An integrated Multi-Objective Optimization Model for Bank Green Supply Chain Network Under Uncertainty Using Fireworks and NSGA-II Algorithm

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Abstract: The research and the proposed model have been performed with the aim of providing integrated multi-objective planning of Bank Sepah green supply chain, in uncertainty and model solution, using meta-heuristic algorithm and providing a suitable conceptual framework. In this regard, first, a model is presented for Multi-Objective Optimization of modm, and then, it is solved using the fireworks algorithm fireworks based on the Pareto archive and NSGA-II genetics. The Green Banking phenomenon has been developed with the same purpose, in the world's banking systems and nowadays has made significant progress in theoretical and operational terms. Interestingly, Islamic banking is not indifferent to this issue and pays special attention to green banking under the coverage of Ethical banking. The important issue is that in the critical situation of the future trend of the environment in Iran, green banking requires the attention of decision-makers. In this dissertation, Sepah Bank's green supply chain has been reviewed and modeled, which includes three levels of the Central Bank, Sepah Bank branches, and investment centers. The proposed model, based on sustainability dimensions, has three goals. This model is solved using two fireworks and NSGA-II algorithms, and the results of the two algorithms are compared based on quality, evenness, and dispersion indices. The results of the model solution demonstrated that the fireworks algorithm has a greater ability to explore and extract the feasible region of the response than the NSGA-II algorithm. Moreover, the NSGA-II algorithm, compared to the fireworks algorithm, produces higher uniformity responses in less time.

Keywords: Green banking; Supply chain; Fireworks algorithm; NSGA-II; Pareto Archive

1. Introduction

Nowadays, the rapid changes in the market are known to everyone. Technology is progressing rapidly, and every day, new goods and services are introduced to the market, consumers' tastes are changing, and competitors' behavior is unpredictable. In such an environment, providing the right goods and services, at the right cost and time, to consumers is not only the most important factor in competitive success but also plays a key role in the survival of trading companies. Furthermore, despite all the environmental efforts made so far, human activities are still upsetting the ecological balance. The development of human knowledge and his ability to increase the utilization of the environment and its resources, and on the other hand, the concern about the depletion of natural resources, and upsetting the balance of vital processes on Earth, has attracted the researchers' attention more than before to the environment and its effective and susceptible factors. Banks play an important role in economic growth and development, the protection of basic resources, and the reduction of destructive environmental effects, as well as public welfare in society. This important role has led to the formation of a green supply chain in banks and developing and implementing its concepts. An overview of the performance of the world's top banks opens new windows of business thinking based on the green supply chain [1]. The Green Supply Chain in Banks seeks to integrate and address the technology and developments of conventional behavioral habits in the banking business, changing traditional trends and creating a new platform based on a sustainable approach, and preserving natural resources along with development and transformation. Supply chain management (SCM) is managing and coordinating a complex network of activities involved in delivering the end product to the customer. The idea of green supply chain management (GSCM) is to remove or minimize waste (energy, greenhouse gas, chemical/hazardous gas, solid waste) along the supply chain [2].

On the other hand, Banks play an important role in economic growth and development, the protection of basic resources, and the reduction of destructive environmental effects, as well as public welfare in society. This important role has led to the formation of a green supply chain in banks and developing and implementing its concepts. An overview of the performance of the world's top banks opens new windows of business thinking based on the green supply chain. The Green banking tries to integrate and address the technology and developments of conventional behavioral habits in the banking business, changing traditional trends and creating a new platform based on a sustainable approach, and preserving natural resources along with development and transformation [3]. Green banking emphasizes the health and well-being of products, and their compliance with environmental standards, and in addition to reducing the costs are looking for promoting products that are beneficial to the environment and society. Green banking, by increasing the level of awareness and environmental knowledge of people, changes their common view of their surroundings. Meanwhile, industry executives seek ways to increase the organization's performance while protecting the environment. One of the tools of this approach is the green supply chain. The green supply chain is, in fact, the developed traditional supply chain, and its focus on environmental elements is the basis for achieving the goals of the supply chain [4].

Given the importance of the green supply chain, as well as the importance of this concept in the banking industry, this dissertation presents integrated multi-objective planning of Bank Sepah Green Supply Chain, in uncertainty and model solution using Metaheuristic; and the general principles have been addressed in the present chapter. The research is further structured as follows. The research literature is presented in the second section. The third section examines the proposed solution method. The fourth section deals with the mathematical model and describes the model components. In the fifth section, computational results are presented, and finally, there are in the sixth section, conclusions, and some recommendations.

1.1. Literature Review

The available literature related to the green supply chain has been examined in this section. Kuei et al. (2015) conducted a study in China entitled "Identifying and Determining Factors Improving the Performance of Green Supply Chain Management." The research results show that indicators such as environmental compatibility, organizational support, high-quality and decent human resources, customer pressure, legal pressures, government support to improve the environmental and economic performance of organizations have been very effective and important [5].

Chin et al. (2015) conducted a study in Malaysia entitled "Investigating the Relationship between Green Supply Chain Management and Sustainable Performance in Manufacturing Companies." The results show that paying attention to the green supply chain activities, such as green purchase, green production, green logistics increases and promotes sustainable performance in economic, social, and environmental dimensions [6].

In their study, Halim et al. (2015) examined the six goals of one of Malaysia's top banks: asset accumulation, debt reduction, stock wealth, income, profitability, and optimal financial management. To find an optimal solution, they addressed these goals using the target planning model from 2010 to 2014. The results of this study can be used as a guide for financial institutions, in decision making and strategy development, to deal with various economic scenarios. [7]

Balbas et al. (2015) have addressed the issue of capital allocation in terms of risk and ambiguity. Their model is comprehensive in many ways. For example, in their modeling, they evaluated both discrete and continuous-time modes. Their paper includes four important features that are the high performance of the model, the linearity of the model in addition to stability, adaptation to changing market parameters, and the using pathological factors in a probabilistic model [8].

Ruimin et al. (2016) provided a strong environmental closed-loop supply chain network, which includes manufacturing centers, customer centers, collection centers, and disposal centers. They introduced a multi-objective Mixed-integer linear programming (MILP) model that simultaneously considered two conflicting goals. The first goal was to minimize economic costs, and the second was to minimize the impact of the supply chain on the environment. They solved the model using LP-metric. Finally, they demonstrated the efficiency of the model by an example [9].

Talaei et al. (2016) presented a robust fuzzy programming approach for the closed-loop supply chain, considering the emission of pollutant gases. They first converted the fuzzy model to deterministic using the ranking method of Jimenez and then presented Robust Optimization [10].

Dubey et al. (2016) conducted a study aimed at providing a model for the empowering factors of green supply chain management. To provide this model, they used empowering factors such as green technology, waste management, production management, reverse logistics, customer needs consideration, supplier relationship management, information management, and process integration. The results showed that process integration, information management, and green technology were important and fundamental factors to implement green supply chain management [11].

Wong et al. (2016) conducted a study entitled "Investigating the Relationship between Green Supply Chain Management Activities on Financial Operators of Thai Companies." First, by studying thematic literature, five measures of green supply chain management, including green procurement, green production, green transport, green logistics, eco-compatibility were identified, and then, the results of data analysis with multivariate regression analysis approach were shown, according to which green production measures, reverse logistics and eco-compatibility, respectively, have the highest impact on corporate financial performance [12].

Bruno et al. (2017) addressed loans and the allocation of inadequate resources in European banks in times of crisis. The aim of this study was to investigate the relationship between portfolio quality and lending in European banks during the years 2005-2014. The results confirm the negative relationship between the poor quality of portfolio and lending, as it explains a higher NPL ratio, reduced loan growth, and loan allocation in favor of government debt (as a percentage of total assets) [13].

Metawa et al. (2017) examined the optimization of bank lending decisions. This paper proposes an Intelligent model based on a genetic algorithm (GA) to organize bank loan decisions in a highly competitive environment with credit crisis constraints (GAMCC). GAMCC provides a framework to optimize bank goals while making a loan portfolio, maximizing bank profits, and minimizing the risk of dynamic lending decisions. Compared to advanced methods, GAMCC is a more intelligent tool, which enables banks to reduce loan screening time by a wide range from 12 to 50 percent [14].

Menon et al. (2017) conducted a study entitled "Study of Green Banking Initiatives in Sustainable Performance of Manufacturing Companies in India". Research results shows that considering supply chain activities increases and promotes sustainable performance in economic, social, and environmental dimensions [15].

Basiri and Heydari (2017) have presented a mathematical model for supply chain coordination. In this paper, the coordination of the green channel in a two-stage supply chain (SC) is examined. The studied SC sells a traditional non-green traditional product, and also plans to replace the current traditional green product with a new green one. Demand for both products follows the retail price as well as the green quality of the products, and retail sales efforts; a mathematical model is designed for their paper scenario and is solved by numerical examples [16].

H. Golpira et al. (2017) examined the green chain management taking into account the risk of retailers. They introduced a multi-objective mathematical model for the Multi-tier sustainable supply chain. In their model, they consider the parameters such as demand, the amount of pollution caused by the facility, and the amount of pollutant emitted gases in a probabilistic manner. Moreover, in their model, they have considered return risk of products, which has been evaluated using CVAR [17].

Ivanov et al. (2017) have presented a mathematical model for supply chain planning based on dynamic conditions. They reviewed a multi-echelon and multi-period supply chain, taking into account periodic and dynamic planning, and have presented a mathematical model for it to minimize supply chain costs [18].

Puji Nurjanni et al. (2017) have presented a mathematical model for a sustainable green supply chain. In their model, they consider environmental and other costs of the supply chain as the goal minimization of the mathematical model. In order to investigate the related costs to environmental impacts, they have taken in to account the costs of the emitted pollutant gases [19].

Rezaei and Kheirkhah (2017) have studied the sustainable closed-loop supply chain, and have proposed a three-objective mathematical model for economic, social, and environmental purposes. They also have used the cuckoo metaheuristic algorithm to solve the model [20].

E. Laskowski (2018) identified green banking indices as the banking future dimensions in Poland and presented the following five components: green supply management capabilities, environmental questions, environmental commitment, environmental assessment of suppliers, and how to collaborate with suppliers [21].

Chen et al. (2018) identified criteria to evaluate green banking of environmental sustainability, the current situation and future plans in the Bangladesh industry, and to examine its economic and financial situation in Asia. They classified these criteria into four groups of green procurement, environmental sustainability, green distribution, and logistics in the future [22].

In their study, Bottani and Casella (2018) have examined the issue of the sustainable closed-loop supply chain, considering the reduction in emissions of environmental pollutants. They provided a model to solve this problem, and then, solved the model using a simulation tool for a case study [23].

Vafaei Nejad et al. (2019) have developed a multi-objective mathematical model for a sustainable green supply chain. In their model, they modeled a multi-period, multi-item supply chain, and used the Epsilon -constraint method to solve the model [24].

Zhen et al (2019) studied a sustainable green supply chain problem under unspecified demand to minimize total operational cost and CO_2 emission. A scenario-based lagrangian relaxation approach and is applied to model stochastic programming [25].

Eka Normasari et al. (2019) investigated a capacitated vehicle routing problem. They developed a simulated annealing algorithm. Results indicate that the proposed algorithm could find suitable solution in logical time. As well, the sensitivity analysis shows that total distance depends on number of customers and car traffic range [26].

da Costa et al. (2019) developed a mathematical model for vehicle routing problem in green supply chain. A genetic algorithm is used to solve problem to minimize CO_2 emission [27].

Madankumar et al. (2019) studied vehicle routing problem in green supply chain considering receive and deliver simultaneously. To do this end, a mixed-integer programming model is developed. Furthermore, a branch and bound solution approach is applied [28].

Zhou et al. (2019) studied bank system using three stage data envelopment analysis under uncertainty [29]. In this study, a three-stage contains asset structure, assignment and profitability is proposed to analyze bank structures and identify the specific causes of each inefficiency. A multi-stage DEA is developed to measure performance over consecutive periods in which unused assets were transferred to subsequent periods. The proposed model is used to assess Chinese commercial banks efficiency from 2014 to 2016. The results show that inefficiency in different stage for several banks is happened.

