Original Research

Fuzzy modeling of allocation of financial resources of sustainable projects and Solving with GSSA algorithm

Mohsen Amini Khouzani[1].Alireza Sadeghi[2*]. Amir Daneshvar[3].Adel Pourghader Chobar[4]

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* Corresponding Author, ar.sadeghi.1976@gmail.com

1- Department of Financial Engineering, Shahr-e-Qods Branch, Islamic Azad University,Tehran, Iran
2- Department of Financial Management, Science and Research Branch, Islamic Azad University, Tehran, Iran,
3- Department of Industrial Management, Science and Research Branch, Islamic Azad University, Tehran, Iran
4- Department of Industrial Engineering, Faculty of Industrial and Mechanical Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran

Abstract
The problem of allocation of financial resources in projects is one of the most important problems of mathematical optimization. Incorrect allocation of financial resources can lead to project failure, increased costs, and reduced profitability. The importance of this issue has led to the modeling of a financial resource allocation problem for sustainable projects under uncertainty in this article. A fuzzy programming method was used to control model parameters and GSSA, GA, and SSA algorithms were used to solve the model. In the mathematical model, the goal was to optimize the objective function consisting of predicted return, investment risk, and project sustainability. Mathematical calculation results showed that meta-heuristic algorithms have high efficiency in achieving optimal solutions in a short time. so that the average time to solve them was less than 10 seconds. Also, the calculation results showed that increasing the uncertainty rate leads to increasing the value of the objective function and creating a distance from the optimal point. This is due to increasing costs and decreasing profits in sustainable projects. Finally, usage the TOPSIS method, the ranking of solving algorithms was done, and the GSSA algorithm was the most efficient algorithm among other algorithms with a desirability weight of 0.846.

Keywords- Resource allocation; sustainable projects; fuzzy programming; meta-heuristic algorithms

INTRODUCTION

Carrying out the projects of companies and organizations, both small and large projects, requires human and non-human resources, the amount and method of choosing them cannot be an easy task, and resource allocation deals with this. The allocation of resources is called a process in which the managers and managers of a company or institution have explained the available resources of human and non-human resources and make decisions on how these resources work (Marzieh et al., 2018). In the process of planning to advance the project, resources are one of the most important things, if you don't pay attention to them, the project will fail. Allocation of resources is the first step to managing all types of projects. Allocation of resources is a development process, always when various resources such as manpower, energy, materials, and money are not enough to respond to all the desired strategies. This caused the complexity of decision-making by officials regarding project allocation resources (Kaufman et al., 2020).

Allocating more resources, mainly financial resources, to a project leads to the possibility of the growth of investment returns. However, it also has the possibility of increasing investment risk (Daneshvar et al., 2023). On account of the existence of various projects with different expected returns, investment costs, and earned profits, it is very difficult to decide on the FRAP to projects (Zhong et al., 2018). Currently, not only the importance of allocating resources to projects is important, but also paying attention to social, environmental and social aspects has made resource allocation decisions very complicated (Sun & Zhong, 2020; Babaeinesami et al. 2022). Both the sustainability and the management of project resource allocation are actually of higher importance and have quickly hold the attention and interest of experts and researchers. One of the main problems that should be taken into account while making decisions at various levels of the project-oriented organization is sustainability (Muhairi & Nobanee, 2019; Ansari et al. 2023). In addition, those in charge of resource allocation would like to know where and how their allocated resources are consumed. On the other hand, recipients of regular resources tend to have more freedom in allocating resources. Therefore, policymakers, managers, and educational leaders are in search of inventing and using ways through which they can reduce, and achieve the desired goals with specified resources, improve effectiveness and efficiency, and improve the quality of performance of different sub-sectors and groups. The purpose is to prevent the wastage of human and material capital and ensure competitiveness, especially at the international level. The program is considered an important tool in the field of higher education system management and policymakers in reforming or transforming plans in the financial resources management system (Oden and Klon, 1998). Allocating more resources to increase the return on investment also leads to the possibility of increasing investment (Solanki and Virpariya, 2022).

