meeting a scheduled completion date or pointing to the predicted results in terms of time and cost. The Monte Carlo simulation technique examines the impact of the project's challenges and risks; besides, it predicts the project's schedule and budget based on that. So, based on the possible output of various scenarios, the decision-making power is increased. Hence, this research employs the Monte Carlo simulation technique to explore the impact of risk on project activities.

Subsequently, the upcoming sections will thoroughly examine the development of the project schedule and cost model, along with a comprehensive analysis of associated risks.

3.2.1. Schedule Activities. To avoid the high complexity of modeling and due to the scope of the project, the project schedule includes the two parts of construction and operation. Table 4 shows the title of the items related to the list of scheduling activities, which includes the activity level in the WBS, the WBS code of the activity, the name of the activity, and the activity code.

This section encompasses the probability distribution of project activity durations, which are considered at a higher level, leading to relatively long durations. For each activity, a triangular distribution is utilized, incorporating optimistic, most likely (original schedule), and pessimistic values. The project controlling department has provided the calculated optimistic and pessimistic values as percentages of the probable time. Table 5 presents the titles of these items in the model, with the "simulation value" column defining the distribution assumptions for the Monte Carlo simulation of the model.

3.2.2. Probability Modeling of Risk Occurrence and Its Impact on Project Schedule. Table 6 presents the key elements of the risk modeling section and their influence on the project schedule. The "Risk1" entry on the left comprises the risk rating obtained from qualitative analysis, the assumption of uniform probability distributions, and the probability of risk occurrence. On the other side, the "risk impact" item includes the optimistic, most likely, and pessimistic percentage values representing the time effect of the risk, based on inputs from experts and project planners. These values are incorporated using triangular distribution assumptions. The last column contains the conditional formula (equation (3)) used to assess the occurrence and impact of the risk. It should be noted that certain items account for two potential risk occurrences and their corresponding impacts, which are treated independently and combined accordingly.

$$\text{Con\_}t_{i,R_k} = \begin{cases} UD_{R_k} \le P_{R_k}; UD_{R_k}, \\ UD_{R_k} > P_{R_k}; 0. \end{cases} \quad (3)$$

Considering the occurrence probability of the defined risks and also the extent of their impact on the time of each activity, the duration of each activity is obtained from the following equation:

$$FD_i = SV_{ND_i} \times \left(1 + \text{Con\_}t_{i,R_k}\right). \quad (4)$$

3.2.3. Analysis of the Construction Period CPM Network. The schedule network analysis during the construction phase is conducted using the critical path method (CPM). Table 7 presents the titles of the items analyzed in this section. Starting from the left, the columns represent the earliest start time, earliest finish time, latest start time, latest finish time, total float, and critical path index for each activity. To streamline the model, all precedence relations are defined as finish-to-start with corresponding lead or lag values. The calculation method can be observed from the following equation:

$$EST_i = \max_j \left(EFT_j + Lag_{i,j}\right). \quad (5)$$

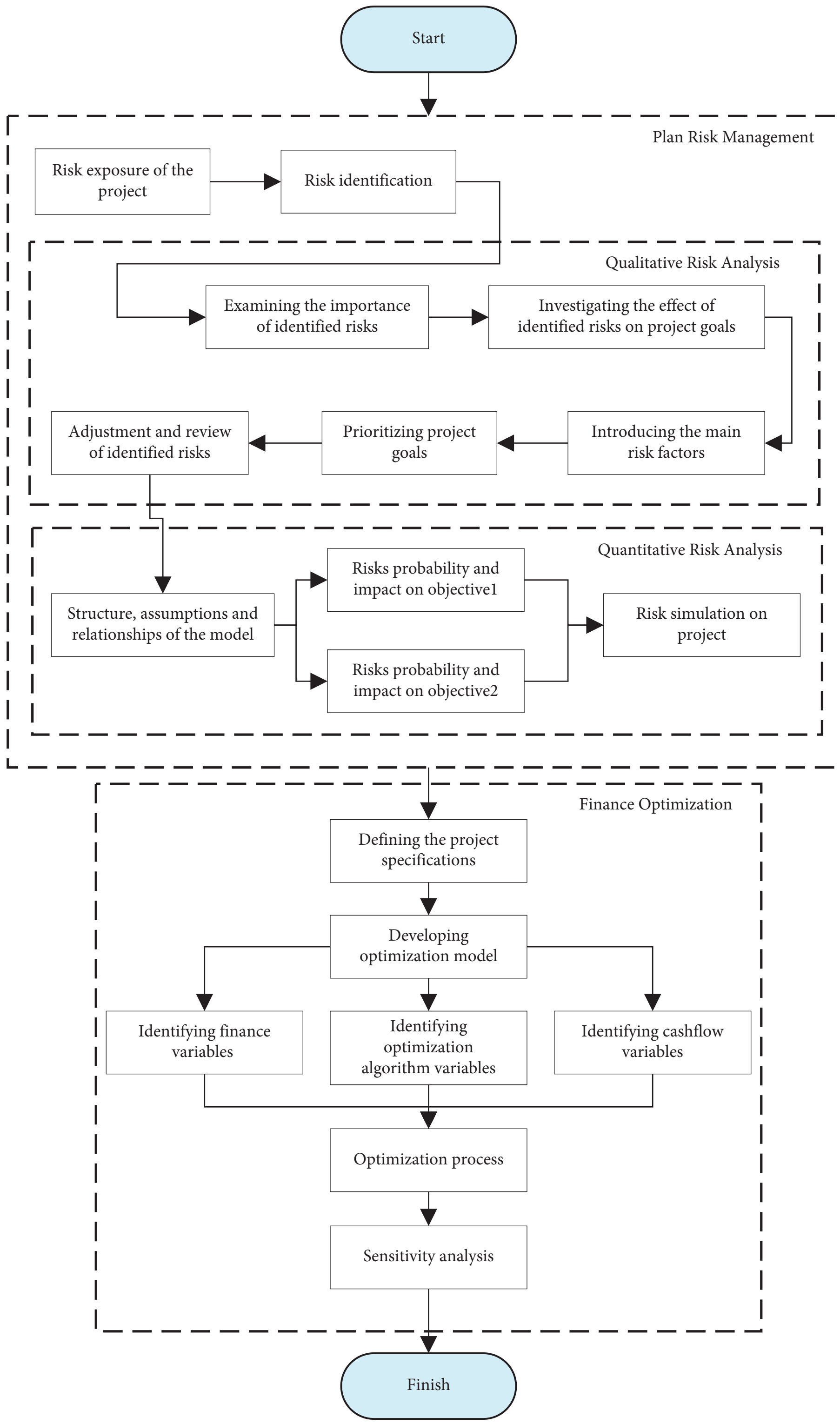


Figure 2: Financing optimization solution approach.

3.2.4. Modeling the Income and Expenses of the Schedule and the Impact of the Occurrence of Risks on It. The main costs incurred during the construction period of the project consist of direct costs associated with specific activities and indirect costs representing daily overheads. Table 8 displays the headings for direct costs. These costs are treated as triangular distributions with three states: pessimistic, probable, and optimistic. The final values are generated through software sampling and recorded in the "simulation value" column. The probable costs are calculated by multiplying the obtained direct cost by the respective weights for each item. The experts from the PMO cost control unit

Table 2: Risk probability ranking.

Rank	Probability range	Description
1	0%–10%	Rarely
2	10%–20%	Very little
3	20%–30%	Low
4	30%–40%	Almost little
5	40%–60%	Medium
6	60%–70%	Almost much
7	70%–80%	Much
8	80%–90%	Very much
9	90%–100%	Very likely

Table 3: Ranking the impact of risk occurrence.

Item	Impact (% of the change in objective)				
Objective	Very low	Low	Moderate	High	Very high
Cost	Small	Less than 10%	10% to 20%	20% to 40%	More than 40%
Time	Small	Less than 5%	5% to 10%	10% to 20%	More than 20%
Other	Small	Less than 10%	10% to 20%	20% to 50%	More than 50%
Rank	1	2	3	4	5

Table 4: The title of the items in the schedule.

Activity list			
Activity level	WBS	Activity name	Activity code

Table 5: The title of the duration items.

Normal distribution of time			
Optimistic	Most likely	Pessimistic	Simulation value

Table 6: The title of the risk probability items and their time effect.

Risk 1	Risk number Risk uniform distribution Probability of risk
Impact of risk	Optimistic Most likely Pessimistic Simulated value Conditional

Table 7: Title of CPM network items.

CPM network analysis			
EST	EFT	LST	LFT

Table 8: Title of direct expenses items.

Normal cost distribution			
Optimistic	Most likely	Pessimistic	Simulated value

provided the necessary information for the values in the probable, optimistic, and pessimistic columns.

Table 9 presents the daily overhead costs, which typically encompass indirect costs arising from factors like the project's unique characteristics and expenses related to the central office. These indirect costs can have a significant impact on the final project cost, particularly as the project duration increases, potentially leading to losses. Additionally, the project's scale influences the rise in overhead costs.

Table 9: The header of daily overhead expense items (indirect).