Table 1. Summary of previous researches

Researcher (year)	supply chain	Green	Banking	uncertainty	multi objectives	mathematical modeling	Meta-heuristic algorithm
Kuei et al. (2015)	*	*					
Chin et al. (2015)	*	*					
Ruimin et al. (2016)	*	*			*	*	
Talaei et al. (2016)	*	*		*	*	*	
Dubey et al. (2016)	*	*					
Wong et al. (2016)	*	*					
Bruno et al. (2017)	*	*					
Metawa et al. (2017)	*	*					
Menon et al. (2017)	*	*	*				
Basiri and Heydari (2017)	*	*			*	*	
H. Golpira et al. (2017)	*	*		*	*	*	
Ivanov et al. (2017)	*	*				*	
Puji Nurjanni et al. (2017)	*	*				*	
Rezaei and Kheirkhah (2017)	*	*			*	*	*
E. Laskowski (2018)	*	*	*				
Chen et al. (2018)	*	*	*				
Bottani and Casella (2018)	*	*				*	
Vafaei Nejad et al. (2019)	*	*			*	*	
Zhen et al. (2019)	*	*		*		*	
Eka Normasari et al (2019)	*	*				*	*
De Costa et al. (2019)	*	*				*	*
Madankumar et al (2019)	*	*				*	
Present study	*	*	*	*	*	*	*

According to Table 1, there are many studies that have examined the supply chain and the green supply chain and have proposed an integrated deterministic and/or probabilistic mathematical model for them. Moreover, many studies have developed multi-objective models and used a Meta-heuristic algorithm to solve the model. Some researchers have also been conducted in the field of the green supply chain of the banking industry, but there is no mathematical model in the field of green supply banking chains so far. Therefore, the present study is designed to fill this research gap and provides an integrated multi-objective model for the green supply chain in the banking industry, in uncertainty and model solution using meta-heuristic algorithms to solve the model. Therefore, it can be said that the present study is innovative in the following cases:

- Presenting an integrated mathematical model of the green banking supply chain.
- Considering uncertainty in the parameters of the green banking supply chain.
- Using meta-heuristic algorithms based on the Pareto archive, to solve the green banking supply chain model.

2. Methodology

The present study has used a multi-objective fireworks algorithm based on the Pareto archive to solve the model. In the following, the proposed multi-objective combined algorithm structure is presented to simultaneously optimize three objective functions considered in the model. The purpose of designing the above method is to achieve as much as possible the optimal total or Pareto answers.

2.1. Fireworks algorithms

The fireworks algorithm is a new intelligent algorithm proposed by Ying Tan in 2010. This algorithm, by mimicking the fireworks explosion process, can look for optimal solution efficiency. To the simple introduction of this algorithm, the general optimization problem can be stated as follows:

$$Minimize\ f(x)|\ x_{min} \leq x \leq x_{max} \qquad (1)$$

For the above optimization problem, the main idea of the fireworks algorithm is the initialization of M fireworks and showing them in solution space, and then selects M fireworks, in turn, to continue the iterations process according to the specific rules. Specifically, the fireworks algorithm mainly consists of the following four sections: explosion operator, mutation operator, mapping strategy, and selection strategy. Among them, the explosion operator consists of three parts: the explosion intensity, the explosion amplitude, and the displacement operator. Mutation operators increase population diversity using mutations. The explosion operator is the main component of the fireworks algorithm, and it consists of three parts: explosion intensity, explosion amplitude, and displacement operator. explosion intensity is measured directly by the number of explosion sparks, while the explosion amplitude is measured by the displacement distance. The basic idea is making the decision that the explosion intensity and its amplitude for each firework (potential solution) are less than the value of the fitness function, greater than the explosion intensity, and less than the explosion amplitude (and vice versa). The explosion intensity is measured by the number of explosion sparks, which are shown as follows:

$$s_i = m\ .\ \frac{y_{max} - f(x_i) + \xi}{\sum_{i=1}^{n}\left(y_{max} - f(x_i)\right) + \xi} \qquad (2)$$

Where s_i is the number of sparks produced by i^th^ fireworks; m is a constant value that is limited to the total value of sparks; $f(x_i)$ is the fitness value of the i^th^ fireworks fitness;

$$y_{max} = max\left(f(x_i)\right)(i = 1.2.\ldots.n) \qquad (3)$$

The largest fitness value belongs to the recent population; and ξ is a small positive constant to avoid dividing by zero. As the number of generated sparks may be much higher or much lower for the algorithm, we set more limitation on the number of sparks, and the s_i domain is shown as following:

$$\hat{s}_i = \begin{cases} round\ (a.m)\ if\ s_i < a\ m \\ round\ (b.m)\ if\ s_i > b\ m\ , a < b < 1 \\ round\ (s_i)\quad otherwise \end{cases} \qquad (4)$$

Where $\hat{s}_i$ is the number of sparks generated by the i^th^ fireworks. $round\ (.)$ is a Recursive Function that returns an integer, and a and b are the predefined constant values in leading. Explosion amplitude was measured by the displacement distance, which is represented by the following formula:

$$A_i = \hat{A}\ .\ \frac{f(x_i) - y_{min} + \xi}{\sum_{i=1}^{n}\left(f(x_i) - y_{min}\right) + \xi} \qquad (5)$$

Where A_i is explosion amplitude of the i^th^ fireworks, Â is a constant value, indicating the upper limit of explosion amplitude. After obtaining the explosion intensity and amplitude, we randomly select the z-dimension to create the fireworks mutation. This formula performs the operation as follows:

$$Z = round\ (d.rand(0.1)) \tag{6}$$

where, d is a dimension of x, and $rand$ (0.1) is a function of generating a random number of uniform distribution between 0 and 1. For the selected dimension, the displacement formula is as follows:

$$\Delta x_i^k = x_i^k + rand(0.A_i) \tag{7}$$

Where $rand(0.A_i)$ also returns a random number between 0 and A_i.

We get a number of sparks from the above operation, and only a few can be selected for the next generation. The main idea of the selection strategy is to make sure that these sparks will always be selected in the recent population with the smallest value of fitness, and n-1 remaining spark is determined by the Euclidean distance between that spark and other sparks. The Euclidean distance is shown as follows:

$$R(x_i) = \sum_{j \epsilon k} d(x_i.x_j) = \sum_{j \epsilon k} \|(x_i - x_j)\| \tag{8}$$

Where K is a complete set of recent populations, which not only includes fireworks but also sparks caused by explosions. To ensure variety, sparks that are farther away from other sites will most likely be selected. The probability of selecting the corresponding spark for each spark is determined by the following formula:

$$P(x_i) = \frac{R(x_i)}{\sum_{j \epsilon k}\ R(x_i)} \tag{9}$$

This equation indicates that a spark with a larger average distance will most likely be selected, while a spark with a smaller average distance will be less likely to be selected. The formulas consist of a complete iteration of fireworks algorithms, and the selected sparks at this stage will be the initial position of the next iteration. Iteration determines when the stop criterion is met.

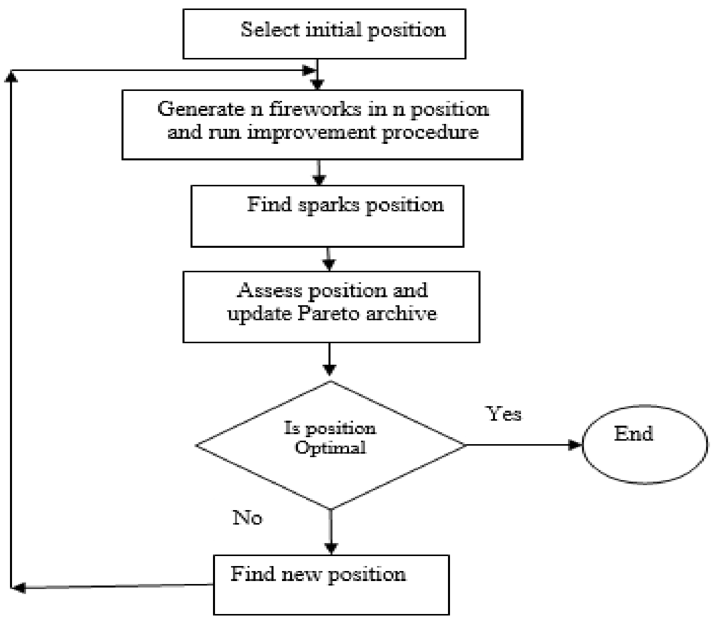


Figure 1. Flowchart of fireworks algorithm steps

In this study, a semi-random approach was used to generate initial responses. Thus, the N feasible (the number of responses in the population) is generated randomly, so that, model constraints are not violated. In this way, in order to produce a feasible answer, each time the number of purchased and sold assets are produced based on the bank's wealth, available budget, borrowed money, etc., in the accepted intervals, as a uniform and random distribution. After generating values, all model constraints will be examined, and if some constraints are not met, the values will be modified or reproduced. To improve the answers, three structures of neighborhood search have been used as a variable neighborhood search (VNS), individually or combined neighborhood search structures. The pseudo-code of our VNS is as figure 2.

```
{for each input solution
K=1
While stopping criterion is meet do
New particle=Apply NSS type k
If new solution is better than then
K=1
Else
K=k+1
If k=4 then
K=1
Endif
Endif
Endwhile
}
```

Figure 2. The pseudo-code of proposed VNS

2.2. NSGA-II algorithm

The solution representation in this algorithm is like a fireworks algorithm. But the general structure of the genetic algorithm is shown in figure 3.

3. Proposed Model

In this section, a proposed model consists of problem definition; assumptions, notation and mathematical model are presented.

3.1. Problem definition

The proposed model includes three levels of central bank, bank branches and investment centers.

3.2. Assumptions

The proposed model assumptions are mentioned as follows:

- The multi-period supply chain network is considered
- Assets purchasing and selling costs are considered as fuzzy number
- Types of investment or assets are attractive, while higher attractive investment has a higher priority
- All investment are used for production centers installation and they include bank's activities in the field of production
- Each production center has various parameters such as workforce damage, job opportunities, hazardous material and waste

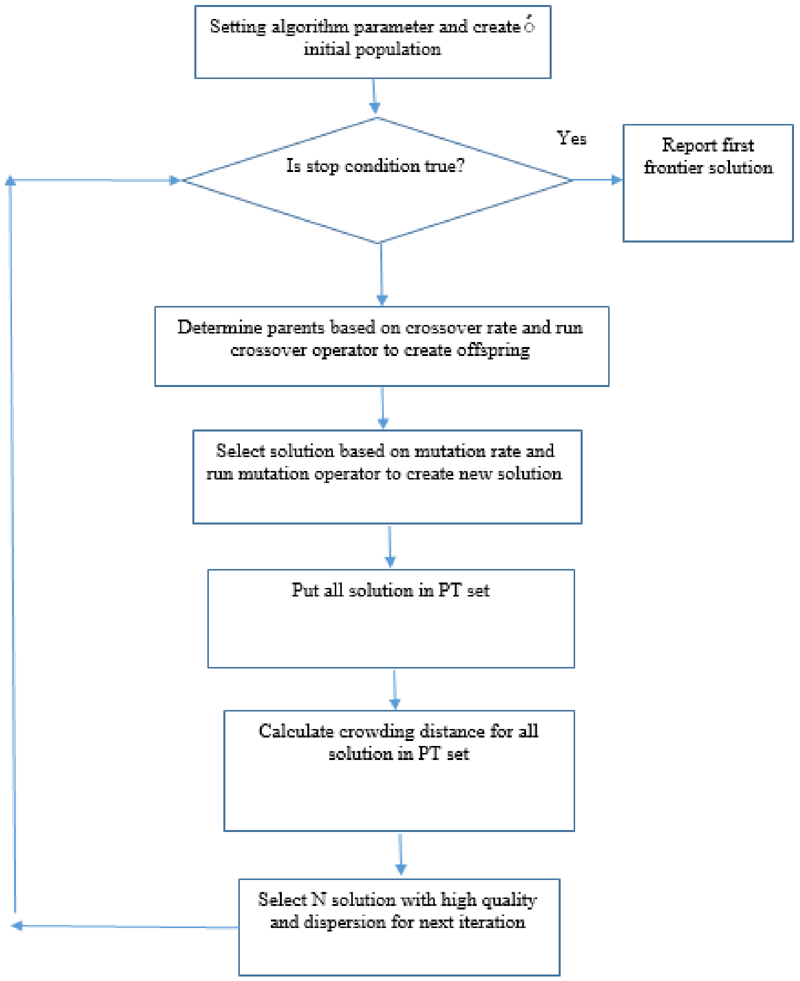


Figure 3. NSGA-II Flowchart

3.3. Notation

3.3.1. Sets

I	Number bank investment or asset
J	Number of branches
T	Planning horizon
S	Number of scenario