Since the characteristic of sustainability is also in the management of resources of high social importance, attention to social, environmental, and social aspects has also allocated resources with many complications. Sustainability is one of the main issues that should be considered in decision-making (Sun and Zhang, 2020). Considering the importance of resource allocation in sustainable projects, in this article, a new model for resource allocation is presented, taking into account characteristics such as expected return, risk, and project sustainability. Also, in this article, the uncertainty in the cost and profit obtained in each project is considered and different algorithms are used for a combination to solve the problem. Even if there are several sources on project management (project portfolio management) or sustainability in general, there are very few writers who have connected sustainability to project management. Therefore, it is obvious that this problem should be included in the allocation of project resources. Due to the significance of the FRAP in projects as well as private and public companies, in this study, a FRAP has been modeled with regard to sustainability aspects. In this model, the main objective is to determine the financial resource of each project with the aim of maximizing the expected return of all projects, minimizing investment risk, and maximizing sustainability aspects. For this purpose, three main objectives have been designed in the form of an objective function in the mathematical model. Due to the uncertainty in the problem, the fuzzy programming method and the development of meta-heuristic algorithms such as GA and SSA under the new algorithm named as GSSA have been developed to solve the problem. The current research is presented in six sections: (1) the introduction and the main purpose of the research were discussed, (2) the research literature is reviewed and the research gap is identified, (3) a mathematical model is presented to FRAP of projects in conditions of uncertainty, and afterwards, using the fuzzy programming method, the uncertain parameters of the problem are controlled, (4) the problem solving method including a new combination of GA and SSA (GSSA) is presented. In this section, the initial solution to the problem and the resulting decoding are also shown, (5) the analysis of different numerical examples with Baron, GSSA, GA and SSA methods is discussed, and finally, (6) the conclusions and suggestions of the research have been discussed.

LITERATURE REVIEW

Lashkari et al. (2018) presented a model for allocating financial resources with goal planning (GP) at Kerman Afzalipur Medical Education Center. With the participation of key informants and operations research experts, they developed twelve focus group discussions (FGDs) to derive a goal-planning model. Then they collected the accounting data of the hospital from 1389 to 1392. WinQSB software was used to run the model. The results showed that the allocation of resources in the hospital only follows the accounting perspective rather than the optimal and satisfactory perspective. Kral et al. (2019), conducted a study to present a mathematical model of integer programming with bivalence variables for project portfolio optimization focusing on Slovak companies. They used the questionnaire to identify the criteria that are important for the managers of the Slovak companies in the optimization of the project portfolio and reflected them in the mathematical model using the mathematical planning method. The results indicated the existence of a gap regarding the compatibility of the project goals and the strategic goals of the company in the optimization of the project portfolio.

Qiao & Guo (2020) presented a model to investigate the efficiency of the allocation of financial resources based on the supply chain in coastal areas. For this purpose, they used a data envelopment analysis model. Then experimental analyzes were performed to evaluate the model. The results showed that due to the limitation of natural conditions, the efficiency of the western and northern parts of a province is relatively low. Yang (2021), presented a model to investigate the risk of asset allocation for rural commercial banks. He used the method of linear fractional differential equation analysis to provide policy recommendations. The results showed that the amount of negative correlation between different levels of credit risk and the allocation of bank resources is different. Appropriate liquidity risk can optimize the bank's resource allocation. Radimanesh et al. (2021) presented a systematic review of all published articles related to the allocation of health financial resources from 1990 to 2020.

After performing various screening steps, they identified suitable studies, extracted and controlled their information, and analyzed the data by content analysis using MAXQDA 10 software. The findings showed that many need-based resource allocation formulas try to deal with healthcare needs by using individual weighting methods. Zhang (2021), proposed a multiple regression model to evaluate the use of financial resources in different regions through the financial system or financial market. He used the Tobit model to perform empirical analysis on the data and based on the DEA model and the Malmquist index model in the data envelopment analysis method, he used Deep software to calculate the resource allocation efficiency. The results showed that through the analysis of the multiple regression model, the total technical financial efficiency of technology increased in northeast China and gradually reduced the difference between the eastern and western regions.