Daily overhead (toman)			
Optimistic	Most likely	Pessimistic	Simulated value

Similar to the probability and risk impacts on the project time, the probability and impact of risks on the direct costs of the project are calculated. One key distinction is that not all risks affecting the project timeline necessarily impact project costs. For instance, delays in the delivery of drawings during the design phase may not directly affect the project's direct costs. However, with the increase of the total project time, the overhead costs increase either and consequently result in a rise in the project total cost. In defining the risk impact on direct costs, the effect of some risks on cost is correlated with the corresponding effect of that risk on time. As an example, the cost impact of a risk on a particular activity may exhibit either a direct or inverse correlation with the time effect of that risk on the same activity. This aspect has been incorporated into the modeling process based on insights from experts in the PMO cost control unit. Consequently, the final costs of each activity are determined by considering the direct cost along with the probability and effect of the associated risks, as shown in the following equation:

$$FC_i = SV_{ND_i} \times \left(1 + \text{Con\_}c_{i,R_k}\right). \tag{6}$$

In line with the research by Song et al. [15], the operating period costs in public-private partnership projects encompass salaries, maintenance, energy, and raw materials. Given the long time horizon of these projects (at least 10 years), accurately estimating the final cost for the period requires annual consideration of existing risks' impact. Therefore, the risks' effect on the operation period is calculated on an annual basis, and the base cost for the following year is adjusted accordingly for the aforementioned four cost categories.

Additionally, inflation risk is separately accounted for at the end of each year, with its impact on all four costs calculated using the triangular distribution function. The final cost of each of the four main operation period costs is computed according to equation (7). Notably, the main costs for year zero are determined based on the input from experts at the cost control unit of the PMO.

$$FOC_{t,u} = FOC_{t-1,u} \times \left(1 + \mathrm{Con\_}c_{u,t,R_k}\right); t > 0. \quad (7)$$

With the completion of the construction period and getting into the operation period of the project, the income of the project would be entered into the cash flow via the sale of the product resulting from the project. As the risks of the operation period affect the costs, the occurrence of these risks could affect the project's income and bring the calculations closer to reality. As the focus of this research is on the waste-to-energy project, the monthly sale of this energy considers the contractor's income during the operation period. According to the opinions of experts in this field, the sale of power from burning biomass is considered income. Depending on the type of devices used in the construction period, the amount of power generated is calculated, and the amount of power sale is obtained as an average. In this way, the contractor's income is calculated during the operation period based on the amount of power sold. By being added to the project's inflows, it completes the cash flows of the entire project from the very beginning of the construction period to the end of the operation period. In that way, the calculation of the final profit of the project would be possible.

3.2.5. Development of Quantitative Risk Analysis Model. The primary objective of this research, as stated at the outset, is to analyze the quantitative impact of project risks on the project's time and final cost. The outcomes of this analysis encompass the construction period's completion time, construction period cost, operation period cost, total cost, income, and final project profit. The calculations for each output are presented in the following equations:

$$TD^C = \max\left(EFT_i\right), \quad (8)$$

$$TC^C = \sum_i FC_i + \left(TD^C \times \mathrm{DOC}\right), \quad (9)$$

$$TC^O = \sum_t \sum_{u=1}^{4} OC_{u,t}, \quad (10)$$

$$TC = TC^C + TC^O, \quad (11)$$

$$TI_t = V_{t,ND} \times S_t. \quad (12)$$

3.3. Financing Optimization Model. In BOT projects, the contractor generally implements the construction period at his own expense and gains profit from the operation phase of the project over several years through the sale of a specific product (or service). Therefore, the cumulative cash flow of the contractor is negative at the beginning of the project and will gradually become positive near the end of the operation period when the final profit of the project is gained. Taking into account this issue, the contractor should keep in mind that in case no proper planning is devised for financing the project during the construction period, it could cause irreparable damages to the project and ultimately to the contractor and eventually cause the project failure or cessation. Therefore, making detailed financial planning prior to the start of the project is necessary for considering the effect of different financing options and the costs of using them in the project. This causes the following:

(1) The contractor could make the necessary planning for using his various financing options (necessary measures to receive various loans and create credits from various institutions) before the start of the project and at the time of contracting.

(2) The effect of loan repayment with different interest rates is observed according to the existing risks on the cash flow, and the best financing option is chosen based on that.

(3) Considering the long period of construction and operation, the economic conditions of the country, failure to consider the effect of loan repayments, and various credits might ultimately lead to the loss of the contractor and cause the project failure. Therefore, by choosing the correct financing option and considering its effect during the project, the contractor might identify and guarantee his profit and plan before the contract.

In this section, different project financing options are introduced, and their effects on the cash flow have been investigated.

3.3.1. Different Project Financing Options. This research incorporates three distinct financing options into the cash flow model, drawing inspiration from Alavipour and Arditi's [31] study. These financing categories comprise short-term loans, a single long-term loan, and lines of credit, covering a comprehensive range of lending methods. The model considers various repayment schedules for these loans. Long-term loans entail monthly repayments throughout the project construction period, while short-term loans are repaid over 3, 6, 9, or 12 months, with options for monthly or quarterly repayments. Additionally, the repayment structure differs between short-term and long-term loans, whereas long-term loans involve fixed monthly repayments of both principal and interest and short-term loans entail principal payment after a specified period followed by monthly interest payments.

In contrast to short-term loans, the amount of credit that a credit account receives can be used until the contractor pays off his debt. Every month, the contractor can borrow an amount based on his needs and repay a portion of that along with its interest. However, the longer the repayment period, the higher the compound interest rate. So, it seems quite wise and logical to repay the credit account in the shortest possible time.

Generally, the interest rate is annually expressed. An annual rate that simultaneously considers borrowing and compounding costs results in an annual effective interest rate [37]. In this research, for calculating the monthly interest rate, it is assumed that a lender announces the annual effective interest rate to the contractor, and the contractor calculates the monthly interest rate based on the annual effective interest rate.

It shall be noted that for bringing the introduced financing model closer to reality, each of the proposed options has limitations. In reality, lenders might have limitations on the amount of a loan or credit account per project period. However, in this research, it is assumed that this amount has no limit.

Apart from the user-input cash flow parameters, the model also takes into account specific financing details such as financing options, annual interest rates, interest payment schedules, and the contractor's credit amount for each period. The model grants the contractor the flexibility to select the minimum cumulative cash flow balance, even allowing for negative values. This implies that the contractor can defer certain costs without incurring interest charges, leading to negative cumulative cash flow. However, if the contractor cannot postpone costs without interest, the minimum cumulative balance is set to zero.

3.4. Creating the Model and the Objective Function. The primary objective of this section is to determine the total cost of financing by analyzing the project's cash flows. Contractors typically receive a significant portion of their profits towards the project's completion. It is at this stage where the combination of positive cash inflows and outflows results in variable profit figures.

As mentioned in the previous section, the total time of the project is equal to the end of the operation period. Equation (13) shows the total time of the project. To finalize the cash flow model, financing flows are added to the input and output flows of the project (mentioned in the previous section). Financing flows include the borrowed amount (financing inflow), repaid amount (financing outflow), and financing cost (financing outflow), which are shown in the following equations:

$$TD = TD^C + TD^O, \tag{13}$$

$$B_y = B_{ST,y} + B_{LT,y} + B_{LC,y}, \tag{14}$$

$$RE_y = RE_{ST,y} + RE_{LT,y} + RE_{LC,y}, \tag{15}$$

$$FI_y = FI_{ST,y} + FI_{LT,y} + FI_{LC,y}. \tag{16}$$

Also, the calculation of the net outflow of financing at the end of the period y and the net flow of financing at the end of the period y is shown in the following equations:

$$TR_y = RE_y + FI_y, \tag{17}$$

$$NF_y = B_y - TR_y. \tag{18}$$

The net cumulative balance of financing cost is calculated using the following equation:

$$NFC_y = \begin{cases} FI_y; t = 0, \\ NFC_{y-1} + FI_y; t \neq 0. \end{cases} \tag{19}$$

So, the objective function of the introduced financing model could be expressed with the following equation:

$$\text{Minimize}\left(TFC = \sum_y FI_y \right). \tag{20}$$

As there are many limitations on the way of the introduced objective function, financing limits and cash flow limits are introduced in the next two sections.

3.4.1. Financing Limitations of the Objective Function. In this section, equations (21)–(25) of financing restrictions related to the objective function are introduced.

The total amount of the borrowed loan related to each short-term loan shall not exceed the limit already set for each short-term loan option:

$$\sum_y B_{ST,y} \leq CL_{ST}. \tag{21}$$

At the end of each period, the borrowed amount for short-term loans and long-term loans should not exceed the respective limits specified for each type of loan, respectively:

$$B_{ST,y} \leq CL'_{ST}, \tag{22}$$

$$B_{LT,y} \leq CL'_{LT}. \tag{23}$$

The credit required at the end of each period should not surpass the total credit line limit:

$$C_{LC,y} \leq CL_{LC}. \tag{24}$$

The credit drawn from the credit line at the end of each period should not exceed the credit limit specified for that period:

$$B_{LC,y} \leq CL'_{LC}. \tag{25}$$

3.4.2. Cash Flow Limitations of the Objective Function. The net cumulative balance of cash flow (including financing flows) in each period is calculated through the following equation:

$$N'_y = \begin{cases} P_y^{\text{in}} - P_y^{\text{out}} + NFC_y; \ y = 0, \\ N'_{y-1} + P_y^{\text{in}} - P_y^{\text{out}} + NFC_y; \ y \neq 0. \end{cases} \quad (26)$$

The constraint applied to the minimum cumulative balance of cash flow (including financing flows) in each period is shown in the following equation:

$$N'_y \geq MN. \quad (27)$$

As in BOT projects, financing is generally considered as the responsibility of the private sector, and a financing schedule should be developed that reflects the different financing methods and the effect of loans and credits' repayments on the final profit of the project. Such a problem, owing to the wide range of financing modes that it has, cannot be solved normally. Solving such a difficult problem requires a strong and efficient model, so that in addition to high accuracy in reaching the optimal solution, it might be able to do this work in a reasonable time. For this particular purpose, this research leans towards using metaheuristic algorithms. These algorithms have different positive and negative aspects that sometimes cause them to reach nonoptimal or near-optimal solutions in a time-consuming process. To solve this problem, the combined algorithm introduced in the research conducted by Tavakolan and Nikoukar [38] has been used. This algorithm is a combination of the shuffle frog algorithm as the basic algorithm and the improved genetic algorithm as the auxiliary algorithm. By eliminating nonoptimal solutions in the previous generations, the mutation operator of the genetic algorithm, while avoiding getting trapped in the local optima, reduces the search space. This improvement in the mutation operator of the genetic algorithm increases the accuracy of the answers, reduces the volume of computations, and thus significantly reduces the time of the program's execution.