3.3.2. Indices

i	Index for bank investment or asset	(i=1,2,…I)
j	Index for branches	(j=1,2,…,J)
t	Index for planning horizon	(t=1,2,…,T)
sen	Index for scenario	(sen=1,2,…,S)

3.3.3. Parameters

$prob_{sen}$	Scenario probability *sen*
r_{it}^{sen}	Investment return *i* in period *t* under scenario *sen*
$\tilde{c}_{buy}$	Fuzzy assets purchasing cost at the beginning of the period
$\tilde{c}_{sell}$	Fuzzy assets selling cost at the beginning of the period

r_l	Lending rate
r_b	Borrowing rate
W_{j0}	Initial investment of branch j at the beginning of the period
α	Confidence level
$B0_i$	Maximum attractive amount of i^{th} investment
B_i	Attractive coefficient of i^{th} investment
d	Maximum Euclidean distance
γ	Absorption coefficient
α_i	Number of job opportunities created by i^{th} investment in production center
sp_i	Average waste created by i^{th} investment in production center
dp_i	Average hazardous materials created by i^{th} investment in production center
θ_w	Weight of waste created in objective function
θ_h	Weight of hazardous material in objective function
θ_l	Weight of workforce damage in objective function

3.3.4. Decision Variables

x_{ijt}^{sen}	Asset *i* monetary amount in branch *j* at the beginning of period *t* under scenario *sen*
v_{ijt}^{sen}	Asset *i* purchasing amount in branch *j* at the beginning of period *t* under scenario *sen*
u_{ijt}^{sen}	Asset *i* selling amount in branch *j* at the beginning of period *t* under scenario *sen*
b_{jt}^{sen}	The amount of money borrowed from the central bank in branch *j* at the beginning of period *t* under scenario *sen*
w_{jt}^{sen}	Capital of branch *j* at the beginning of period *t* under scenario *sen*
$Weight_t$	Desirable weight for period *t*

3.3.5. Fuzzy mixed-integer programming model

The three-objective proposed model is developed based on sustainability including economic, environmental and social aspects.

$$\max z1 = \sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{i=1}^{N} B_i \sum_{sen=1}^{S} \alpha_i x_{ijt}^{sen} \tag{10}$$

Eq. 10 shows that the first objective function considered maximizing job opportunities created through investment in production center by bank branches

$$\min z2 = \sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{i=1}^{N}(1-B_i) \sum_{sen=1}^{S} (\theta_w sp_i + \theta_h dp_i + \theta_l) x_{ijt}^{sen} \tag{11}$$

The second objective function is minimizing environmental negative effect through investment in production center by bank branches shown in Eq. 11.

$$\max z3 = \sum_{sen=1}^{S}\sum_{j=1}^{J} prob_{sen} w_{jT}^{sen} \tag{12}$$

Eq. 12 shows the third objective function contains maximizing bank branches capital.

$$\sum_{i=1}^{N}[(1+\tilde{c}_{buy})v_{ij0}^{sen}+x_{ji0}^{sen}]=w_{j0}+b_{j0}^{sen}\ \ \forall i=1,2,\dots,N, j=1,2,\dots,J, sen=1,2,\dots,S \qquad (13)$$

Eq. 13 indicates that total initial investment of bank is equal to initial capital or budget.

$$x_{ijt}^{sen}=\left(1+r_{i,t-1}^{sen}\right)\left(x_{i,j,t-1}^{sen}-u_{i,j,t-1}^{sen}+v_{i,j,t-1}^{sen}\right)\ \forall i=1,2,\dots,N, j=1,2,\dots,J, sen=1,2,\dots,S \qquad (14)$$

$$x_{ij,1}^{sen}=(1+r_l)\left(x_{ij,0}^{sen}\right)-b_{j1}^{sen}\ \forall i=1,2,\dots,N, j=1,2,\dots,J, sen=1,2,\dots,S \qquad (15)$$

$$x_{ij,t}^{sen}=(1+r_l)\left(x_{ij,t-1}^{sen}+\sum_{i=1}^{N}(1+\tilde{c}_{sell})u_{ij,t-1}^{sen}-\sum_{i=1}^{N}(1+\tilde{c}_{buy})v_{ij,t-1}^{sen}\right)-b_{j,t-1}^{sen}\times(1+r_b)+b_{jt}^{sen}\ \ \forall sen, t=2,3,\dots,T-1, \forall i=1,2,\dots,N, j=1,2,\dots,J, sen=1,2,\dots,S \qquad (16)$$

$$x_{ij,T}^{sen}=(1+r_l)\left(x_{ij,T-1}^{sen}+\sum_{i=1}^{N}(1+\tilde{c}_{sell})u_{ij,T-1}^{sen}-\sum_{i=1}^{N}(1+\tilde{c}_{buy})v_{ij,T-1}^{sen}\right)-b_{jT-1}^{sen}\times(1+r_b), \forall i=1,2,\dots,N, j=1,2,\dots,J, sen=1,2,\dots,S \qquad (17)$$

Eq. 17 states the cash flow in period *t*.

$$\sum_{i=1}^{N}x_{ijt}^{sen}=w_{jt}^{sen}\ \forall j, sen, t=1,2,\dots,T-1, \forall j=1,2,\dots,J, sen=1,2,\dots,S \qquad (18)$$

Eq. 18 calculates the amount of capital saved at the end of period *t* under scenario *sen.*

$$weight_t=\begin{cases}\gamma(w_{jt-1}^{sen}-\tau)^{\varphi} & w_{jt-1}^{sen}\geq\tau\\ -\gamma\left(w_{jt-1}^{sen}-\tau\right)^{\varphi 1} & w_{jt-1}^{sen}\leq\tau\end{cases}\ \forall j=1,2,\dots,J, sen=1,2,\dots,S, t=2,\dots,T \qquad (19)$$

Finally, Eq. 19 calculates bank utility. $\varphi 1$, φ, γ, and τ are obtained from central bank. According to Eq. 19 weight of each period is calculated based on capital obtained from previous period.

$$x_{ijt}^{sen}, v_{ijt}^{sen}, u_{ijt}^{sen}, b_{jt}^{sen}, w_{jt}^{sen}\geq 0 ؛ \forall i=1,2,\dots,N, j=1,2,\dots,J, sen=1,2,\dots,S, t=1,2,3,\dots,T \qquad (20)$$

$$0\leq weight_t\leq 1 \quad ؛ \quad \forall t=1,2,3,\dots,T \qquad (21)$$

Relation (20) and (21) represent the recreational models that can be evaluated in the range of values provided using the model

3.3.6. Model defuzzification

Some of parameters are considered as fuzzy number in the proposed model.

$$\begin{aligned}&\min z=\tilde{c}x\\&ax\leq\tilde{b}\\&x\geq 0\end{aligned} \qquad (22)$$

There are several methods to solve fuzzy mathematical programming problem. In this study, ranking approach proposed by Jimenez (2007) is used. Assume that $\tilde{A}=\{L,M,U\}$ is a triangular fuzzy number, thus its membership function is as follows:

$$\mu A(x)=\begin{bmatrix}f_A(x)=\frac{X-L}{M-L} & L\leq X\leq M\\ 1 & X=M\\ g_A(x)=\frac{X-L}{M-U} & M\leq X\leq U\end{bmatrix} \qquad (23)$$

As well, Figure 4 shows a triangular fuzzy number.

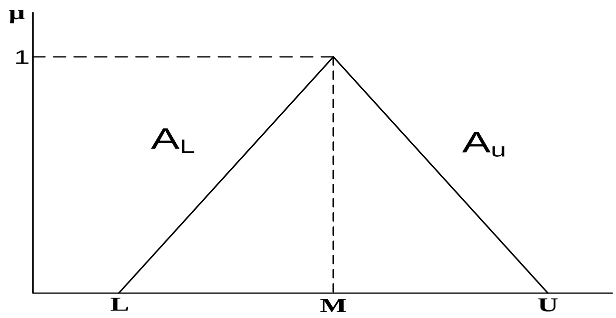


Figure 4. Triangular fuzzy number

It has been assumed that $f_A(x)$ is continuous and ascending and $g_A(x)$ is continuous and descending to ensure the existence of reverse functions $f_A^{-1}(x)$ and $g_A^{-1}(x)$. The expected interval of a fuzzy number is defined as follow:

$$EI(\tilde{A}) = [E_1^{\tilde{A}}, E_2^{\tilde{A}}] = \left[\int_{a1}^{a2} x df_A(x) - \int_{a3}^{a4} x dg_A(x)\right] \tag{24}$$

By aggregating the components as well as changing the variable, we will obtain:

$$EI(\tilde{A}) = [E_1^{\tilde{A}}, E_2^{\tilde{A}}] = \left[\int_0^1 f_A^{-1}(\alpha)d\alpha - \int_0^1 g_A^{-1}(\alpha)d\alpha\right] \tag{25}$$

If the functions $f_A(x)$ and $g_A(x)$ are linear and $\tilde{A}$ is a fuzzy triangular number, its expected interval will be as follow:

$$EI(\tilde{A}) = [\frac{1}{2}(L+M), \frac{1}{2}(M+U)] \tag{26}$$

Also, the expected value of fuzzy number A equals to half of the expected interval range and for fuzzy triangular number $\tilde{A}$ is as follow:

$$EV(A) = \frac{E_1^{\tilde{A}} + E_2^{\tilde{A}}}{2} \tag{27}$$

$$EV(A) = \frac{L + 2M + U}{2} \tag{28}$$

Definition1: for both fuzzy numbers A and B the membership degree A being bigger than B is in following form:

$$\mu_M(\tilde{A}, \tilde{B}) = \begin{cases} 0 & if E_2^a - E_1^b < 0 \\ \dfrac{E_2^A - E_1^B}{E_2^A - E_2^B - (E_1^A - E_2^B)} & if\, 0 \in [E_1^A - E_2^B, E_2^A - E_1^B] \\ 1 & if E_1^A - E_2^B > 0 \end{cases} \tag{29}$$

So that, $[E_1^A, E_2^A]$ and $[E_1^B, E_2^B]$ are the expected intervals of $\tilde{A}$ and $\tilde{B}$. When $\mu_M(\tilde{A}, \tilde{B}) = 0.5$, it can be stated that $\tilde{A}$ and $\tilde{B}$ are equal.