Zhou et al. (2021), used the double difference method (DID) to investigate the effect of green credit policy on companies from two aspects the number of loans taken by companies and the cost of financing. They show that in terms of loan volume, the introduction of green credit guidelines enables green firms to obtain more credible sources than polluters, and for firms with different ownership rights, the effect of green credit policy on non-state firms is greater than on state firms. Is. The results achieved the main goal of directing credit resources to green companies and achieved Pareto improvement in the allocation of financial resources. Wan (2022), presented an optimization model aimed at investigating the problems in the optimal allocation of financial resources, which calculates the optimal allocation coefficient. With the help of Markowitz's investment theory, he quantitatively analyzed two indicators of investment risk and rate of return. First, by analyzing the allocation efficiency and risk of financial resources, the allocation efficiency model was created. Then the multi-objective model was solved with the progressive optimal algorithm. The results showed that the model has strong applicability and can be expected to improve the efficiency of financial resource allocation and reduce the allocation risk.

Solanki and Virparia (2022), presented a study to explain the conceptual framework of the resource allocation model, based on the performance of higher education institutions (HEIs). They identified and analyzed all parameters using supervised machine learning algorithms such as correlation and regression analysis. and data envelopment analysis (DEA) were used to measure the relative efficiency of each institution. An unsupervised machine learning algorithm was implemented to find clusters of institutions based on their relative efficiency. Finally, the input-oriented and output-oriented forecasting model is developed to allocate resources to institutions. The results showed that the prediction model plays a vital role in allocating resources to HEIs based on their performance. Bernada (2022) presented a model to prove that to obtain an optimal portfolio, only traditional statistical methods cannot be used. He chose a random forest regression model to predict stock prices to complement the Markowitz model. To evaluate the efficiency of the modified model compared to the classical model, data was collected from 10 companies and analyzed. Then, some common technical indicators were extracted and a stock price was predicted in each period. Yields and fluctuations were extracted and finally, a performance analysis was done. The results indicated that the 1-day forecasts were approximately 90% accurate and the portfolio of the modified model was better than the portfolio of the classical model. Literature studies show that there are some research gaps in the field of project FRAP, which is addressed in this article as the followings:

- Paying attention to the sustainability aspects of the projects along with the economic aspects,
- Considering uncertainty in project returns in different scenarios,
- Development of new meta-heuristic solution methods by integrating algorithm operators.

Therefore, in the next section, the FRAP of projects is defined by considering uncertainty.

PROBLEM DEFINITION AND MODELING

In this part of the article, the modeling of a problem of optimizing the allocation of financial resources for sustainable projects under uncertainty is discussed. The sustainability of projects is measured based on various economic, social, and environmental indicators. In the economic sector, indicators such as reducing direct costs, reducing indirect costs, maintenance costs, and construction time have been considered. In the social sector, indicators such as projects of public interest, employee safety, and health, knowledge management/leadership, employee rest, and local workers during construction, operation, and maintenance are mentioned. In the environmental sector, indicators such as water consumption, $Co2$ emission, use of sustainable materials, use of materials with less health risk, use of renewable energy, and energy multiplier have an effect. Based on these 15 sustainability indicators, resources have been allocated to projects in this section. Each project is believed to have different expected returns, implementation risks, and sustainability effects according to the allocation of financial resources. Therefore, in allocating financial resources to projects, all the above should be considered simultaneously. Considering the importance of the expected return of each project, the investment risk, and also the sustainability of the project, a single-objective model has been presented to minimize the weighted sum of the above. In this model, the final goal is to make the right decisions regarding the number of financial resources allocated to each project. The assumptions of the designed model are as follows:

- Each project is considered in different scenarios.
- It is not possible to allocate less or more financial resources to projects.
- The risk, stability and expected return of each project are different.
- The profit obtained from the allocation of financial resources to each project, the investment cost, and the return of the project are considered non-deterministic.
- Each nondeterministic parameter is defined in the set of fuzzy triangular numbers.