4. Results

In this section, the obtained results are discussed based on the previous section. At first, the data collection procedure and real project information are described as a case study; then, the quantitative analysis result and also the optimization of financing result are presented. After that, for checking the effect of the input variable change on the final results, a sensitivity analysis is performed, and eventually, the results are discussed.

4.1. Data Collection and Project Inputs. The data required for the current research were collected during the process and according to the following procedure:

(i) Using a questionnaire filled up by the project members, the risk exposure of the project is calculated

(ii) Risks related to the project have been identified using field and library studies, as well as interviews with project stakeholders

(iii) To identify the possibility of contamination and the effect of the identified risks on the main objectives of the project, a questionnaire was compiled and filled up by experts in the field related to the project

(iv) The schedule and cost estimation of the project activities were compiled by the contractor planning members and were used in this research

(v) The required information and assumptions of the project, including the specifications and scope of the project, the cost and revenues of the exploitation period, assumptions related to financing, and others are prepared by the contractor's planning team and are used in the research

In the first part, which is the first step in the risk identification process, the risk exposure of the project is checked. As mentioned, to ensure consistent results, two simple questionnaires were used, one of which was expected to be filled up by the authors and the other by a member of the private sector. In both methods, the project is placed in the high-risk group and shows that the risk study will be necessary for the project; therefore, according to the decision made in terms of the necessity of project risk management, the research process can be continued.

In the next step, project risks are identified. Considering the four main goals of time, cost, quality, and scope for the project and using the AHP method prioritization among the project goals have been performed to identify the risks and their probability and impact. The results are shown in Table 10.

As it is evident from Table 10, based on the collective opinion, the order of the project objectives is in the sequence of time, cost, quality, and scope. The weights of time and cost are higher than the others, and in the comparison between the weights of time and cost, the time objective has a higher priority. So, in the risk assessment, the time factor shall be given more attention than the rest of the factors. Also, the two factors of time and cost are considered for modeling.

To collect information about the importance of the identified risks, their probability, and their impact on the selected time and cost goals, a questionnaire was prepared and distributed among experts. Figure 3 shows the severity of each of the optimistic and pessimistic approaches in a descending order. As can be seen, the downward trend of both approaches is almost constant, and it should be noted that high-ranked risks have significant numbers in terms of probability and impact.

4.2. Case Study. To model the introduced framework, a real case study is introduced in the field of renewable and new energies that focuses on the conversion of waste to energy through incineration. In this project, several assumptions have been considered for developing a schedule. These assumptions are mentioned as follows:

(i) The schedule is in the construction period and is divided into four categories: engineering, procurement, construction, and precommissioning.

Table 10: Project objectives ranking.

Rank	Average	Scope	Quality	Cost	Time	Objectives
1	0.53	0.45	0.48	0.62	0.56	Time
2	0.23	0.18	0.36	0.21	0.19	Cost
3	0.15	0.27	0.12	0.07	0.14	Quality
4	0.09	0.09	0.04	0.10	0.11	Scope
	1.00	11.00	8.33	4.83	1.78	Total

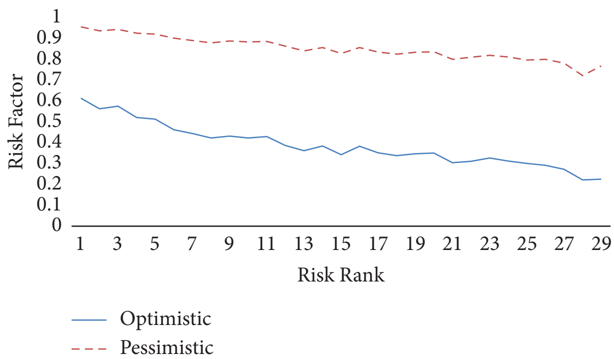


Figure 3: Risk ranking chart.

(ii) The design phases of this project, which are carried out in Iran, include the design of structures and buildings, mechanical facilities, electrical facilities, precision instruments, and landscaping. Each of these phases is divided into two subsets of engineering phases 1 (initial design) and 2 (shop drawings).

(iii) In the procurement phase, the disciplines of structure and architecture, mechanical and electrical instrumentation, and landscaping are mentioned in the activity order, with merely this difference that some of the main mechanical and electrical equipment, owing to the nature of the project, are procured from outside of Iran. So, this section is considered a separate activity.

(iv) As the process of importing externally procured equipment into the workshop entails the continuous and long process of ordering, manufacturing, sending, and installing, the external procurement activity is thus considered a one-year activity.

(v) For each of the defined items in the procurement section, one activity in the construction phase is considered.

(vi) Considering that the import and installation of the main external procured equipment must be done continuously, the project structure and building must be completed before the equipment is entered the workshop.

(vii) The approximate initial duration of the project, regardless of the impact of risks, is three years.

The schedule of the construction period is shown in Figure 4.

The Monte Carlo simulation model for the construction and operation periods can be observed in Figures 5 and 6, considering the mentioned scenarios.

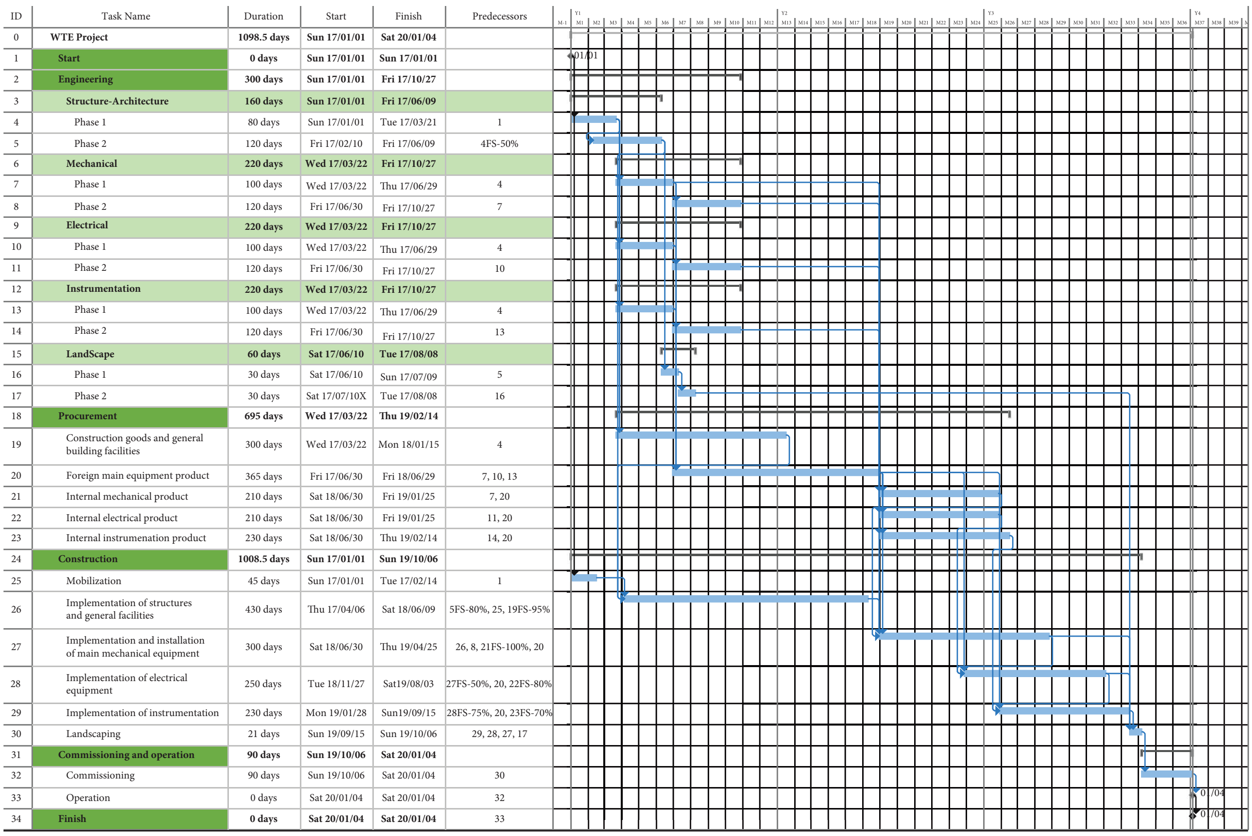
To implement the model, the Crystal Ball software is used as an Excel add-in. Using the Monte Carlo method, distributions are sampled and the number of simulation runs is considered 10,000; besides, the confidence level of 95% is considered as the stop criteria for the simulation.