When $\mu_M(\tilde{A}, \tilde{B}) \geq \alpha$, it can be stated that $\tilde{A}$ is bigger equal to $\tilde{B}$ minimally with the degree α, which is displayed as $\tilde{A} \geq_\alpha \tilde{B}$

Definition 2: suppose the vector $x \in R^n$, it is acceptable with degree α if:

$\min\{\mu_M(\tilde{A}x, \tilde{B})\} = \alpha$ (which can be displayed as $\tilde{A}x \geq_\alpha \tilde{B}$). Equation (21) can be re-written as follow:

$$[(1-\alpha)E_2^A + \alpha E_1^A]x \geq \alpha E_2^B + (1-\alpha)E_1^B \tag{30}$$

According to the above mentioned definitions, the fuzzy model can be converted into its equivalent definite and accurate model, which has been shown in follow:

$$\begin{aligned} & Min EV(\widetilde{C})x \\ & s.t: \\ & x \in \{x \in R^n \mid \widetilde{A}x \geq_\alpha \widetilde{B}, x \geq 0\} \end{aligned} \tag{31}$$

Now, according to defuzzification procedure, certain form of fuzzy constraint is transformed as follows.

$$\sum_{i=1}^{N}[(1+\alpha)\frac{c_{buy}^1 + c_{buy}^2}{2} + (1-\alpha)\frac{c_{buy}^2 + c_{buy}^3}{2})v_{ij0}^{sen} + x_{ji0}^{sen}] = w_{j0} + b_{j0}^{sen}, \forall i = 1,2,\dots,N, j = 1,2,\dots,J, sen = 1,2,\dots,S \tag{32}$$

$$\begin{aligned} x_{ij,t}^{sen} = (1+r_l)\Bigg(x_{ij,t-1}^{sen} + \sum_{i=1}^{N}(1+\alpha)\frac{c_{sell}^1 + c_{sell}^2}{2} + (1-\alpha)\frac{c_{sell}^2 + c_{sell}^3}{2}))u_{ij,t-1}^{sen} \\ - \sum_{i=1}^{N}(1+\alpha)\frac{c_{buy}^1 + c_{buy}^2}{2} + (1-\alpha)\frac{c_{buy}^2 + c_{buy}^3}{2}))v_{ij,t-1}^{sen}\Bigg) \\ - b_{j,t-1}^{sen} \times (1+r_b) + b_{jt}^{sen}, t = 2,3,\dots,T-1 \forall i = 1,2,\dots,N, j \\ = 1,2,\dots,J, sen = 1,2,\dots,S \end{aligned} \tag{33}$$

$$\begin{aligned} x_{ij,T}^{sen} = (1+r_l)\Bigg(x_{ij,T-1}^{sen} + \sum_{i=1}^{N}(1+\alpha)\frac{c_{sell}^1 + c_{sell}^2}{2} + (1-\alpha)\frac{c_{sell}^2 + c_{sell}^3}{2}))u_{ij,T-1}^{sen} \\ - \sum_{i=1}^{N}(1+\alpha)\frac{c_{buy}^1 + c_{buy}^2}{2} + (1-\alpha)\frac{c_{buy}^2 + c_{buy}^3}{2}))v_{ij,T-1}^{sen}\Bigg) \\ - b_{jT-1}^{sen} \times (1+r_b), t = 2,3,\dots,T-1, \forall i = 1,2,\dots,N, j \\ = 1,2,\dots,J, sen = 1,2,\dots,S \end{aligned} \tag{34}$$

4. Computational Results

In this section, first of all, sample problems are designed based on Sepah Bank branches in Tehran, and then the algorithm and model parameters are set. Then, comparison indices and model solution results are presented for sample problems.

4.1. Sample problems

To solve the model, sample problems were designed based on Sepah Bank branches in Tehran, whose number is 219. Sample problems are presented in small, large, and medium sizes. It should be noted that the problems are a subset of 219 Sepah Bank branches in Tehran.

Table 2. Sample problems in different size

Sample size	Small			Medium			Large		
No. of sample	No. of branches	No. of assets	No. of period	No. of branches	No. of assets	No. of period	No. of branches	No. of assets	No. of period
1	10	4	6	20	4	6	50	10	6
2	10	6	6	20	6	6	70	10	6
3	10	8	6	20	8	6	100	10	6
4	10	10	6	20	10	6	120	10	6

5	10	12	6	20	12	6	140	10	6
6	15	4	6	30	4	6	160	10	6
7	15	6	6	30	6	6	180	10	6
8	15	8	6	30	8	6	190	10	6
9	15	10	6	30	10	6	200	10	6
10	15	12	6	30	12	6	219	10	6

4.2. The algorithm parameters setting

MINITAB software has been used to set some parameters of the proposed algorithms. Some of these parameters are population size, mutation rates, crossover rates, the number of iteration of the algorithm in the NSGA-II genetic algorithm and the parameters of population size (number of fireworks locations), the upper limit of explosion amplitude, and controlling the number of sparks (m) and the number of iteration of the algorithm.

To set the parameters of the algorithms, their values have been examined at the three levels shown in Tables (3) and (4).

Table 3. NSGA-II parameters

Population size	Crossover rate	Mutation rate	No. of iteration
70	0.75	0.006	150
150	0.85	0.009	300
200	0.95	0.01	500

Table 4. fireworks algorithm parameters

Population size	Explosion range upper bound	No. of sparks	No. of iteration
70	5	0.5	150
150	10	1	300
200	15	2	500

To do the analysis, GAP criterion (relative deviation percentage) has been used, which its calculation is shown as follows:

$$GAP = \left(\frac{alg_{sol} - best_{sol}}{best_{sol}}\right) \times 100 \quad (35)$$

alg_{sol}: The objective function value, obtained by combining the parameters.

$best_{sol}$: The best value of the objective function obtained by the algorithm execution.

In fact, the problem is executed for each of the combinations listed in the corresponding table, and the GAP criterion is calculated for each algorithm, and finally, is plotted in the corresponding diagram.

Table 5. NSGAII algorithm orthogonal

Sample No.	Population size	Crossover rate	Mutation rate	No. iteration	GAP value
1	70	0.75	0.006	150	0.5032
2	70	0.85	0.009	300	0.1259
3	70	0.95	0.01	500	0.7419
4	150	0.75	0.009	500	0.6635
5	150	0.85	0.01	150	0.4917
6	150	0.95	0.006	300	0.0045
7	200	0.75	0.01	300	0.7124
8	200	0.85	0.006	500	0.7280
9	200	0.95	0.009	300	0.2942

Table 6. NSGAII algorithm orthogonal

Sample No.	Population size	Explosion range upper bound	No. of sparks	No. iteration	value GAP
1	70	5	0.5	150	0.5032
2	70	10	1	300	0.1259
3	70	15	2	500	0.7419
4	150	5	0.5	500	0.6635
5	150	10	1	150	0.4917
6	150	15	2	300	0.0045
7	200	5	0.5	300	0.7124
8	200	10	1	500	0.7280
9	200	15	2	300	0.2942

The result obtained from MINITAB software is depicted as follows.

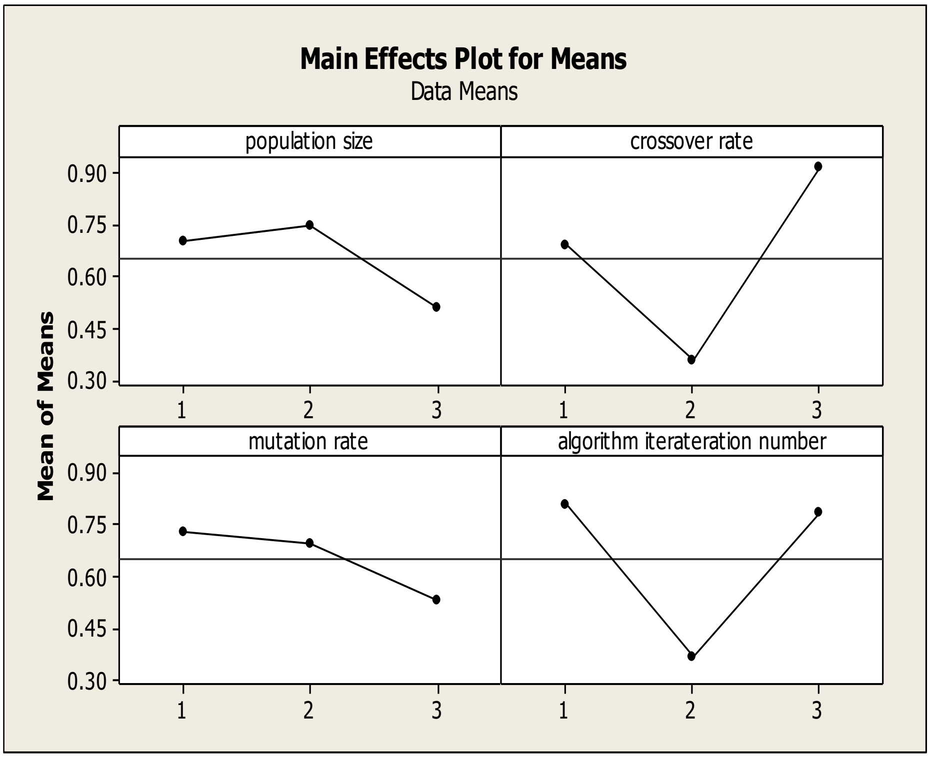


Fig. 5 The mean effect of NSGA-II

Figure 5 shows the analysis by Taguchi methods to set the parameters for the genetic algorithm, which can be observed in the figure 5, level 3 for the mutation rate, and level 2 for the crossover rate; level 3 and level 2, respectively are more effective for population size and iteration of algorithms. Therefore, the values of 200, 300, 0.01, and 0.85 have been defined respectively for population size, iteration of algorithms, mutation rate, and crossover rate.

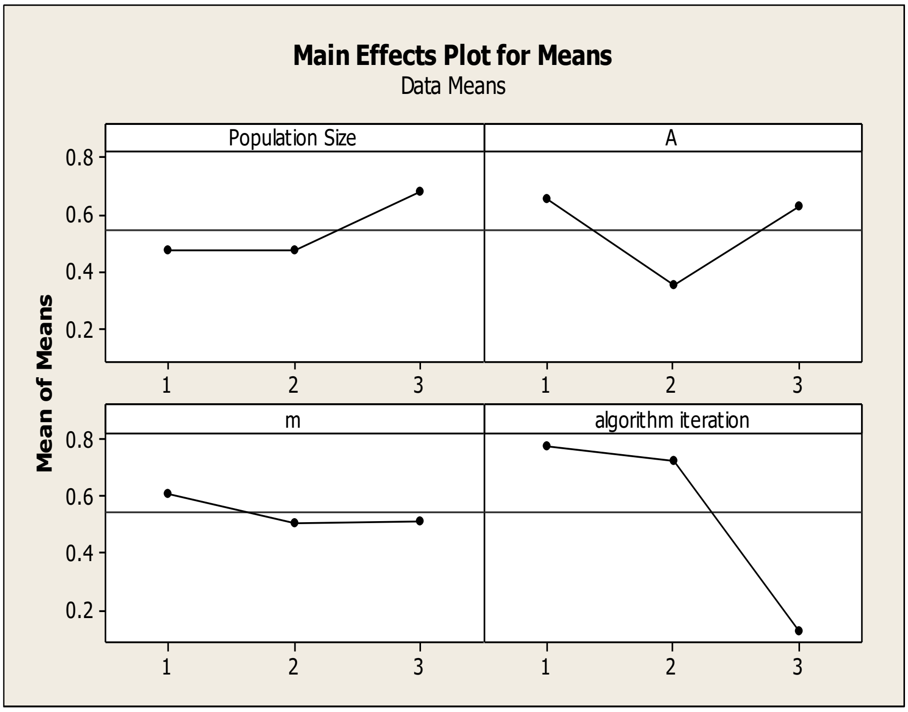


Fig. 6 The mean effect of fireworks algorithm

Figure 6 shows the analysis by Taguchi methods to set the parameters for the fireworks algorithm which can be observed in the chart (4-2), level 2 for the algorithm control parameters; level 2, and level 3, respectively are more effective for population size and iteration of algorithms. Therefore, the values 200, 500, 10 and 1 have been defined respectively for population size, iteration of algorithms, upper limit of explosion amplitude (A) and parameter controlling the number of sparks (m).

4.3. The model parameters setting

To solve the model, the parameters are set as follows: In the presented model, a number of model parameters are considered fuzzy. A triangular fuzzy number has been used to produce fuzzy values. To produce triangular numbers corresponding to each of the fuzzy parameters (m1, m2, m3), initially, m2 is generated, then the random number r is generated in the interval of (0.1), and m1 is generated using the relation $m2 * (1 - r)$ and m3 will be generated using the relation $m2 * (1 + r)$. To initialization, m2 fuzzy parameters, and the values of m1 and m3 are determined using the MATLAB. This is why we will only mention m2 in setting these parameters.

- data available in the database of Sepah Bank branches have been used for the parameters related to return on investment, lending and borrowing rates and transaction costs and the m2 fuzzy parameter has been determined according to these data.

- The amount of investment attraction is determined by experts.