According to the above assumptions, the number of $i \in N$ projects is considered in the $j \in J$ scenario. Each considered project has $\tilde{c}_i$ investment cost and $\tilde{g}_i$ profit earned from investing in it. Also, the efficiency of the project in different scenarios is shown by $\tilde{h}_{ij}$. On the other hand, the weight of the sustainable index of each project and its normalization is indicated by s_i and t_i, respectively. The parameters α, β and γ also show the uncertainty rate, the influence factor of the stability index, and the influence factor of the expected return on the project risk. Since the goal is to allocate financial resources to each project, this allocation is defined by the symbol X_i. According to the definition of the above symbols, the management model for the allocation of financial resources in conditions of uncertainty is presented as follows:

$$MinZ = (1-\beta)(1-\gamma)\sum_{i=1}^{N}\sum_{j=1}^{M}\left(\tilde{h}_{ij}-\frac{\tilde{g}_i-\tilde{c}_i}{\tilde{c}_i}\right)^2 X_i^2-(1-\beta)\gamma\sum_{i=1}^{N}\frac{\tilde{g}_i-\tilde{c}_i}{\tilde{c}_i}X_i-\beta\sum_{i=1}^{N}t_i s_i X_i \tag{1}$$

$s.t.$:

$$\sum_{i=1}^{N}X_i=1 \tag{2}$$

$$0\le X_i\le 0.2,\ \ \forall i\in N \tag{3}$$

In the above model, equation (1) deals with the minimization of the weighted sum of total project returns, total investment risk, and project sustainability under one equation. In the first part of the equation, the amount of variance of the allocation of financial resources of projects in different scenarios has been calculated. In the second part of the equation, the value of the total efficiency of the projects is calculated, and in the third part of the equation, the sustainability index of the projects is calculated. Relationship (2) shows that financial resources should be allocated to different projects and this amount should not be less or more than the total financial resource. Equation (3) also shows that the amount of financial resources allocated to each project is a maximum of 20% of the total financial resources. Due to the non-determinism of the model, the fuzzy programming method has been used to control the non-deterministic parameters. In this method, each non-deterministic parameter is specified under three numbers $,C^1,C^2\ ,C^3$ which respectively express the optimistic, probable, and pessimistic values of the fuzzy number $\tilde{C}$. Also, the α parameter is used as an uncertainty rate in the control of non-deterministic parameters, which should take a value between 0.1 and 0.9. According to the application of the fuzzy planning method in the problem of allocating financial resources to projects, the controlled model is as follows:

$$\begin{aligned}MinZ = {}&(1-\beta)(1\gamma)\sum_{i=1}^{N}\sum_{j=1}^{M}\left(\left((1-\alpha)\left(\frac{h_{ij}^2+h_{ij}^3}{2}\right)+\alpha\left(\frac{h_{ij}^1+h_{ij}^2}{2}\right)\right)\right.\\&\left.-\frac{(1-\alpha)\left(\frac{g_i^1+g_i^2}{2}\right)+\alpha\left(\frac{g_i^2+g_i^3}{2}\right)-(1-\alpha)\left(\frac{c_i^1+c_i^2}{2}\right)+\alpha\left(\frac{c_i^2+c_i^3}{2}\right)}{(1-\alpha)\left(\frac{c_i^1+c_i^2}{2}\right)+\alpha\left(\frac{c_i^2+c_i^3}{2}\right)}\right)^2 X_i^2\\&-(1\\&-\beta)\gamma\sum_{i=1}^{N}\frac{(1-\alpha)\left(\frac{g_i^1+g_i^2}{2}\right)+\alpha\left(\frac{g_i^2+g_i^3}{2}\right)-(1-\alpha)\left(\frac{c_i^1+c_i^2}{2}\right)+\alpha\left(\frac{c_i^2+c_i^3}{2}\right)}{(1-\alpha)\left(\frac{c_i^1+c_i^2}{2}\right)+\alpha\left(\frac{c_i^2+c_i^3}{2}\right)}X_i\\&-\beta\sum_{i=1}^{N}t_i s_i X_i\end{aligned} \tag{4}$$

$s.t.$:

$$\sum_{i=1}^{N}X_i=1 \tag{5}$$

$$0\le X_i\le 0.2,\ \ \forall i\in N \tag{6}$$

The change in the shape of the above objective function and the use of the α parameter have led to the control of the model. Since the decision-making variables are multiplied together in the model, it has led to the creation of a non-linear model, which should be solved using meta-heuristic algorithms. Therefore, in this article, the combined genetic algorithm and Salp swarm optimization are used.