4.3. Quantitative Analysis Results. The subsequent part of this section presents the outcomes derived from the Monte Carlo simulation concerning the primary objectives, which encompass the construction period's duration, the construction period's cost, the operation period's cost, the total cost, and the overall profit. Figure 7 shows the obtained cumulative and the density distribution functions for the time of the construction phase. The average duration is about 1446 days (48 months), and its standard deviation is about 76 days (2.5 months). The fitted distribution for this Figure 7 is the beta distribution with an A–D value of 0.4348; besides, the average duration is 1446 days which is compared to the initially estimated duration of 1095 days (three years) which shows a 32% increase. According to the probability of the obtained risks and their impact on project duration, the probability of project implementation in the estimated duration is almost equal to zero, which indicates the prominence of the identified risks.

Figure 8 shows the obtained cumulative and density distribution functions for the cost of the construction phase. The average cost is about 582 billion tomans, and its standard deviation is about 19 billion tomans. The fitted distribution for the figure is the beta distribution with an A–D value of 0.8719. Moreover, the average cost of 582 billion tomans, compared to the initially estimated cost of 510 billion tomans, shows an increase of 14%, according to the probability of the obtained risks and their impact on the project cost, and the probability of the project implementation in the estimated cost is almost equal to zero, which indicates the primacy of the identified risks.

Figure 9 shows the obtained cumulative and the density distribution functions for the cost of the operation phase. The average cost obtained is about 1,945 billion tomans, and its standard deviation is about 757 billion tomans. The average cost obtained is 1,945 billion tomans which compared to the initial estimated cost of 1,700 billion tomans shows an increase of 11%. Considering the probability and the risk impact on the cost of operation, the probability of implementing the project with the estimated cost is almost zero, which indicates the importance of the identified risks.

Figure 10 shows the obtained cumulative and density distribution functions for the total cost of the construction and operation phases (the total cost of the BOT contract implementation). The average cost obtained is about 2,525 billion tomans, and its standard deviation is about 758 billion tomans. The average cost obtained, being compared to the initial estimated cost of 2210 billion tomans, shows an increase of 14%.



ID	Task Name	Duration	Start	Finish	Predecessors
0	WTE Project	1098.5 days	Sun 17/01/01	Sat 20/01/04	
1	Start	0 days	Sun 17/01/01	Sun 17/01/01	
2	Engineering	300 days	Sun 17/01/01	Fri 17/10/27	
3	Structure-Architecture	160 days	Sun 17/01/01	Fri 17/06/09	
4	Phase 1	80 days	Sun 17/01/01	Tue 17/03/21	1
5	Phase 2	120 days	Fri 17/02/10	Fri 17/06/09	4FS-50%
6	Mechanical	220 days	Wed 17/03/22	Fri 17/10/27	
7	Phase 1	100 days	Wed 17/03/22	Thu 17/06/29	4
8	Phase 2	120 days	Fri 17/06/30	Fri 17/10/27	7
9	Electrical	220 days	Wed 17/03/22	Fri 17/10/27	
10	Phase 1	100 days	Wed 17/03/22	Thu 17/06/29	4
11	Phase 2	120 days	Fri 17/06/30	Fri 17/10/27	10
12	Instrumentation	220 days	Wed 17/03/22	Fri 17/10/27	
13	Phase 1	100 days	Wed 17/03/22	Thu 17/06/29	4
14	Phase 2	120 days	Fri 17/06/30	Fri 17/10/27	13
15	LandScape	60 days	Sat 17/06/10	Tue 17/08/08	
16	Phase 1	30 days	Sat 17/06/10	Sun 17/07/09	5
17	Phase 2	30 days	Sat 17/07/10X	Tue 17/08/08	16
18	Procurement	695 days	Wed 17/03/22	Thu 19/02/14	
19	Construction goods and general building facilities	300 days	Wed 17/03/22	Mon 18/01/15	4
20	Foreign main equipment product	365 days	Fri 17/06/30	Fri 18/06/29	7, 10, 13
21	Internal mechanical product	210 days	Sat 18/06/30	Fri 19/01/25	7, 20
22	Internal electrical product	210 days	Sat 18/06/30	Fri 19/01/25	11, 20
23	Internal instrumenation product	230 days	Sat 18/06/30	Thu 19/02/14	14, 20
24	Construction	1008.5 days	Sun 17/01/01	Sun 19/10/06	
25	Mobilization	45 days	Sun 17/01/01	Tue 17/02/14	1
26	Implementation of structures and general facilities	430 days	Thu 17/04/06	Sat 18/06/09	5FS-80%, 25, 19FS-95%
27	Implementation and installation of main mechanical equipment	300 days	Sat 18/06/30	Thu 19/04/25	26, 8, 21FS-100%, 20
28	Implementation of electrical equipment	250 days	Tue 18/11/27	Sat19/08/03	27FS-50%, 20, 22FS-80%
29	Implementation of instrumentation	230 days	Mon 19/01/28	Sun19/09/15	28FS-75%, 20, 23FS-70%
30	Landscaping	21 days	Sun 19/09/15	Sun 19/10/06	29, 28, 27, 17
31	Commissioning and operation	90 days	Sun 19/10/06	Sat 20/01/04	
32	Commissioning	90 days	Sun 19/10/06	Sat 20/01/04	30
33	Operation	0 days	Sat 20/01/04	Sat 20/01/04	32
34	Finish	0 days	Sat 20/01/04	Sat 20/01/04	33

Figure 4: The developed schedule.

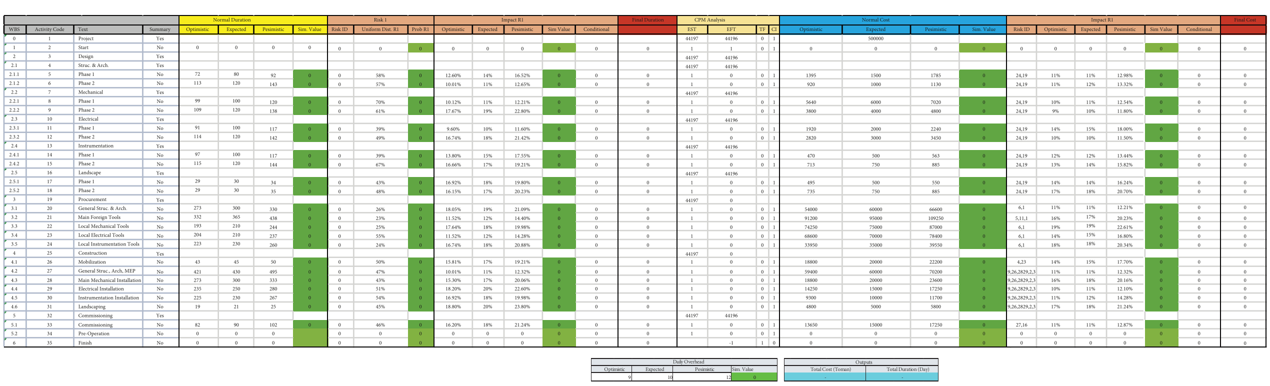


Figure 5: Monte Carlo simulation model framework in software (construction period).

It should be noted that the mentioned numbers are calculated based on a 50% confidence level and do not have a high reliability. Therefore, to increase the reliability of the mentioned numbers, it would be necessary to check higher confidence levels. Table 11 shows the project time and cost at different confidence levels.

Considering that through the conversion of waste to energy via burning, the contractor's income is obtained during the operation period; therefore, through the calculation of the power plant capacity, the estimated amount of required electricity, the minimum guarantee of electricity purchase by the government, and also the basic rate of electricity purchase the final income of the project during the operation could be calculated. Considering the current net value of money, the optimal operational period and the final profit of the contractor could be calculated. According to the mentioned topics, the following assumptions are considered for calculating the income of the operation period:

(i) The maximum power of the power plant is 10 MW

(ii) The minimum purchase guarantee by the government is considered to be 5 MW

(iii) The estimation of the required amount of electricity is deemed to be a normal curve with a mean of 7 MW and a standard deviation of 1 MW

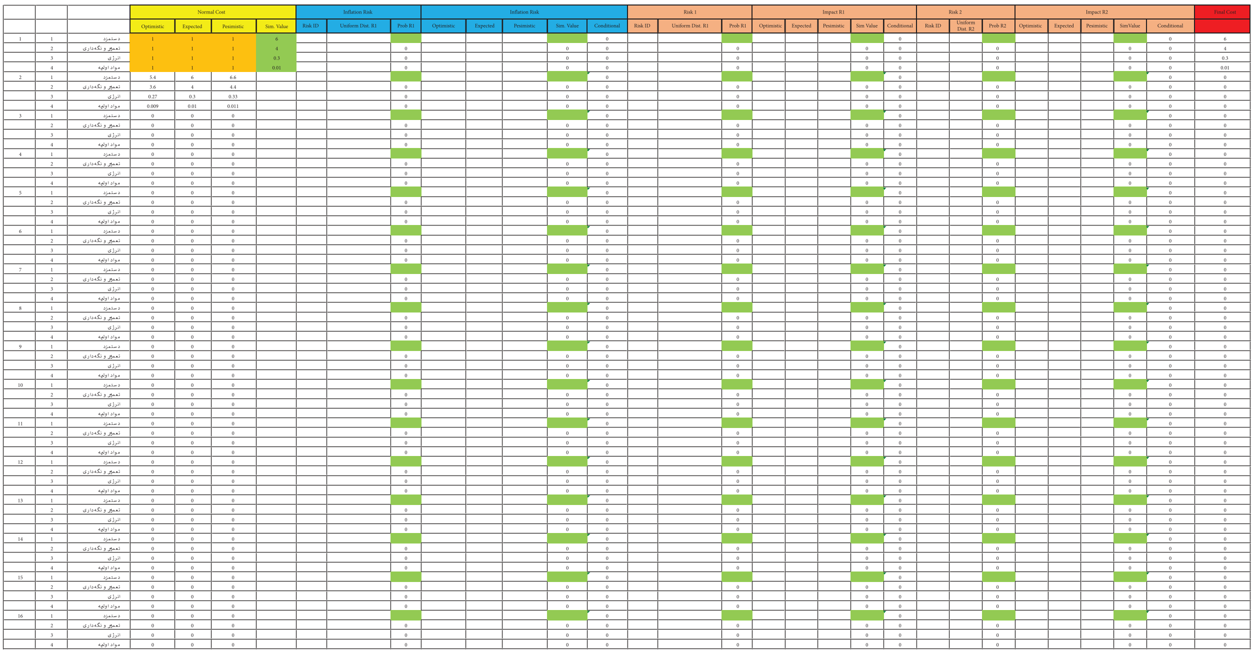


Figure 6: Monte Carlo simulation model framework in software (operation period).