- Expert opinion has also been used to calculate the parameters related to environmental and social effects.

- The number of courses is equal to 6 and the number of scenarios is equal to 5.

4.4. Comparative indicators

There are various indicators to evaluate the quality and dispersion of multi-objective meta-heuristic algorithm. In present study, three following indicators were used for comparisons (Tavakoli Moghaddam et al, 2011 and 2010).

Quality indicator: This indicator compares the quality of Pareto efficiency answers obtained by each method. In fact, the indicator level all Pareto efficiency answers obtained from both methods and determine what percentage of level one’s answers belong to each method. Whatever the percentage is higher, the algorithm has higher quality.

Spacing indicator: This criterion tests the uniformity of obtained Pareto efficiency answers’ distribution at the response boundary. The indicator is defined as follows:

$$s = \frac{\sum_{i=1}^{N-1} \left| d_{mean} - d_i \right|}{(N-1) \times d_{mean}}$$

Where, (d_i) indicates the Euclidean distance between two non-dominated adjacent answers and (d_{mean}) is the mean of d_i values.

Dispersion indicator: this indicator is used to determine the amount of non-dominated answers on the optimal boundary. The dispersion indicator is defined as follow:

$$D = \sqrt{\sum_{i=1}^{N} \max(\left\| x_t^i - y_t^i \right\|)}$$

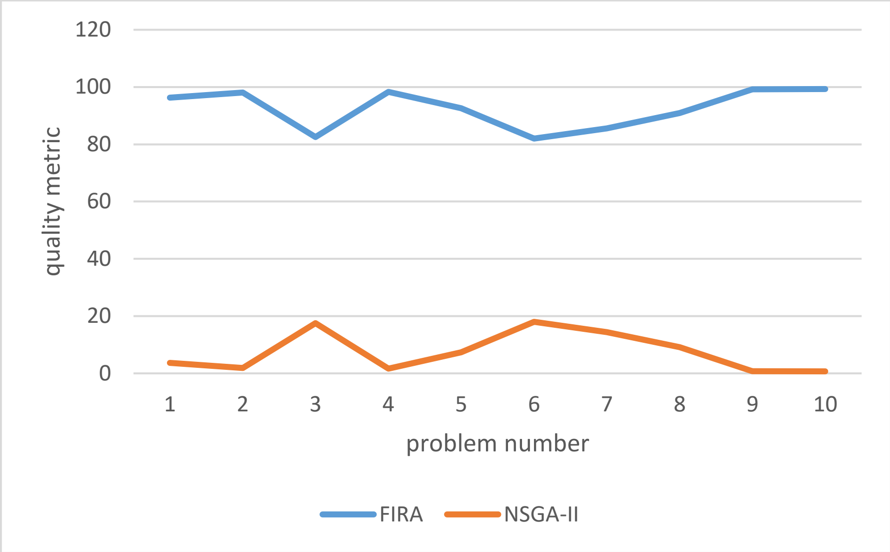
Where, ($\left\| x_t^i - y_t^i \right\|$) indicates the Euclidean distance between two adjacent answers of (x_t^i) and (y_t^i) on the optimal boundary.

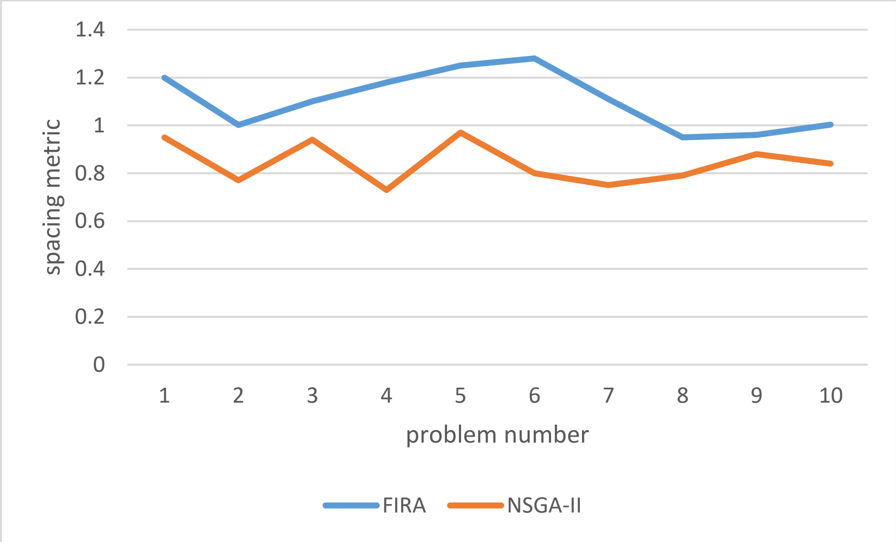
4.5. Solution results

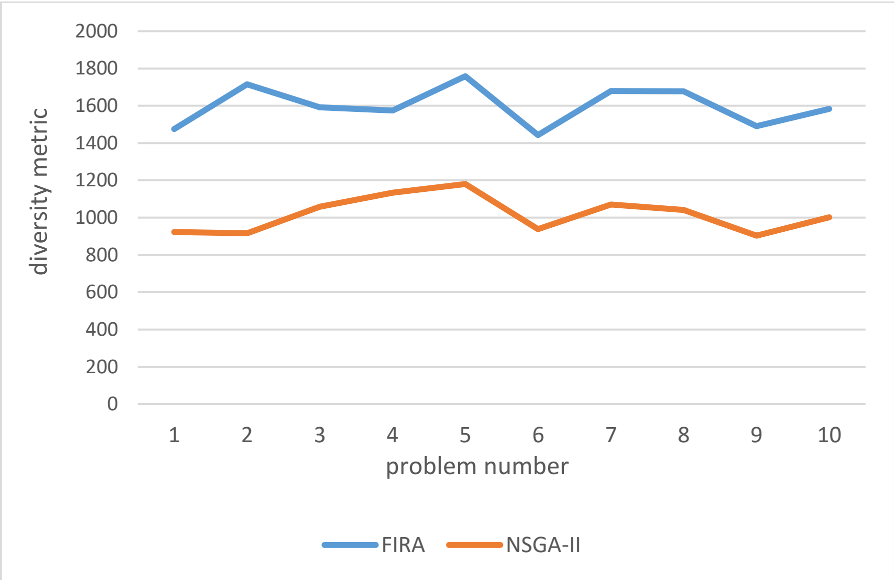
This section has analyzed the performance of the proposed fireworks algorithm, and the NSGA-II algorithm, to solve the problem of case study, and randomly designed problems. In this study, in order to more accurately compare the performance of multi-objective fireworks and NSGA-II algorithms, comparative results are shown to solve small, medium, and large size problems based on the presented indices in Tables 7 to 9.

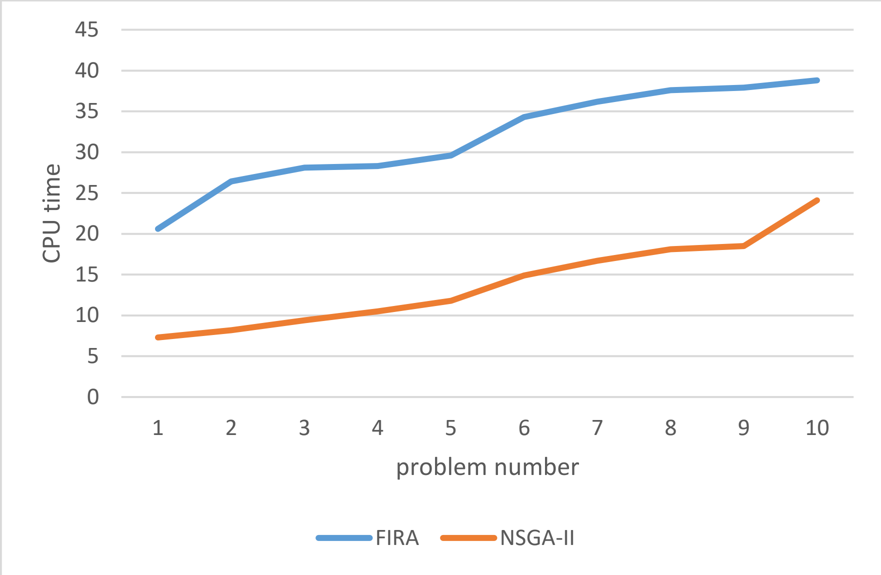
Table 7. Solution results of small size problem

Prob.	Fireworks algorithm					NSGA-II				
	Quality metric	Spacing metric	Diversity metric	cpu time	No. of Pareto solution	Quality metric	Spacing metric	Diversity metric	cpu time	No. of Pareto solution
1	96.3	1.2	1475.8	20.6	41	3.7	0.95	922.7	7.3	53
2	98.1	1.002	1715.4	26.4	98	1.9	0.77	916.1	8.2	22
3	82.5	1.10	1592.6	28.1	97	17.5	0.94	1059.2	9.4	62
4	98.3	1.18	1574.8	28.3	64	1.7	0.73	1133.7	10.5	67
5	92.6	1.25	1758.5	29.6	86	7.4	0.97	1180.2	11.8	54
6	82	1.28	1442.9	34.3	40	18	0.80	938.9	14.9	58
7	85.6	1.11	1678.6	36.2	60	14.4	0.75	1070.6	16.7	57
8	90.9	0.95	1676.8	37.6	94	9.1	0.79	1040.8	18.1	40
9	99.2	0.96	1490.2	37.9	85	0.8	0.88	903.5	18.5	53
10	99.3	1.003	1583.9	38.8	97	0.7	0.84	1001.1	24.1	29


120
100
80
60
40
20
0
quality metric
1 2 3 4 5 6 7 8 9 10
problem number
FIRA
NSGA-II


1.4
1.2
1
0.8
0.6
0.4
0.2
0
spacing metric
1 2 3 4 5 6 7 8 9 10
problem number
FIRA
NSGA-II


2000
1800
1600
1400
1200
1000
800
600
400
200
0
diversity metric
1 2 3 4 5 6 7 8 9 10
problem number
FIRA
NSGA-II



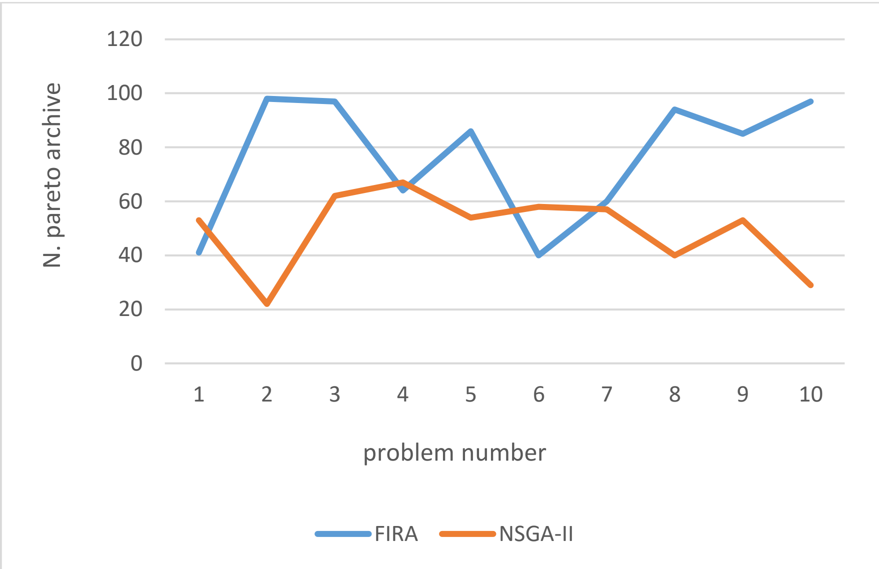
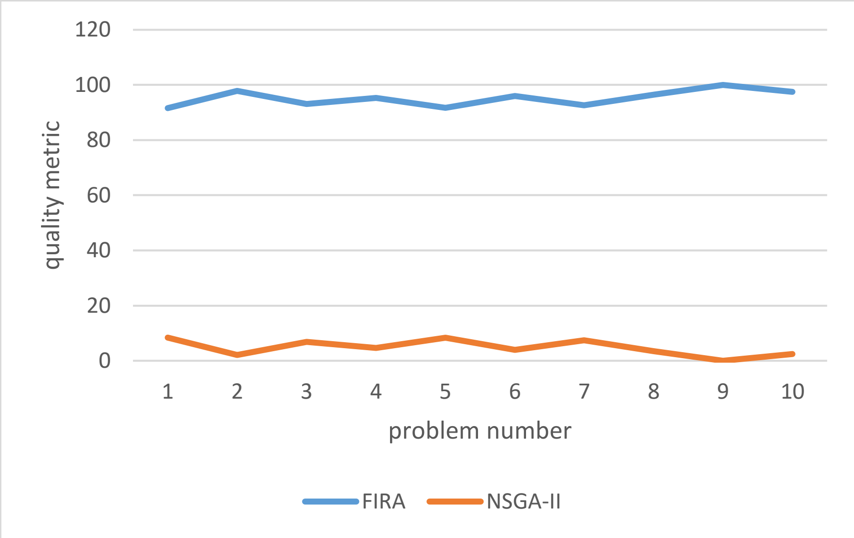