DESIGNING THE INITIAL SOLUTION AND ADJUSTING THE PARAMETERS OF THE ALGORITHMS

The purpose of this section is to provide a suitable initial solution for problem-solving with meta-heuristic algorithms. For this purpose, a problem with 7 projects has been considered, a total financial resource should be divided between them. Figure (1) shows the initial answer and its decoding. In this form, a string of random numbers between 0 and 0.2 is created as the total number of the project. After generating the random answer, a correction mechanism is used to allocate the financial resources correctly. In this mechanism, each gene produced in the initial answer is generated by the sum of random numbers so that the total allocation of financial resources to the projects is equal to 1.

7	6	5	4	3	2	1	Project
0.08	0.17	0.19	0.16	0.15	0.15	0.19	The initial answer

Corrective mechanism

7	6	5	4	3	2	1	Project
0.07	0.16	0.17	0.15	0.14	0.14	0.17	Allocation of financial resources

FIGURE 1
THE INITIAL ANSWER TO THE PROBLEM

After determining the amount of allocation of financial resources to each of the projects, the value of variable X is obtained, in which all the constraints of the problem are met. Therefore, by placing it in the objective function, the total amount of the objective function of allocating financial resources for sustainable projects is obtained. Considering the use of meta-heuristic algorithms in problem-solving, before analyzing the numerical examples, the parameters of the meta-heuristic algorithms used in this article have been adjusted. The purpose of the parameter setting of meta-heuristic algorithms is to achieve a set of initial parameter values for each algorithm, which increases the efficiency of that algorithm in finding near-optimal solutions. In this article, GSSA, SSA, and GA algorithms are used to solve the problem. Table (1) shows the optimal parameters of each meta-heuristic algorithm using the Taguchi method.

TABLE 1
OPTIMUM VALUES OF META-HEURISTIC ALGORITHM PARAMETERS WITH THE TAGUCHI METHOD

Algorithm GSSA		Algorithm SSA		Algorithm GA	
200	L	200	Max it	200	Max it
150	N Salp	150	N Salp	100	N pop
0.08	Pc	0.08	Pc	0.08	Pc
0.8	Pm	0.7	Pm	0.7	Pm

After setting the optimal parameters of meta-heuristic algorithms, in the next section, the analysis of different numerical examples with meta-heuristic algorithms is discussed. Also, to validate the model, the obtained results have been compared with Baron's method.

ANALYSIS

After presenting the mathematical model of managing the FRAP in conditions of uncertainty, as well as presenting meta-heuristic algorithms for solving the FRAP, the analysis of the numerical results has been carried out. For this purpose, three algorithms GA, SSA and GSSA have been applied to solve the problem. BARON solver has also been used to validate the mathematical model. Table (2) shows the interval limits of deterministic and non-deterministic parameters of FRAP.

TABLE 2

INTERVAL LIMITS OF FRAP PARAMETERS

Parameter	optimistic	Probable	Pessimistic
$\tilde{g}_i$	$\sim U(10000, 12000)$	$\sim U(8000, 10000)$	$\sim U(6000, 8000)$
$\tilde{c}_i$	$\sim U(4000, 6000)$	$\sim U(6000, 8000)$	$\sim U(8000, 9000)$
$\tilde{h}_{ij}$	$\sim U(0.5, 0.6)$	$\sim U(0.4, 0.5)$	$\sim U(0.3, 0.4)$
s_i	$\sim U(0.2, 0.6)$	β	0.5
t_i	$s_i / \sum_{i \in N} s_i$	γ	0.5

In the analysis of the numerical example for validation, the uncertainty rate is considered to be 0.5, which is its probable state. According to the parameters of the model, the results obtained in table (3) are for a numerical example with 10 projects and 3 scenarios. Besides, the numerical results presented for the following numerical example were obtained through the BARON solver.