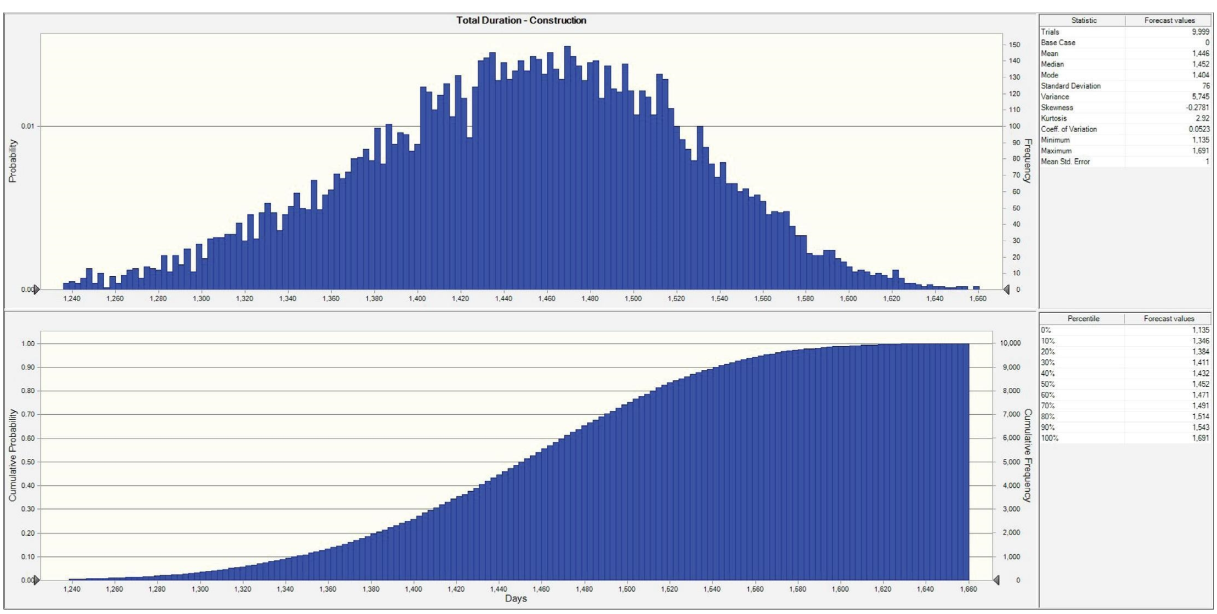


Figure 7: The distribution obtained from the simulation for the final time of the construction period.

(iv) The minimum purchase price of basic power is 777 tomans per kilowatt-hour

(v) Incomes in different years are calculated based on the estimated inflation in the previous year

(vi) The annual discount rate is considered 15%

Figure 11 shows the probabilistic diagram of the optimized time of the operation period. As could be seen, an average of 18 years is needed for the operation period with the mentioned conditions, so that the contractor does not incur any losses but based on the initial estimate, a 15-year operation period is needed.

Also, with confidence levels of 70% and 90%, 19 and 21 years are entailed for ensuring the contractor's profit. The obtained results indicate that in case the risks of the project are taken into account and an operation of 15 years period is selected, at the time of the contract, the contractor would suffer irreparable losses.

Figure 12 shows the probability distribution diagram of the obtained optimal profit that corresponds to the obtained optimal period in the operation phase. With confidence levels of 50%, 70%, and 90%, the predicted profit of the contractor (net present value of money) would be equal to 20, 34, and 51 billion tomans, respectively.

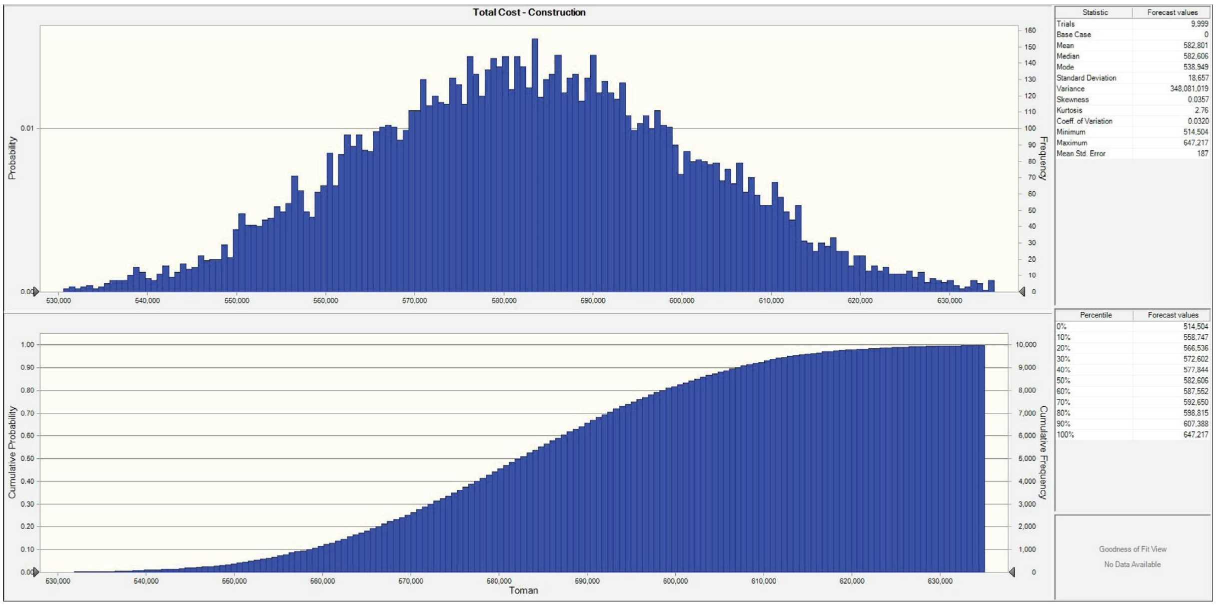


Figure 8: The distribution obtained from the simulation for the final cost of the construction period.

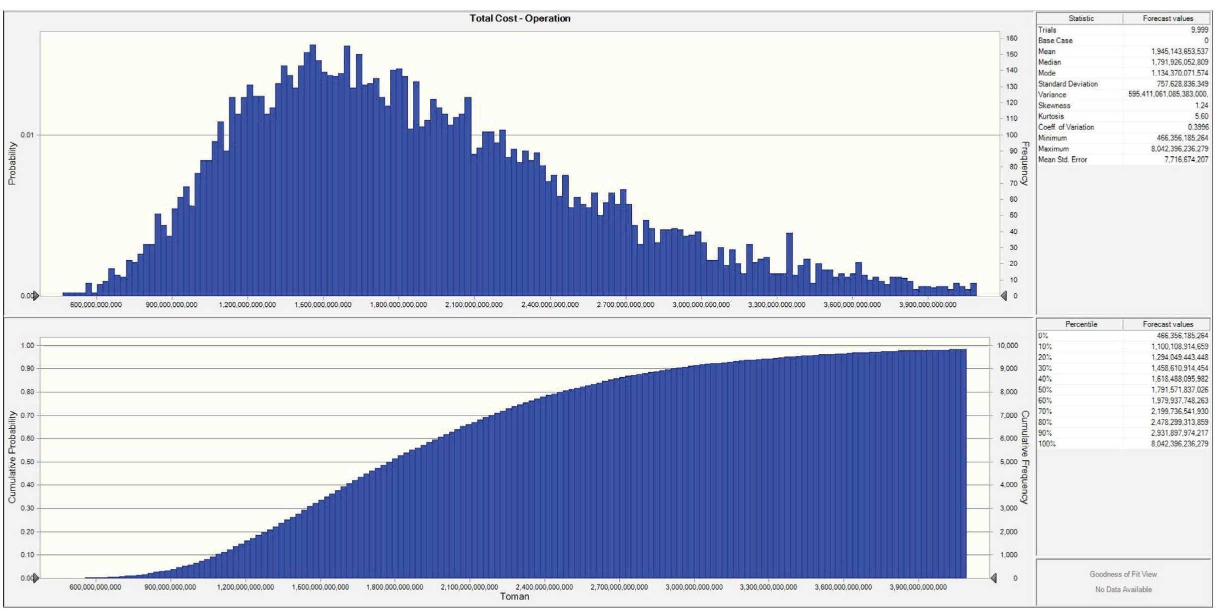


Figure 9: The distribution obtained from the simulation for the final cost of the operation period.