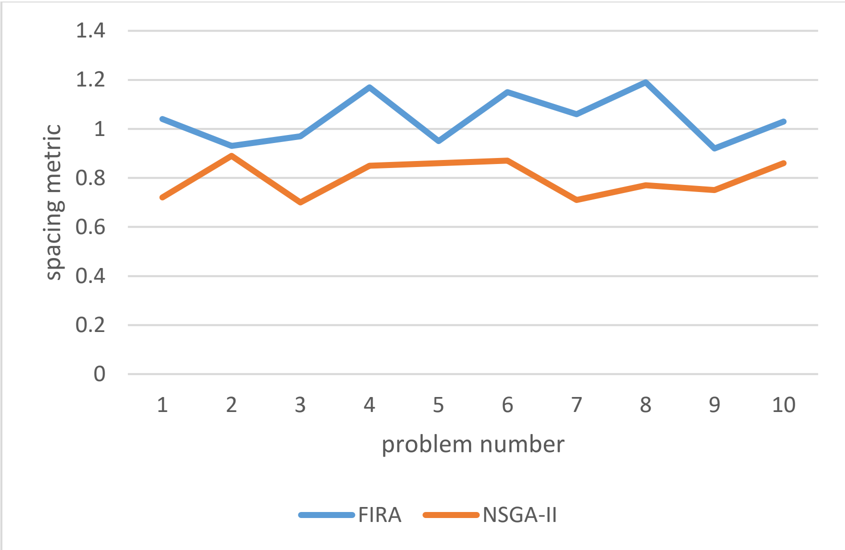
Figure 7. Wiktionary, Quality metric, Spacing metric, Diversity metric, cpu time, Number of pareto responses, for small size issues

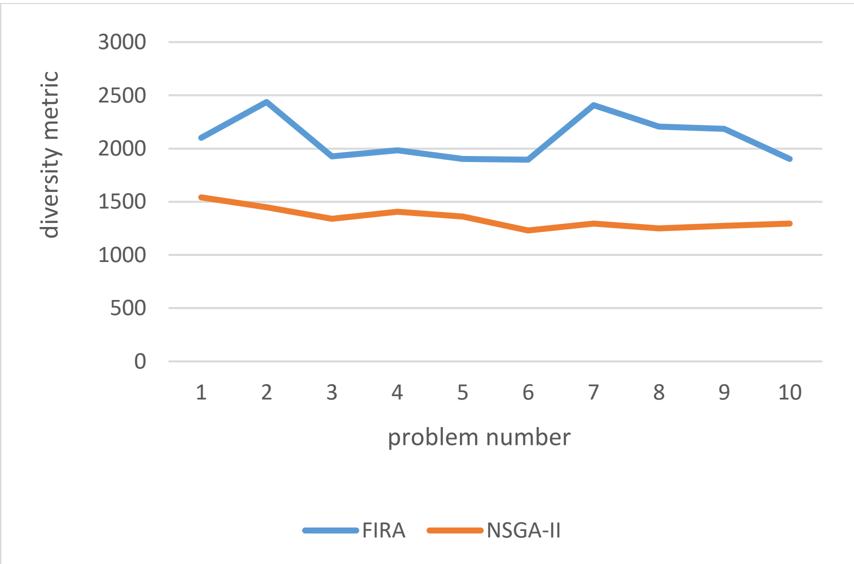
Table 8. Solution results of medium size problem

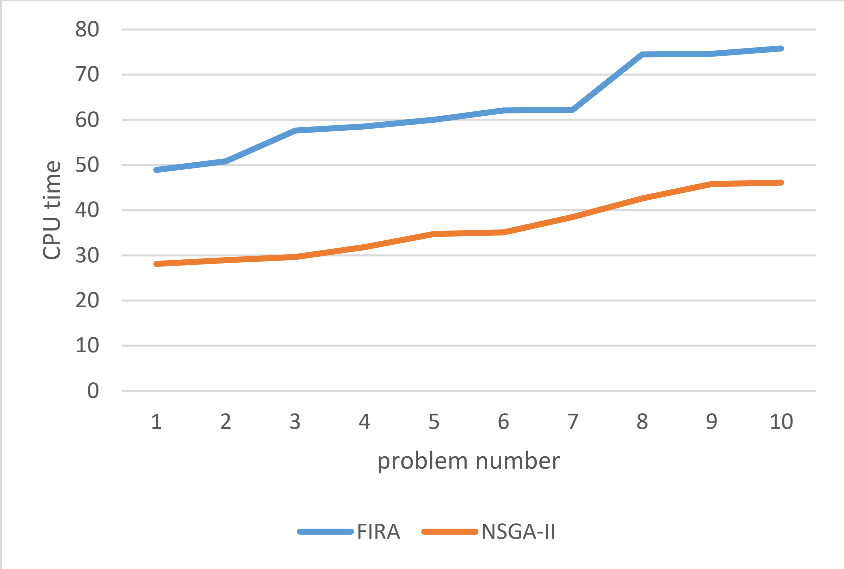
Prob.	Fireworks algorithm					NSGA-II				
	Quality metric	Spacing metric	Diversity metric	cpu time	No. of Pareto solution	Quality metric	Spacing metric	Diversity metric	cpu time	No. of Pareto solution
1	91.6	1.04	2101.9	48.9	96	8.4	0.72	1541.2	28.1	78
2	97.9	0.93	2437.4	50.8	105	2.1	0.89	1448.8	28.9	61
3	93.1	0.97	1927.2	57.6	137	6.9	0.70	1340.3	29.6	92
4	95.3	1.17	1984.6	58.5	81	4.7	0.85	1405.2	31.8	53
5	91.7	0.95	1901.8	60.01	83	8.3	0.86	1360.7	34.7	88
6	96.02	1.15	1895.2	62.1	92	3.98	0.87	1230.3	35.1	53
7	92.6	1.06	2408.5	62.2	125	7.4	0.71	1295.9	38.5	66
8	96.5	1.19	2205.7	74.5	131	3.5	0.77	1249.3	42.6	84
9	100	0.92	2184.9	74.6	125	0	0.75	1273.5	45.8	95

10	97.5	1.03	1901.4	75.8	112	2.5	0.86	1295.9	46.1	66









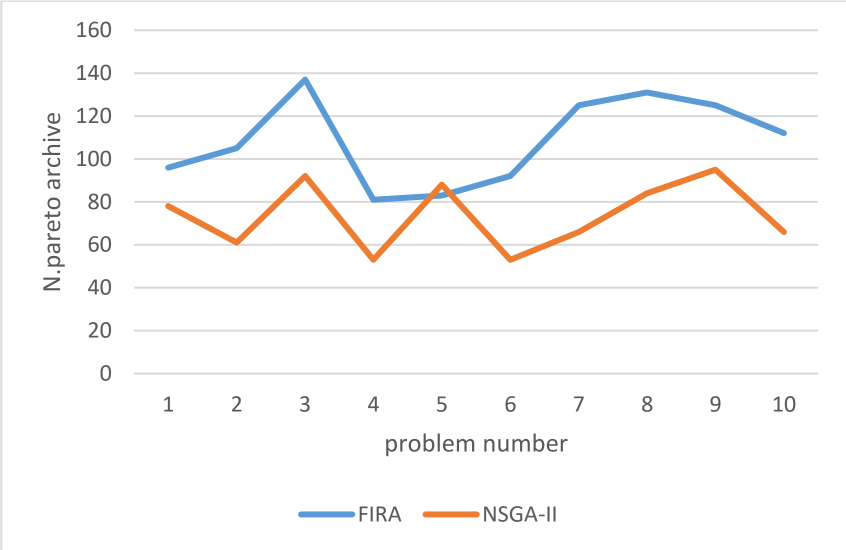
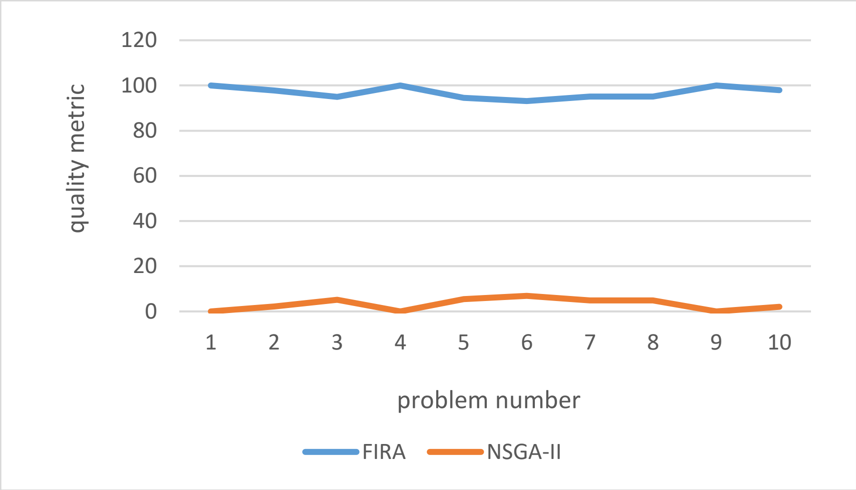


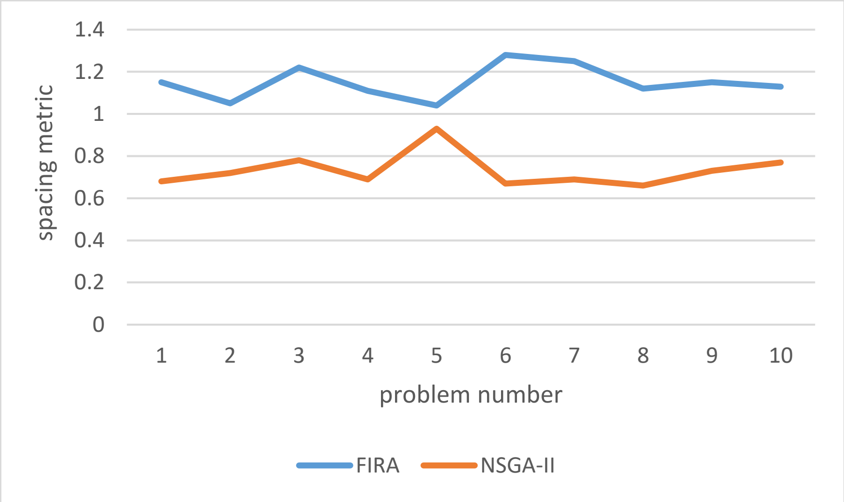
Figure 8. Wiktionary, Quality metric, Spacing metric, Diversity metric, cpu time, Number of pareto responses, for medium size issues