TABLE 3

EXPECTED RETURN, RETURN VARIANCE OF EACH PROJECT

Project	X_i	S_i	V_i	R_i
1	0.111	0.494	1.054	0.271
2	0.027	0.234	1.235	0.204
3	0.081	0.260	1.18	0.312
4	0.114	0.374	1.004	0.321
5	0.075	0.25	1.066	0.286
6	0.148	0.447	0.980	0.336
7	0.135	0.505	1.063	0.318
8	0.086	0.262	1.024	0.307
9	0.031	0.356	1.258	0.178
10	0.191	0.478	0.917	0.394

Table (3) shows the amount of financial resources allocated to each project. Based on the analysis, the predicted total return is equal to 0.319, the total risk of the project is equal to 0.124, and the total sustainability index is 0.048. The existence of uncertainty in the parameters of the problem leads to changes in the amount and method of investment in projects. To investigate these changes, the uncertainty rate is considered between 0.1 and 0.9. Table (4) shows the predicted total return, the total risk of the projects and the total sustainability index at different rates of uncertainty.

TABLE 4

DIFFERENT VALUES OF PROBLEM DECISIONS IN DIFFERENT RATES OF UNCERTAINTY

α	ST	VT	RT
0.1	0.051	0.048	0.642
0.2	0.051	0.067	0.533
0.3	0.050	0.087	0.471
0.4	0.049	0.107	0.394
0.5	0.048	0.124	0.319
0.6	0.047	0.142	0.250
0.7	0.046	0.162	0.185
0.8	0.045	0.184	0.125
0.9	0.045	0.195	0.096

As can be observed from the findings of the above table, the projected return value of the entire project has reduced and the investment risk has grown as a result of the rising uncertainty rate, rising investment expenses, and falling project profits. The sustainability of the project has also diminished as the uncertainty rate has increased. Figure (2) depicts the major problem variables' changing process at various rates of uncertainty. The amount invested in each project at various rates of uncertainty is also shown in Figure (3).