4.4. Financing Results. To ensure the correct performance of the introduced method, the results obtained from the algorithm on a numerical example of their research have been compared with the results obtained on that by Alavipour and Arditi [31]. Table 12 represents the comparative results, and as can be seen, the obtained results are similar and valid.

Table 13 shows the basic information that is necessary for the hybrid optimization algorithm. Using a form created in the VISUAL STUDIO software, this information is entered by the user.

The initial information has three parts: hybrid algorithm specifications, financing specifications, and general project specifications. As can be seen in the table, the initial population size of the algorithm is considered 100 chromosomes, which is divided into 10 groups. The generations' improvement is carried out during 100 iterations with a single-point crossover and a mutation rate of 25%.

The necessary specifications for financing are considered based on the current condition of the project and its risks. As can be seen, the annual percentage rate for long-term loans is 8%, the annual percentage rate for short-term loans (3 to 12 months) is 23% to 8%, and the annual percentage rate for credits is 15%; besides, the time of receiving a long-term loan is at the beginning of the project (month 0), and its repayment would be until the end of the construction period. The limit for receiving long-term loans is 300 billion tomans.

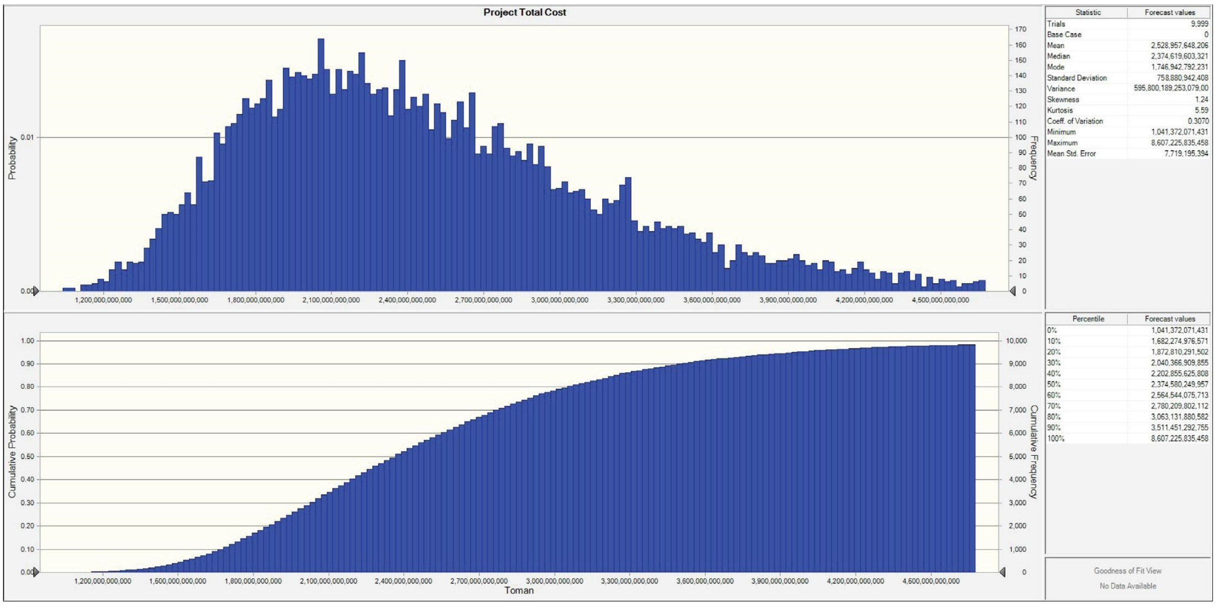


Figure 10: The distribution obtained from the simulation for the total final cost of the BOT contract.

Table 11: Project implementation time and cost at 50%, 70%, and 90% confidence levels.

Item	Initial estimate	Confidence level		
		50%	70%	90%
Construction period time (days)	1,095	1,450	1,490	1,540
Construction period cost (billion tomans)	510	582	592	606
Operation period cost (billion tomans)	1,700	1,819	2,213	2,949
Total cost (billion tomans)	2,210	2,400	2,795	3,526

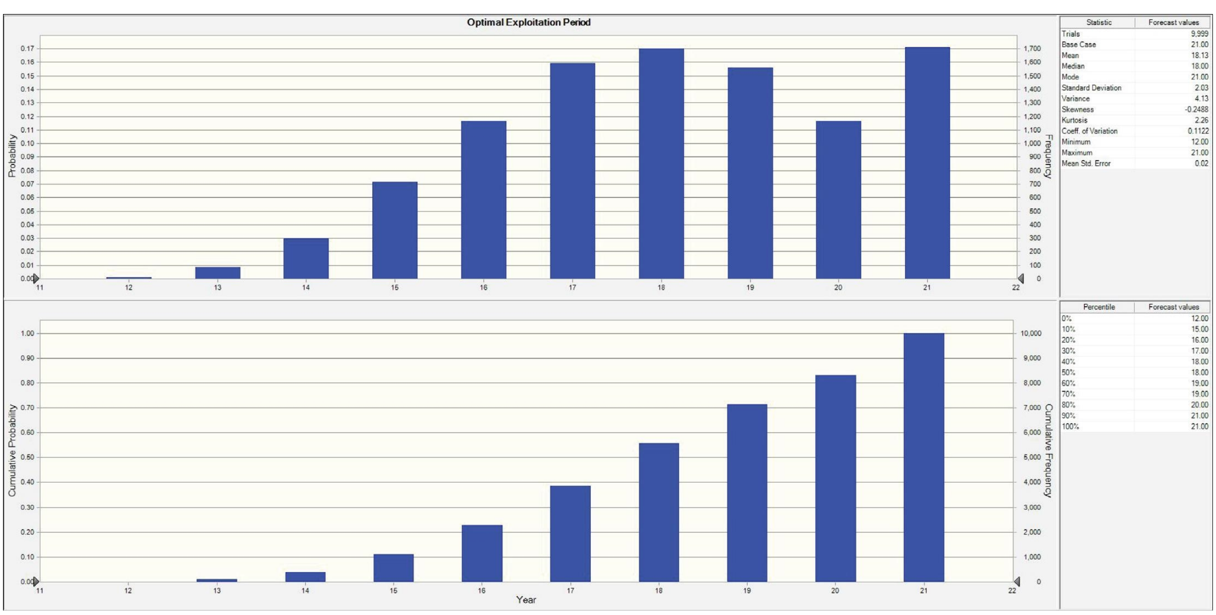


Figure 11: The distribution obtained from the simulation to calculate the optimal exploitation period.

For short-term loans, the amount is 2 billion tomans, and there is no limit for receiving credit. The minimum negative cumulative balance of the contractor's cash flow is considered zero.

It should be mentioned that for investigating the effect of financing on the project, the considered confidence level of time, based on the simulation results, is 90%. And the operation period is 20 years. The information on cash

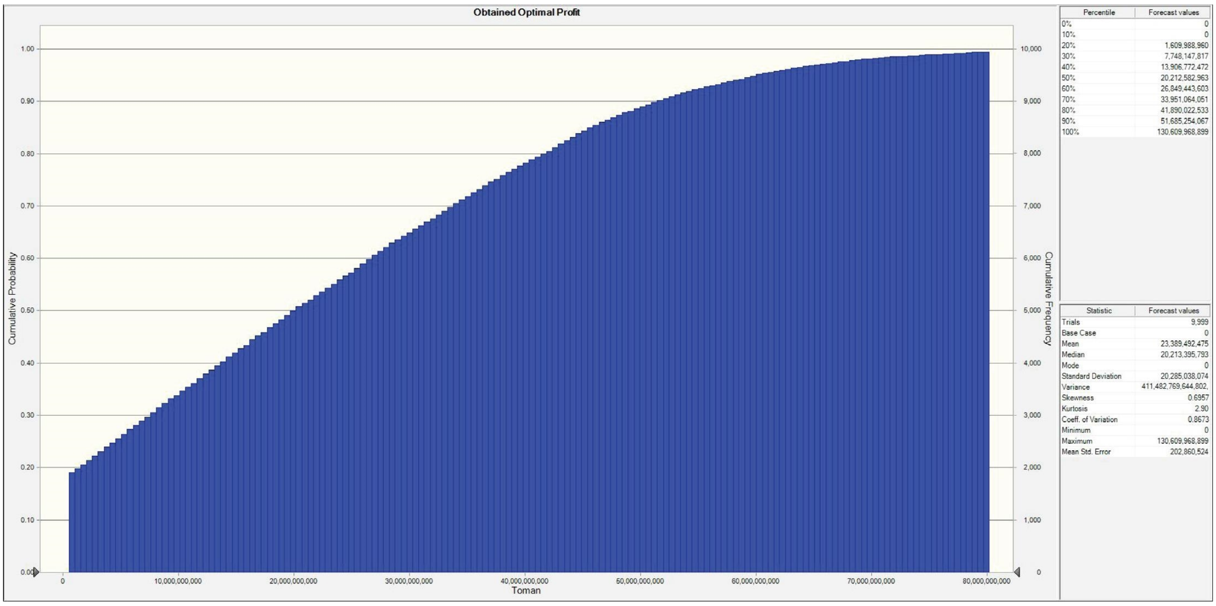


Figure 12: The distribution obtained from the simulation to calculate the profit in the optimal operation period.