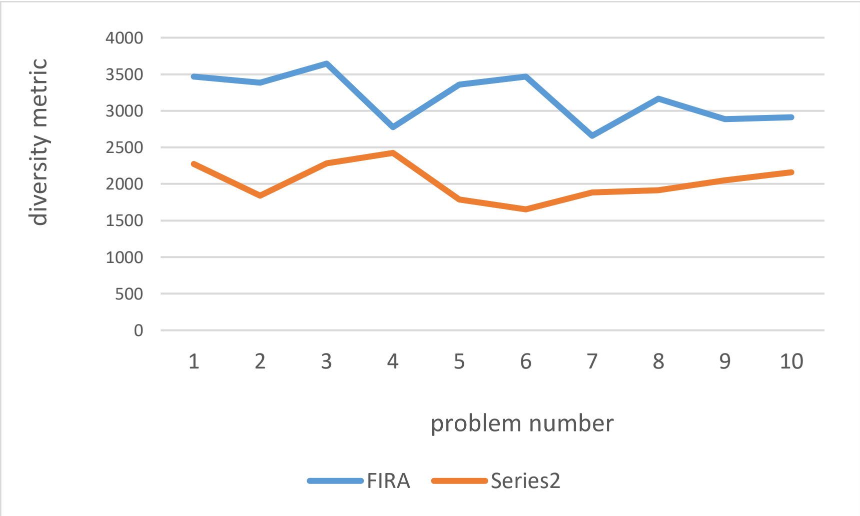
Table 9. Solution results of large size problem

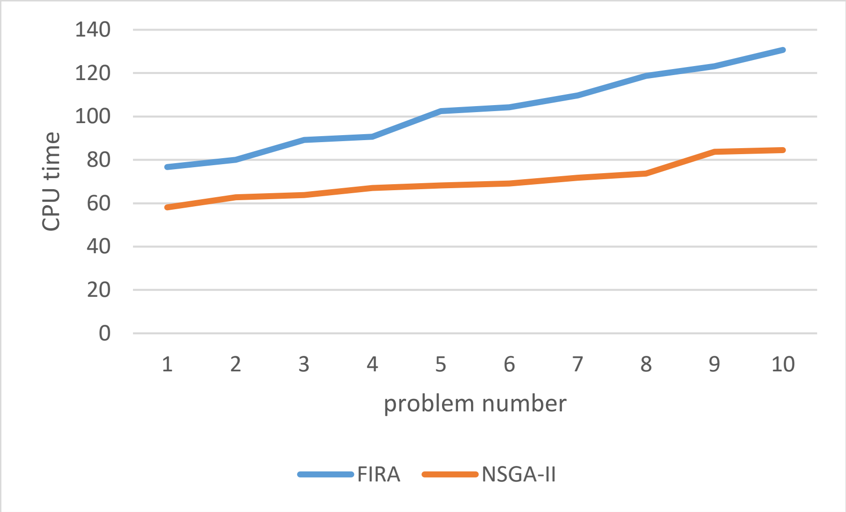
Prob.	Fireworks algorithm					NSGA-II				
	Quality metric	Spacing metric	Diversity metric	cpu time	No. of Pareto solution	Quality metric	Spacing metric	Diversity metric	cpu time	No. of Pareto solution
1	100	1.15	3466.6	76.7	83	0	0.68	2273.4	58.1	55
2	97.8	1.05	3385.1	80.1	160	2.2	0.72	1840.8	62.8	83
3	94.9	1.22	3645.3	89.2	162	5.1	0.78	2283.6	63.8	75
4	100	1.11	2277.2	90.7	152	0	0.69	2424.5	67.1	89
5	94.5	1.04	3357.3	102.5	89	5.5	0.93	1788.2	68.2	86
6	93.1	1.28	3469.6	104.3	104	6.9	0.67	1652.6	69.1	95
7	95.1	1.25	2658.3	109.7	110	4.9	0.69	1885.6	71.8	95
8	95.1	1.12	3166.6	118.8	141	4.9	0.66	1914.4	73.7	67

9	100	1.15	2887.1	123.1	92	0	0.73	2051.4	83.7	85
10	97.9	1.13	2913.1	130.7	145	2.1	0.77	2160.2	84.5	60









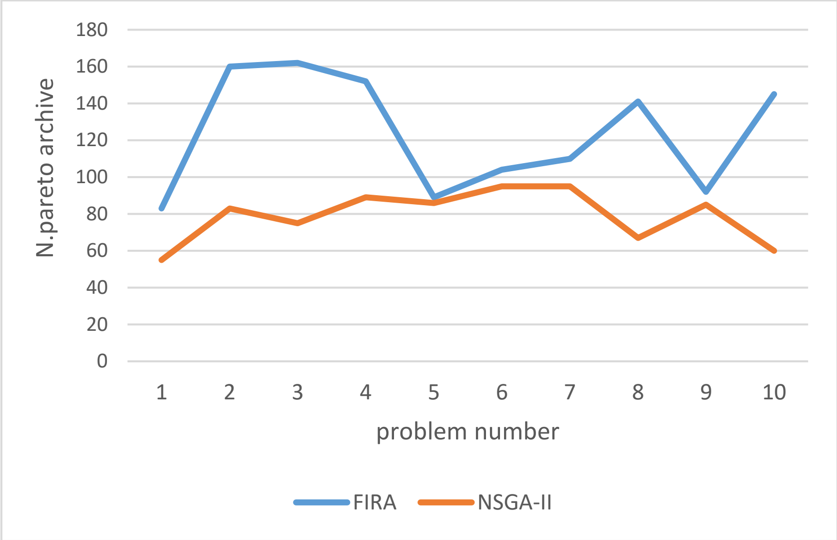


Figure 9. Wiktionary, Quality metric, Spacing metric, Diversity metric, cpu time, Number of pareto responses, for medium size issues

The comparative results of the above tables, and the related values to the comparative indices, indicate that the fireworks algorithm in all cases has a higher ability to produce higher quality answers than the NSGA-II algorithm. The fireworks algorithm is able to generate responses with a higher dispersion than the NSGA-II algorithm; In other words, the fireworks algorithm is more capable to explore and extract the feasible region than the NSGA-II algorithm. As the above tables show, the NSGA-II algorithm produces higher uniform responses than the fireworks algorithm.

The above tables also show the execution time of the algorithms, which implies that the values of the multi-objective fireworks algorithm have a higher solving time. Since, considering the designed structure of the proposed method, this method intelligently searches many points in the answer space in each iteration; it is obvious that it uses more computational time than the NSGA-II method. In the continuation of this section, the values of the variables for the problem with 50 branches are presented for the 6th period in Tables 10 and 11.

Table 10. The amount of purchase, services and sales based on each scenario

Amount of variables	Purchase					Services and sales				
Branch / Scenario	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
Independent Central Tehran	23	78	42	93	63	2	21	19	6	0
Independent Tehran Bazaar	95	25	88	75	22	11	21	25	23	21
Khayyam	53	91	65	93	68	16	2	11	2	16
Farabi	34	23	19	33	66	25	15	19	22	6
Enghelab	4	90	94	24	58	3	7	15	4	4
North Saadi	64	97	24	89	44	23	18	24	1	1

University of Tehran	59	13	32	22	48	15	10	17	11	9
Bu Ali	1	34	89	19	80	4	19	12	6	12
Tehran Meydan-e Shohada	26	77	11	56	60	10	11	20	23	14
South Rudaki	63	28	35	92	22	10	7	16	4	22
Tehran Sarcheshmeh	32	16	9	20	49	10	2	16	9	15
30 Tir St., Tehran	65	97	85	12	82	1	5	17	18	24
Jomhouri, Tehran	63	76	91	43	39	8	14	13	21	11
East Taleghani	31	81	56	67	14	3	1	3	11	8
Shoosh Bazar, Tehran	6	48	9	95	57	3	19	25	19	23
Meydan-e Jahad ,Tehran	86	9	45	62	97	24	15	24	16	19
Yousef Abad	53	17	78	81	71	25	22	23	17	23
Sartip Namjoo North	0	60	72	94	12	25	6	5	16	2
Dr. Shariati Tehran	57	28	41	73	37	9	7	0	18	7
Valiasr Squar	9	36	91	11	63	25	18	7	8	7
Piroozi ,Tehran	67	46	93	71	72	9	20	7	22	18
Tehran Red Crescent	11	32	40	31	5	8	12	10	13	20
DavoodiyehTehran	6	74	15	52	6	16	14	7	17	8
Shemiran	59	7	35	68	16	6	9	11	23	20
Abbasabad Bazaar, Tehran	84	83	58	48	31	3	12	11	22	20
North Felestin	77	73	85	30	69	3	24	16	1	11
North Sohrevardi	66	54	87	78	2	23	11	8	21	24
Jalaliyeh	28	26	51	32	65	10	6	22	12	19
Majidiyeh	45	25	25	62	55	19	21	11	10	18
South Saadi	84	77	17	15	16	24	11	17	3	20
Nazi Abad	63	22	35	43	16	16	13	0	6	8
Ebn-e-Sina	94	63	70	8	21	15	5	7	3	4
Tohid square	66	92	32	1	93	5	22	14	3	24
Haft Tir	61	54	25	29	89	3	16	4	16	22
Sharif Tehran	20	49	59	26	86	17	20	8	10	12
Mahmoudiyeh Station	8	30	24	33	45	13	5	8	11	2
Qolhak	98	1	32	94	9	8	9	19	25	8
Mellat	13	92	29	10	83	24	7	20	15	5
Moniriyeh Square	6	61	28	8	29	21	1	12	0	5
Bahar Street	10	21	9	88	78	3	24	6	16	18
Palizban	49	9	18	19	16	20	11	23	8	9
West Taleghani	9	33	51	74	58	9	11	4	10	17
East 15 Khordad	32	8	49	39	70	23	24	11	1	25
Azeri Junc	42	85	88	62	70	16	2	1	10	15
Holy Shrine Defenders	76	46	43	47	80	3	7	23	9	6
Karim Khan Zand	31	30	56	90	61	1	12	9	17	2
Zahir-ol-Eslam	89	57	51	35	12	18	22	4	5	1
Sattar Khan Street	2	23	65	65	12	24	23	6	7	7
Mohammadiyeh Square	83	42	27	25	67	2	9	12	22	23
Nizamabad Tehran	86	50	2	47	95	2	3	14	5	9

Table 11. The branch wealth and amount of borrowed money based on each scenario

Amount of variables	Purchase					Services and sales				
Branch / Scenario	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
Independent Central Tehran	1521	1704	1676	1863	1953	2769	2861	2961	3132	3309