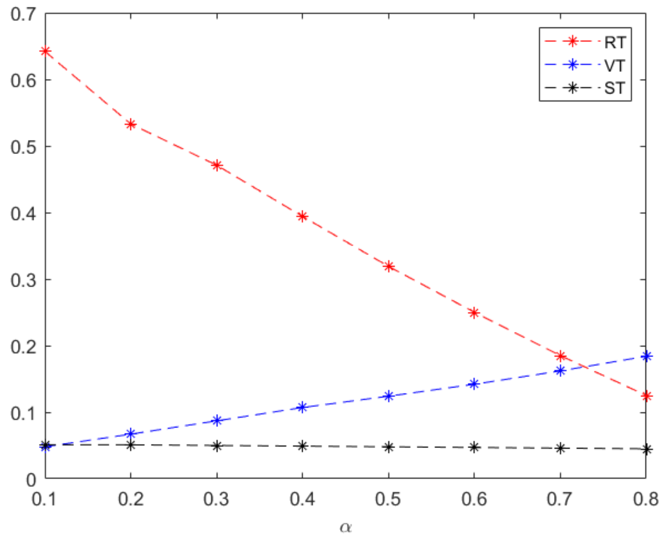

FIGURE 2
THE PROBLEM VARIABLES IN DIFFERENT UNCERTAINTY RATES

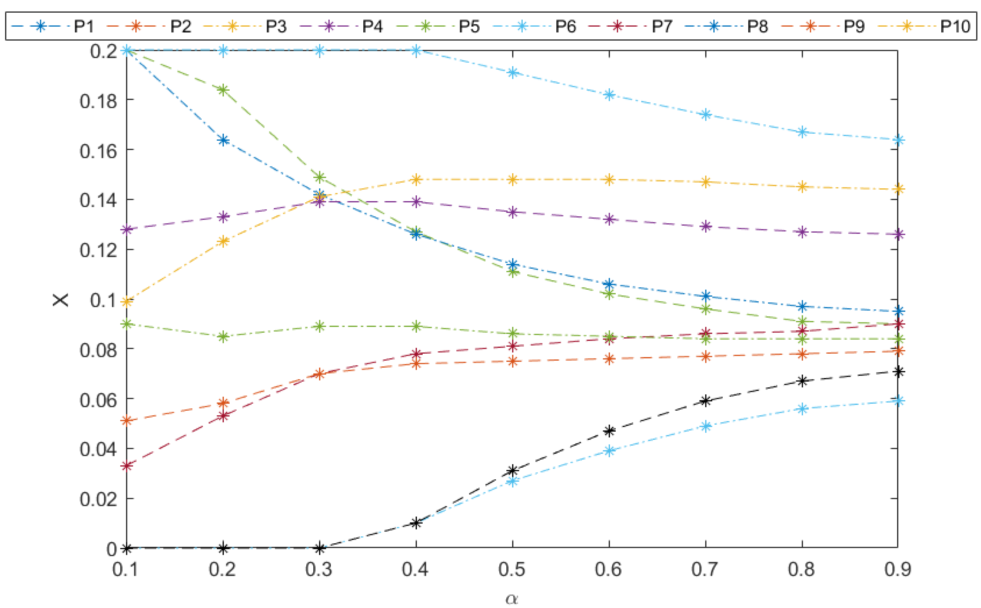

FIGURE 3
THE AMOUNT OF FINANCIAL RESOURCE ALLOCATED TO EACH PROJECT AT DIFFERENT RATES OF UNCERTAINTY

Based on Figure (2), it can be seen that with the increase of the uncertainty rate, the allocation of financial resources to each of the projects has changed according to the objective of the problem. The changes of influencing coefficients β and γ on the main objectives of the problem have been investigated. As stated, if the value of β is equal to 1, only the sustainability index will play a role in the allocation of financial resources. By changing the value of β, the way and amount of investment changes. Table (5) shows the changes of the variables of the problem in different influence coefficients β and γ.

TABLE 5
VALUES OF PROBLEM DECISIONS IN DIFFERENT INFLUENCE COEFFICIENTS Β AND Γ

β	γ	ST	VT	RT
0	0.5	0.044	0114	0.314
1	0.5	0.059	0.201	0.328
0.5	0.1	0.044	0.108	0.302
	0.2	0.044	0.109	0.305
	0.3	0.045	0.111	0.308
	0.4	0.046	0.116	0.313
	0.5	0.048	0.124	0.319
	0.6	0.050	0.136	0.326
	0.7	0.051	0.146	0.329
	0.8	0.053	0.159	0.330
	0.9	0.055	0.175	0.331
0.1	0.5	0.044	0.115	0.314
0.2		0.045	0.116	0.315

According to table (5), it can be seen that with the increase of β and γ, the value of the predicted total return, the total investment risk and the sustainability index increase. Besides, if $\beta = 1$, the value of the total sustainability index is at its highest value, 0.059. Also, the lowest value of the total sustainability index with a value of 0.044 is when $\beta = 0$. In addition, the highest expected return is equal to 0.328. At this rate, the total investment risk has reached its highest value of 0.201. Therefore, the decision-maker can make the best decision regarding the allocation of financial resources to projects, considering three different aspects. After checking the outputs of the model with BARON solver, the numerical example is solved with GA, SSA and GSSA. Figure (4) shows the convergence of meta-heuristic algorithms in reaching the optimal solution.

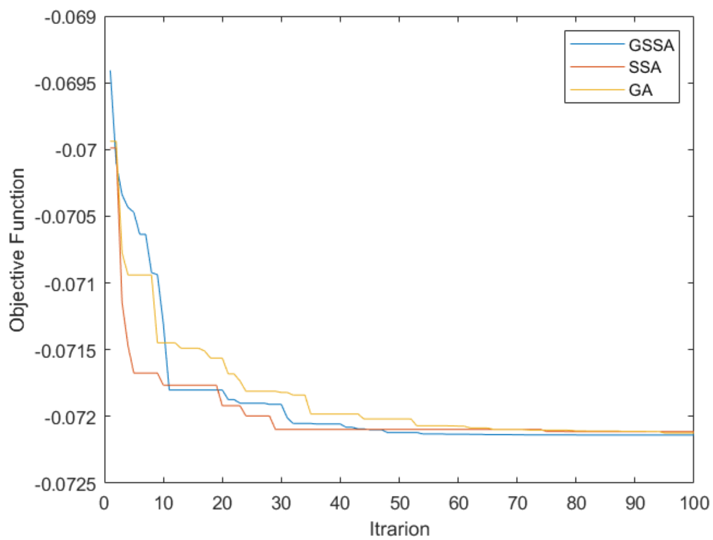

FIGURE 4
CONVERGENCE OF ALGORITHMS IN ACHIEVING THE SOLUTION

According to figure (4), it can be seen that the GSSA has obtained better results than the GA and SSA. Also, based on the general results, the values of the predicted total return, the total risk of the projects and the total sustainability index are shown in Table (6).