Table 12: Comparative results between the current research and Alavipour and Arditi [31].

Item	Current result	Alavipour and Arditi [31] result
Minimum financing cost ($)	119,890	120,202

Table 13: Basic information of the combined algorithm.

Hybrid algorithm information
Population size = 100
The number of groups = 10
Number of generations = 50
Single-point crossover
Reproduction rate = 20%
Mutation rate = 25%

inflows and outflows of the project during the period of construction and operation is given in Table 14.

To implement the financing optimization, the project information is read from an excel sheet the address of which is given by the user. The algorithm is written in VB.Net language. After the start of the program, cash inflows and outflows are calculated for each period of the project. These flows would be used in calculating the financing flow of the project. Then, the hybrid algorithm, based on the given information and limitations, applies different financing options to the cash flow of the project, calculates the optimal option, and prints the results in an Excel sheet. The obtained results show all the incoming and outgoing liquidity flows for the project, long-term loans, short-term loans, and credits received in each period (monthly) from the beginning of construction to the end of the operation. Tables 15 and 16 show the summary of the results obtained from the project financing optimization.

As can be seen, the cumulative balance of cash flow with financing, compared to the cumulative balance of cash flow without financing, is quite 23% different. This indicates the importance of proper financing, as well as its impact and also the significance of the cost of repaying long-term and short-term loans and credits. Considering the impact of financing in the estimation of operation periods can determine the project's failure or success.

4.5. Sensitivity Analysis. To examine the effects of the changes on the total cost of the project financing, a sensitivity analysis is performed in the negative credit limit of the contractor's cumulative cash flow (final profit of the project). As shown in Table 17, the analysis is based on five stages of change in the negative credit limit.

Figure 13 shows that in the initial state of the project, a change in the negative cumulative balance of the contractor's cash flow has had the greatest impact on the reduction of financing costs compared to the initial state (credit limit = zero). As the negative credit limit increases, its effect intensity is reduced, so the increase of the negative credit limit of the contractor, compared to 300,000 million tomans, does not have much effect on the reduction of financing costs.

As expected, the worst case occurs when the contractor cannot accept a negative credit limit (the credit limit is zero). Hence, in order to prevent the contractor from surpassing the credit limits, a considerable financing cost is necessary. This aspect clearly demonstrates how the negative credit limit of the contractor's cash flow contributes to reducing financing costs.

Table 14: Time information and cash flows of the construction and operation period.

Item	Start time Month	Finish time Month	Cash outflow (expenses) Million toman	Cash inflow (revenue) Million toman
Activity 1	0	1	—	—
Activity 2	0	5	2,187	—
Activity 3	2	9	1,456	—
Activity 4	4	11	8,727	—
Activity 5	10	17	5,813	—
Activity 6	4	11	2,912	—
Activity 7	10	17	4,363	—
Activity 8	4	11	728	—
Activity 9	10	17	1,091	—
Activity 10	8	11	728	—
Activity 11	10	12	1,089	—
Activity 12	4	18	74,846	—
Activity 13	10	27	126,750	—
Activity 14	26	35	93,603	—
Activity 15	26	35	87,379	—
Activity 16	26	36	43,716	—
Activity 17	0	3	24,760	—
Activity 18	5	26	75,446	—
Activity 19	26	41	25,153	—
Activity 20	33	45	18,883	—
Activity 21	35	47	12,552	—
Activity 22	46	48	6,288	—
Activity 23	47	52	18,770	—
Operation period year 1	52	64	13,341	57,209
Operation period year 2	64	76	16,874	70,872
Operation period year 3	76	88	20,896	87,480
Operation period year 4	88	100	25,151	106,242
Operation period year 5	100	112	30,613	130,456
Operation period year 6	112	124	37,357	160,679
Operation period year 7	124	136	45,679	196,528
Operation period year 8	136	148	55,388	241,854
Operation period year 9	148	160	67,326	298,795
Operation period year 10	160	172	81,520	363,871
Operation period year 11	172	184	98,729	442,236
Operation period year 12	184	196	119,293	543,390
Operation period year 13	196	208	143,843	659,752
Operation period year 14	208	220	174,063	806,007
Operation period year 15	220	232	208,858	992,106
Operation period year 16	232	244	252,676	1,211,273
Operation period year 17	244	256	304,557	1,457,233
Operation period year 18	256	268	364,097	1,798,119
Operation period year 19	268	280	438,586	2,201,486
Operation period year 20	280	292	525,569	2,672,643

Table 15: Cumulative information on the inflows and outflows of financing funds.

Item	Total borrowed	Total repaid Million tomans	Financing cost
Long-term loan amount	257,150	298,337	−41,187
The total amount of short-term loans	59,916	63,915	−3,999
The total amount of credits received	34,941,255	37,366,766	−2,425,511
Total	35,258,321	37,729,018	−2,470,697

Besides, the results show that the amount of credit used is much higher than the amount of short-term and long-term loans. Thus, to investigate the effect of changes in the repayment percentage on the final cost of financing, another sensitivity analysis is performed on the repayment percentage of the financing options (credit line, short-term loan, and long-term loan).

Figure 14 demonstrates the change in the financing cost arising from the change in the repayment percentage of the credit line. As predicted, a drastic change is observed in the

Table 16: Cumulative project flows in the state without financing and with financing.

Item	Million tomans		
	Total input	Total output	Cumulative balance
Project without financing	14,498,208	3,663,378	10,834,830
Project with financing	49,756,529	41,392,396	8,364,133
Reduction of the cumulative balance of the project			23%

Table 17: The results of the financing sensitivity analysis.

Million tomans				Impact on profit
Negative credit	Finance cost	Finance inflow	Finance outflow	
(500,000)	(82,599)	1,041,595	1,124,194	−1%
(400,000)	(243,609)	3,083,461	3,327,070	−2%
(300,000)	(520,119)	6,581,893	7,102,012	−5%
(200,000)	(961,156)	12,321,226	13,282,382	−9%
(100,000)	(1,617,027)	19,483,335	21,100,362	−15%
—	(2,495,862)	32,983,869	35,479,731	−23%

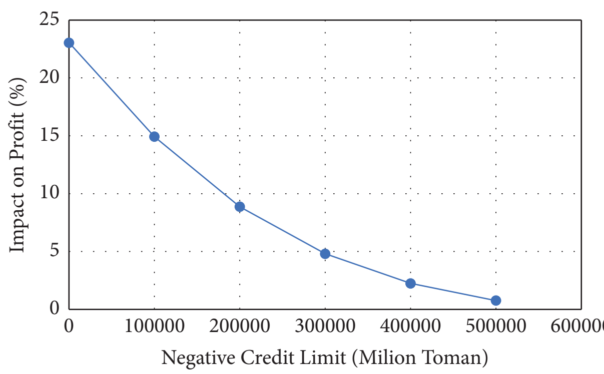


Figure 13: The effect of a change in the negative credit limit on the reduction of the final profit of the project.

cost of financing due to the change in the repayment percentage. In this way, if a credit line with a lower repayment percentage is used, financing costs would be significantly reduced. At the same time, no significant effect is observed on account of the change in the repayment percentage of long-term and short-term loans.

5. Discussion

In this section, the obtained results and their superiority are examined compared to other research. It shall be noted that the obtained results have been seen and approved by the project contractor. Based on the results obtained from this research, the implementation and operation planning of the project have been revised.

(i) The results obtained from the questionnaire indicate that risks such as inflation, currency supply, and contractors' claims are among the risks which are most likely to occur and have an impact on the time and cost of the project. Moreover, the risks of delay in the delivery of imported goods and equipment, changes in the vendor list, and changes in technical maps shall be placed in the planning priority.

(ii) The results of the quantitative risk analysis show that according to the project conditions and in case the current conditions continue, with 90% confidence, in the construction period, the implementation of waste-to-energy power plant construction projects can face a 32% increase in time and a 20% increase in cost. Being aware of these issues, and planning to face them before project implementation, or including these risks in the contract clauses can create a guarantee for the profitability and success of the project.

(iii) According to the conditions of the project risks, with 90% confidence, the impact of the risks of the operation period on costs, including salaries and wages, maintenance, raw materials, and energy, can lead to an increase of 40%. If these risks and their impact on the costs of the operation period are not taken into account, the operation period would increase, which causes contractual and legal conflicts between the contractor and the client.