Independent Tehran Bazaar	2021	1802	1703	2161	1975	2968	3144	2894	3093	2927
Khayyam	1850	1511	1932	1946	1945	3013	2705	3296	3276	3218
Farabi	1836	2189	1686	2170	2162	3001	3166	2876	3537	3430
Enghelab	2133	1617	2077	1668	1646	3464	2617	2985	3060	2827
North Saadi	1927	1574	2188	1973	1996	3069	2677	3148	3302	2988
University of Tehran	1932	1761	2011	1702	1665	3029	3035	3342	2995	2864
Bu Ali	2102	1639	1741	1970	1584	3338	2952	2883	3127	2634
Tehran Meydan-e Shohada	2064	1843	1909	1987	1925	3335	3138	3231	2976	2892
South Rudaki	1904	1738	1575	1548	1815	3064	2797	2580	2647	2821
Tehran Sarcheshmeh	1628	2166	2134	1678	1821	2702	3333	3310	2645	3168
30 Tir St., Tehran	1668	2144	2116	1657	1963	2643	3089	3331	2572	2899
Jomhouri, Tehran	2121	1537	2072	1967	2039	3314	2493	2988	3337	3060
East Taleghani	1520	2017	1683	2091	1745	2551	2985	2890	3142	2672
Shoosh Bazar, Tehran	1843	1688	1916	1741	1963	2765	2927	2997	2789	3084
Meydan-e Jahad ,Tehran	1618	1796	1516	2046	1791	2895	2944	2441	3112	2698
Yousef Abad	2185	1884	1798	1973	2089	3206	2879	2943	3107	3438
Sartip Namjoo North	1999	2160	1719	1505	2083	3120	3308	2715	2729	3081
Dr. Shariati Tehran	1850	1792	1613	1922	1680	3094	2766	2575	2835	2627
Valiasr Squar	1830	2188	1625	1771	1929	2910	3115	2628	3092	2983
Piroozi ,Tehran	1542	1711	1796	2141	1908	2810	3036	2769	3321	3036
Tehran Red Crescent	1977	1991	1566	1501	1879	3074	3171	2561	2828	2830
DavoodiyehTehran	1530	1966	1919	1824	2109	2772	3331	2840	2898	3507
Shemiran	1550	1877	1830	1797	1685	2802	3125	3048	2920	2751
Abbasabad Bazaar, Tehran	1865	1989	1987	1823	1723	2986	3180	3028	2750	2772
North Felestin	1568	1967	1990	2039	1583	2478	3275	3159	3028	2514
North Sohrevardi	2073	1625	1947	1726	2158	3138	2965	3195	2957	3207
Jalaliyeh	2072	1590	1524	2049	1952	3184	2984	2674	3114	2875
Majidiyeh	2006	2199	1548	1830	1836	3041	3099	2716	3179	2989
South Saadi	1605	1620	1724	1525	1948	2604	2953	2847	2484	3229
Nazi Abad	1962	1523	1872	1623	1881	3273	2729	2834	3017	3097
Ebn-e-Sina	1863	1893	1958	2005	1953	2978	3288	3103	3175	2898
Tohid square	2181	2117	1785	1831	1881	3525	3281	3111	3084	2821
Haft Tir	1954	1968	2074	1607	2005	3050	3108	3411	3007	3294
Sharif Tehran	2060	1633	2003	1739	1866	3345	2934	3038	2783	3219
Mahmoudiyeh Station	1818	1758	2178	1925	2196	2916	2772	3182	3032	3363
Qolhak	1803	1823	1872	1634	1653	3107	2972	3054	2766	2608
Mellat	2078	2187	1728	2017	1574	3356	3537	2948	3299	2887
Moniriyeh Square	1558	1609	1574	1670	1577	2647	2796	2683	2979	2646
Bahar Street	1593	2099	1928	2142	1545	2601	3422	2931	3092	2592
Palizban	1621	1951	2045	1688	1783	2916	3220	3419	2677	3056
West Taleghani	1774	1763	1796	2036	1814	3149	2956	2737	3116	2719
East 15 Khordad	2082	1634	1564	1632	1756	3146	2657	2517	2560	2680
Azeri Junc	2062	1800	1687	1701	2034	3298	3033	2658	2862	3268
Holy Shrine Defenders	1542	1837	1608	1564	1940	2661	2779	2591	2632	3142
Karim Khan Zand	1779	1584	1697	1903	2040	3096	2797	2907	2891	3203

Zahir-ol-Eslam	1869	1913	1808	1978	2153	3153	3143	2995	2982	3418
Sattar Khan Street	1792	1658	1869	1883	2181	2776	2923	2795	3236	3435
Mohammadiyeh Square	1960	1769	1820	1798	1634	3291	3114	3186	3036	2925
Nizamabad Tehran	1940	1908	2113	1951	1597	3335	3299	3377	3085	2641

4.6. Sensitivity analysis

This section examines the changes in objective functions for changes in "the maximum attraction of the ith investment, based on employment and environmental benefits."

Table 12. Changes in objective functions caused by changes in the number of job opportunities created in the production center set up by the investment

BO_i value	Z_1	Z_2	Z_3
0.01	4061.59	3449.54	92504.92
0.05	4104.81	3305.23	92317.77
0.08	4127.89	3290.48	92512.77
0.1	5337.58	3098.96	92569.96
0.2	5396.52	2934.34	92470.40
0.3	5556.67	2851.33	92564.50
0.4	5607.87	2672.89	92261.38
0.5	5692.53	2588.53	92561.46
0.6	5741.25	2398.35	92702.84
0.7	5780.18	2243.01	92640.64

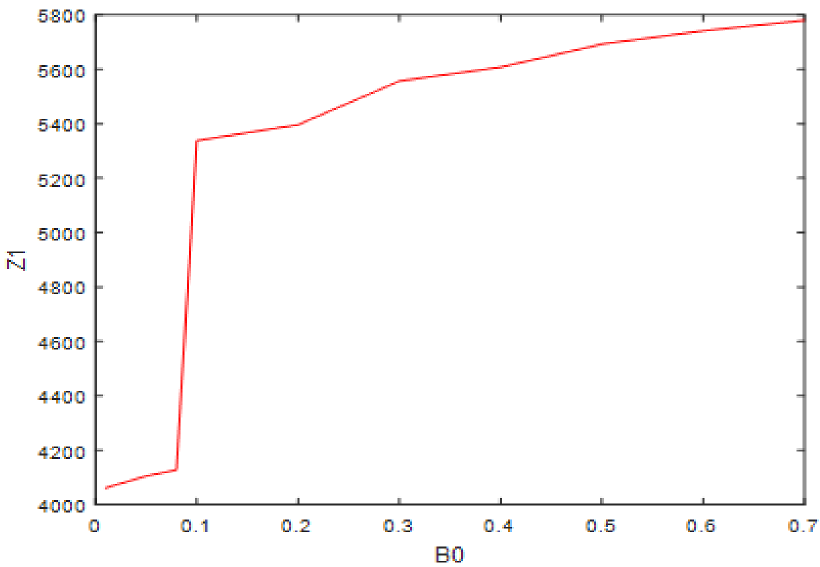


Figure 10. Changes in the amount of job creation, through investment in production centers, by bank branches

As can be seen in figure 7, increasing the amount of "maximum attraction of the ith investment, based on employment and environmental benefits" increases the function of the first objective function or "the amount of job creation through investment in production centers, by bank branches.

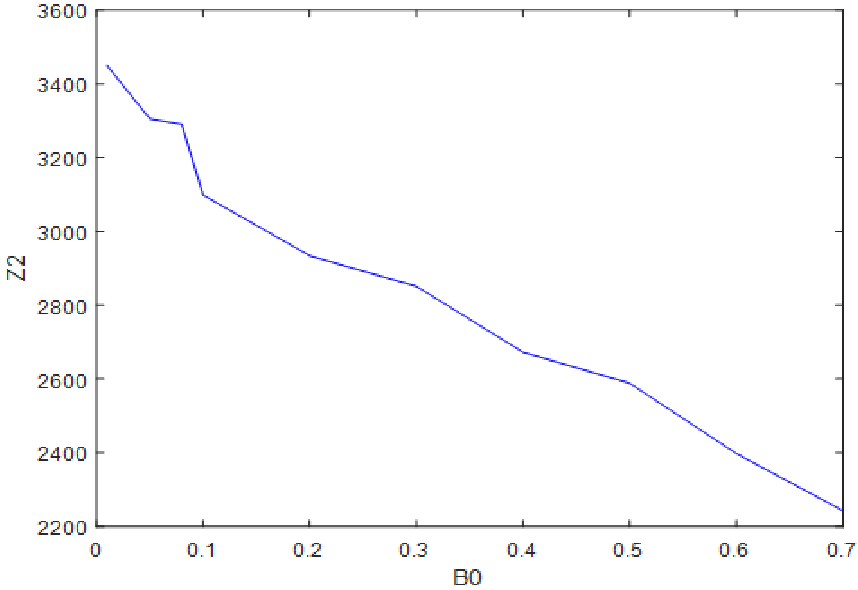


Figure 11. Changes in the negative environmental impacts caused by investment in production centers by bank branches

As shown in figure8, increasing the amount of "maximum attraction of the ith investment, based on employment and environmental benefits" reduces the function of the second objective or " negative environmental impacts caused by investment in production centers by bank branches.

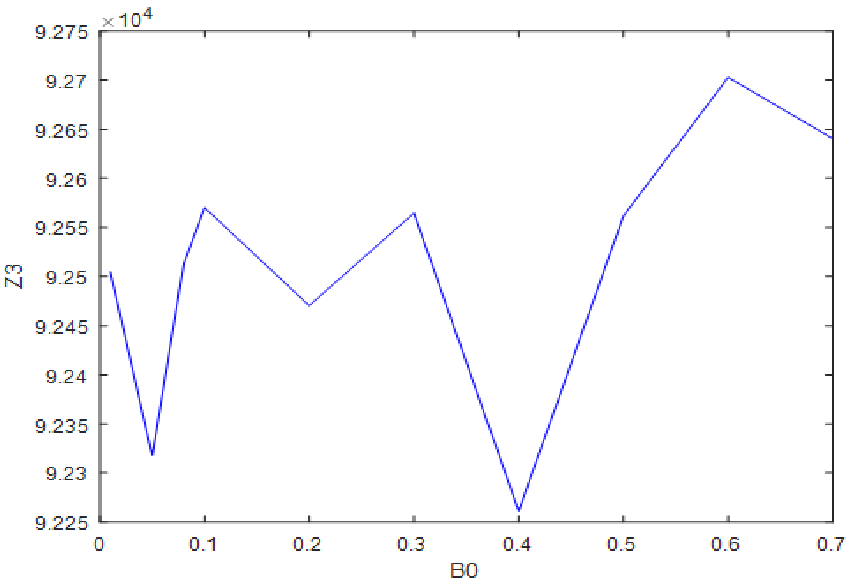


Figure 12. Changes in the ultimate wealth of bank branches

As can be seen in figure 9, changes in the bank's ultimate wealth caused by changes in the " maximum attraction of the i^{th} investment, based on employment and environmental benefits", do not behave regularly, and sometimes increase and sometimes decrease.

5. Conclusions and future directions

As mentioned above, this study aims to "provide integrated multi-objective planning of Bank Sepah green supply chain, in uncertainty and model solution, using meta-heuristic algorithm (fireworks algorithm based on the Pareto archive and NSGA-II genetics)" that to achieve this, a three-goals fuzzy mathematical model was first designed based on the scenario. In the present dissertation, Sepah Bank's green supply chain has been reviewed and modeled, which includes three levels of the Central Bank, Sepah Bank branches, and investment centers. It is assumed that each branch can operate in N assets or investments, each of which includes production centers. How branches operate is in the form of stocks purchase from production centers, or lending to those centers. Each investment has an attractiveness score, which is based on employment, and positive social and environmental activities. In this study, a three-objective mathematical model was presented for the green banking supply chain, and this model was solved using two meta-heuristic algorithms of fireworks and NSGA-II. The results of the present study are as follows:

- Fireworks algorithm in all cases has a higher ability to produce higher quality answers than the NSGA-II algorithm.
- The fireworks algorithm is able to generate responses with a higher dispersion than the NSGA-II algorithm; In other words, the fireworks algorithm is more capable to explore and extract the feasible region than the NSGA-II algorithm.
- The NSGA-II algorithm produces higher uniform responses than the fireworks algorithm
- The execution time of the algorithms, which implies that the values of the multi-objective fireworks algorithm have a higher solving time. Since, considering the designed structure of the proposed method, this method intelligently searches many points in the answer space in each iteration, it is obvious that it uses more computational time than the NSGA-II method.
- Increasing the amount of "maximum attraction of the i^{th} investment, based on employment and environmental benefits" increases "the amount of job creation through investment in production centers, by bank branches
- Increasing the amount of "maximum attraction of the ith investment, based on employment and environmental benefits" reduces " negative environmental impacts caused by investment in production centers by bank branches.
- Changes in the bank's ultimate wealth caused by changes in the " maximum attraction of the ith investment, based on employment and environmental benefits", do not behave regularly, and sometimes increase and sometimes decrease

Recommendations for future researches are:

- Using other algorithms such as Whale, SPEA-II, DE, COA, etc. to optimization and increasing the time period.
- Considering other risks of the green supply chain, disruptions of the green supply chain, and adding them to the mathematical model at the same time.
- providing the operational planning solutions in the green supply chain, and developing it by domestic incomes and foreign investment.
- Conducting the same research on other active public and private banks in Iran, and comparing the results with the results of this study and considering the social dimensions and job creation in the integrated model.
- It is recommended that bank branches pay attention to the criteria and all aspects of sustainability for investment and purchase.
- It is recommended that bank branches take advantage of the experience and skill of experts and professionals, and invest considering scientific results.

The bank's managers and shareholders are suggested by studying and reviewing global successful green banks policies, improve their mission and strategic goals, as well as improve their strategic planning, and consider these banks as their models, and take the necessary steps for sustainable development and wealth.

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