TABLE 6
THE MAIN VARIABLES OF THE PROBLEM OBTAINED WITH DIFFERENT METHODS

Method	ST	VT	RT	Time
BARON	0.048	0.124	0.319	3.18
GA	0.047	0.121	0.316	0.51
SSA	0.047	0.121	0.316	0.62
GSSA	0.048	0.121	0.317	0.83

Table 6's findings demonstrate that the GSSA beat BARON to almost ideal outcomes in a lot less time. The GA has the quickest time to find a problem. The GSSA has the greatest expected return and total sustainability index among the findings. According to table (7), 10 numerical instances with significantly bigger sizes are taken into consideration, and table (8) shows the value of the objective function produced via meta-heuristic methods as well as how long it took to compute.

TABLE 7
THE NUMERICAL EXAMPLES IN LARGER SIZES

Problem	projects	scenarios	Problem	projects	scenarios
1	100	30	2	150	40
3	200	50	4	250	60
5	300	70	6	400	80
7	500	80	8	600	90
9	800	120	10	1000	200

The value of the objective function obtained and the resultant computation time are displayed in table (8) following the use of meta-heuristic techniques to solve the problem.

TABLE 8
THE OBFV AND THE CALCULATION TIME OBTAINED FROM THE SOLUTION OF LARGE NUMERICAL EXAMPLES

Problem	Time			OBFV		
	GSSA	SSA	GA	GSSA	SSA	GA
1	0.94	0.92	0.83	0.352	0.354	0.358
2	1.12	1.09	0.95	0.445	0.452	0.449
3	1.39	1.32	1.06	0.559	0.552	0.545
4	1.70	1.62	1.28	0.567	0.560	0.564
5	2.43	2.28	1.68	0.594	0.604	0.600
6	3.20	3.03	2.37	0.636	0.637	0.642
7	4.53	4.28	3.28	0.721	0.727	0.723
8	6.17	5.92	4.94	0.730	0.739	0.738
9	9.67	9.12	6.91	0.831	0.845	0.829
10	15.67	14.79	11.29	0.920	0.927	0.924
Average	4.682	4.437	3.459	0.6355	0.6397	0.6372

The results of Table (8) show that the GSSA has a higher efficiency than the GA and SSA in searching for a near-optimal solution. This is despite the fact that the GA has been able to solve the problem in a shorter computing time.

CONCLUSION AND FUTURE PROPOSALS

In this article, a mathematical model for managing the FRAP of projects under unpredictable project return, investment cost, and earned profit circumstances was proposed. The major goal of presenting the model is to distribute a portion of the budget to each project in a way that simultaneously maximizes predicted returns on all projects, investment risk, and sustainability indicators. As a result, the fuzzy programming method was used to control the non-deterministic parameters. For each of the non-deterministic parameters, a multivariate fuzzy number was created based on the opinions of the experts. The BARON solver and GSSA were utilized since the specified mathematical model was not linear. The total return on investment decreases as a result of the rise in costs and decline in profit, and the risk of investing in projects rises, it has been observed, as the uncertainty rate in the project grows. The whole sustainability index has likewise declined under similar circumstances. As a result, the projected return on the projects, the investment risk, and the sustainability index all decline in the most pessimistic condition as compared to the likely state. Because meta-heuristic algorithms were developed for this study, it was found that the GSSA had the best outcomes in terms of project returns forecast, investment risk, and sustainability index. While it took the GA less time to arrive at a nearly ideal solution. Therefore, the outcomes of 10 numerical examples in larger design sizes demonstrated that the GSSA obtained the best value of the objective function from solving the mathematical model, in accordance with the high efficiency of meta-heuristic algorithms in solving the problem of managing the FRAP for projects. As a result, this algorithm's efficiency is higher than the efficiency of any of the individual SSA or GA algorithms. Following the completion of this research, it is advised to incorporate project dependability into the mathematical model and use the fuzzy robust approach to regulate non-deterministic parameters. Additionally, adding additional objective functions to the model can produce more accurate results.

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