(iv) Using the developed model of this research can help the managers and planners of the contractor. So, in the case of developing the project as a BOT, due to

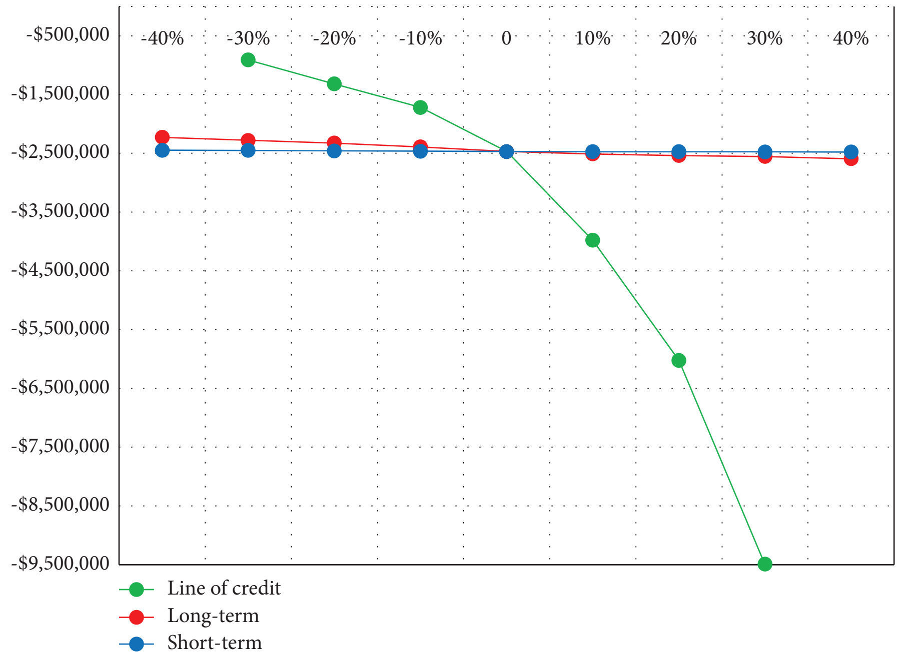


Figure 14: The effect of a change in the negative credit limit on the financing cost.

the risks of this period and at the time of signing the contract, they can predict the increase in the operation duration. In the investigated case study, an increase of 33% (5 years) in the duration of the operation period is predicted compared to when no risks are considered in the project. Therefore, it would be necessary to modify the operation period at the beginning of the project by considering the risks of the project and its effect on the construction and operation period.

6. Managerial Insights and Practical Implications

The proposed model can be applied to solve financing optimization problems with a variety of financing options. In practice, the results of the model can help contractors and investors to plan the project considering risk impact and financial issues. Furthermore, the proposed model can help contractors to determine and promote an appropriate finance scheduling to guarantee the project profit. Also, correct estimation of the operation period can reduce conflicts between the project stakeholders.

Presently, the impact of project risks on project schedules and costs cannot be calculated using planning software (such as Primavera P6 and MS Project). These programs cannot produce optimized financing flows based on project schedules; therefore, almost any schedule that does not take into account the project's constraints and risks would be impractical. As mentioned throughout the study, the study's practical contribution is focused on a workable financial schedule for a real project that takes into consideration the uncertainties of the project activities and the effects that they have on project objectives (time and cost). This, when calculating real time and cost, could enable project managers to take advantage of cutting-edge planning tools that reflect the project's existing features and uncertainties and produce an optimized financing schedule.

While taking risks into account, to provide a workable finance schedule, the proposed framework might be added to software like MS Project as a plugin. Additionally, the proposed method is used on the mentioned actual project and will be applied to additional contractor projects upon request.

7. Conclusion

In this article, a financing optimization model has been developed that considers the impact of the risks on the BOT contract and focuses on a waste-to-energy power plant construction project. This study presents a finance-based scheduling model that might handle a variety of constraints. Compared with previous research, there are some significant results and improvements in the proposed model:

(i) The results of quantitative risk analysis have shown that in waste-to-energy projects, depending on the conditions, there might be a significant increase in the construction time and cost and also operating cost which may cause longer operation time. With a confidence level of 90%, up to 40% increase in the time and up to 60% increase in the total cost of the project have been calculated, which shows the importance of quantitative risk management in such projects. To prevent project failure, this issue is to be considered by contractors before the contract gets signed.

(ii) To ensure the profit of the project, the time of the operation period with a confidence level of 90% has been calculated as 21 years, which shows a 40% increase compared to the initial operation period of 15 years. This issue shows that not considering the effect of risks can lead to a significant loss for the contractor and increase the conflicts between the client and the contractor.

(iii) The financing optimization model introduced in this research might check the cash flows of the project in all time frames of the project.

(iv) According to the analysis of the flows during the life of the project and according to the constraints of the contractor, a financing plan is carried out, based on which the contractor can prevent the occurrence of negative liquidity during the project and also can calculate the effect of loans and credits' repayments on the final profit of the project.

(v) The results of the application of this optimization model to the case study of the waste-to-energy project have shown that the consideration of financing from the beginning of the construction period, the repayment of loans and credits along with their interest rates, can lead to a decrease of 23% in the project's profit.

(vi) This issue shall also be considered by the contractor at the time of signing the contract. Besides, if the contractor can increase the negative credit limit of his cumulative cash flow during the project, he can prevent the reduction of the final profit of the project to an acceptable extent. The result of the first sensitivity analysis shows that if the contractor can bear a negative cash flow of up to 300 billion, the reduction of the project's profit due to the payment of financing costs can be reduced from 23% to 5%. This issue causes more significant profit for the contractor.

(vii) In addition, the results of the second sensitivity analysis show that the change in the interest rate for the credit line option can have a significant effect on the change in the financing cost of the project. This is while the change of interest rate in both long-term and short-term loans does not have much effect on the cost of financing.

The financing optimization model, along with the quantitative risk analysis model other than helping planners and managers to make strategic decisions, allows them to get aware of the project conditions prior to implementation. At the same time, this model is designed as an Excel add-in, which is easy to work with; besides, it offers an acceptable calculation and processing speed due to the large scale of the project.

Similar to all other research, this research also has had its limitations, one of which has been the examination of risks and their impact on other areas of renewable and new energy, i.e., wind and solar energy projects.

Since the quantitative risk analysis model is written in an Excel file via the Crystal Ball plugin, the automatic analysis of the schedule would not be probable. The schedule must be written in an Excel file, and the problem inputs must be determined manually. On the other hand, as the types of projects and contracts can be different, the cash flow information of the incoming and outgoing activities in the financing optimization model is to be written manually in Excel. In terms of calculations, it is assumed that these flows are divided equally over the entire duration of the activity.

According to the mentioned limitations, the following items are suggested to improve future research:

(i) Considering the basic need for risk management in projects, especially infrastructural projects, preformation of the studies on different areas is suggested (such as other renewable energies); besides, it is suggested that the process of risk identification and management is performed and compiled in a documented manner.

(ii) The development of an automatic and comprehensive platform for risk management that has a suitable user interface, as well as various capabilities compatible with other areas of construction projects, is introduced as another suggestion for future studies.

Notations

Indices

k: Index of identified risk $k \in \{1, 2, \ldots, K\}$
R_k: Set of identified risks (risk k)
i: Index of project activity $i \in N$
t: Index of operation year $t \in \{1, 2, \ldots, T\}$
u: Index of operation cost $u \in \{1, 2, 3, 4\} \subset U$
y: Index of cash flows period $y \in \{0, 1, \ldots, Y\}$.

Parameters

n: Number of identified risks
P_{R_k}: Probability of risk R_k occurrence
I_{R_k}: Impact of the risk R_k occurrence
$\text{Con\_}t_{i,R_k}$: Conditional impact of risk R_k on activity i duration
UR_k: Random value drawn from a uniform distribution (related to risk R_k)
FD_i: Final duration of activity i considering its risk impacts
SV_{ND_i}: Random value drawn from a normal distribution for activity i
EST_i: Earliest start time of successor activity i
EFT_j: Earliest finish time of predecessor activity j
$Lag_{i,j}$: Required time interval between the start time of successor activity i and the completion time of predecessor activity j
LST: Latest start time of an activity
LFT: Latest finish time of an activity
$\text{Con\_}t_{i,R_k}$: Conditional impact of risk R_k on activity i cost
FC_i: Final cost of activity i considering its risk impacts
$FOC_{t,u}$: Final cost of operation cost u at operation year t considering its risk impacts
$\text{Con\_}c_{u,t,R_k}$: Conditional impact of risk R_k on operation cost u at operation year t
TD^C: Total construction duration

TC^C: Total construction cost
DOC: Daily overhead cost during the construction period
TC^O: Total operation cost
TC: Total project cost
TI_t: Total income at operation year t
$V_{t,ND}$: Amount of power sales at operation year t drawn from a normal distribution
S_t: Price of one unit of power sale at operation year t
TD^O: Total operation duration
TD: Total project duration
B_y: Total amount borrowed at the end of period y
RE_y: Total amount repaid at the end of period y
FI_y: Total financing cost at the end of period y
TR_y: Total outflow of financing at the end of the period y
NF_y: Net flow of financing at the end of the period y
NFC_y: Net cumulative balance of financing cost at the end of the period y
TFC: Total financing cost
N'_y: Net cumulative balance of cash flows (project and finance) at the end of period y
P_y^{in}: Total project inflow at the end of period y
P_y^{out}: Total project outflow at the end of period y.

Decision Variables

$B_{ST,y}$: The cumulative lent short-term loan amount at the end of period y
$B_{LT,y}$: The cumulative lent long-term loan amount at the end of period y
$B_{LC,y}$: The cumulative lent line of credit amount at the end of period y
$RE_{ST,y}$: The cumulative repaid short-term loan amount at the end of period y
$RE_{LT,y}$: The cumulative repaid long-term loan amount at the end of period y
$RE_{LC,y}$: The cumulative repaid line of credit amount at the end of period y
$FI_{ST,y}$: The cumulative financing cost of short-term loan at the end of period y
$FI_{LT,y}$: The cumulative financing cost of long-term loan at the end of period y
$FI_{LC,y}$: The cumulative financing cost of line of credit at the end of period y
CL_{ST}: Total limit set for short-term loan options
CL'_{ST}: The limit set for short-term loan options at the end of each period
CL'_{LT}: The limit set for long-term loan options at the end of each period
$C_{LC,y}$: Required credit at the end of period y
CL_{LC}: Total limit of the line of credit
CL'_{LC}: The credit limit in each period
MN: Minimum cumulative balance of cash flow in each period.

Data Availability

Data generated or analyzed during this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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