Designing an Integrated Engineering Model of Optimal Multi-Objective Green Supply Chain Planning for Banks with a Fuzzy Model and Solving the Model using Meta-Heuristic Algorithms

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Abstract The present research and model is aimed at presenting an integrated multi-objective optimal supply chain model of Sepah Bank's green supply chain in terms of model uncertainty using meta-heuristic algorithms and providing a suitable conceptual framework. In this regard, a multi-objective optimization model is presented and solved using fireworks algorithms based on Pareto Archive and NSGA-II. The green banking phenomenon has emerged with the same purpose in the banking system of the world and today it has made significant progress in theoretical and operational aspects. The interesting thing is that Islamic banking is not indifferent to this issue and it has a special focus on green banking under ethical banking. Given the likelihood of larger environmental crises occurring in Iran, this responsibility for the Iranian banking system will be felt more tangibly. What is important is that the critical conditions of the future environmental trends in the country require that green banking be considered. In this paper, the Green Supply Chain of Sepah Bank is examined and modeled, which includes the three levels of Central Bank, Sepah Bank Branches and Investment Centers. The proposed model has three goals based on sustainability (economic, social and environmental). This model is solved using two fireworks algorithms and NSGA-II and the results of the two algorithms are compared based on quality, uniformity and diversity indices. Modeling results showed that the fireworks algorithm was more capable of exploring and extracting the solvable area than the NSGA-II algorithm. The NSGA-II algorithm also produces higher uniformity responses than the fireworks algorithm in less time.

Keywords: *Green banking; Supply chain; Fireworks algorithm; Genetics algorithm*

1. Introduction

Model development is a technique or procedure that will be Nowadays, very fast changes in the market are not covered. Technology is advancing rapidly and new products and services are coming into the market every day, changing consumer tastes and competitors behavior is unpredictable. In such an environment, delivering the right goods and services at the right price and at the right time to the consumer is not only the most important factor for competitive success, but also a key factor in the survival of businesses. Also, in spite of all the environmental efforts that have been made so far, human activities still disturb the balance of nature. Developing human knowledge and ability to increase the utilization of the environment and its resources, and other concerns about the end of natural resources and disrupting the balance of vital processes on Earth, have made researchers more aware of the environment and its affecting factors than ever before. The development of human knowledge and ability to increase the utilization of the environment and its resources, and in other words the concern about the end of natural resources and the disruption of the equilibrium of the vital processes of the Earth, has made researchers more interested in the environment. Banks play an important role in economic growth and development, protecting basic resources and reducing environmental damages, as well as paying attention to public welfare. This important role is to create a green supply chain in banks and develop and implement its concepts. [1].

Recently, supply chain management has focused on the role of the supply chain in influencing the natural environment. The supply chain is an integrated manufacturing process in which raw materials are transformed into finished products and then delivered to the final consumer. A growing number of supply chains are investing in recycling systems to recover waste or products used by customers. Green Supply Chain Management (GSCM), also known as Environmental Supply Chain Management (ESCM), or Sustainable Supply Chain Management (SSCM). Green supply chain organizations, with a view to sustainable development, have the ability to view the world in a realistic and purposeful way and take steps to improve the global environment [2]. Strict environmental laws, an urgent need for sustainability and market pressures force companies to ensure the sustainability of their operations [3]. Green banking integrates technology and changes in customary behavior in banking businesses, as well as changing traditional trends and creates a new framework based on a sustainable approach to evolution and development [4]. Green Banking emphasizes the health and safety of products and their

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compliance with environmental standards and promotes products that are beneficial to the environment and society in order to reduce costs. Green banking is changing the way people perceive the environment around them as their environmental knowledge increases.

In [5] presents a new model of location-routing-green inventory, under uncertainty. Simultaneously the number and location of distribution centers, the allocation of retailers to these centers and the active routes, and the order of their demand per route, the optimal amount of each order, the number of orders each distribution center and the level of reliability in each distribution center Determines simultaneously. In order to reduce the expected annual cost as well as the amount of emissions from the transport fleet during the delivery process throughout the network. Supply chain network design using an integrated neuro-fuzzy and MILP approach is presented in [6]. Duran studied the inventory location model and provided a Mixed Integer Linear Programming model. This model examines the effect of pre-location on the mean response time. In their model, the maximum number of warehouses and the inventory level constraint are assumed in a pre-location [7]. In [8], it deals with the integration of sustainability and supply chain management, taking into account current conditions and future opportunities. Research to date has focused more on supply chain management and sustainability individually. However, integrating these two concepts together has greatly impacted supply chain management decisions on the use of opportunities. A mathematical model for supply chain planning with dynamic conditions is presented in [9]. A multilevel and multi-period supply chain with dynamic scheduling has been investigated and a mathematical model has been proposed to minimize supply chain costs. Vafaeenezhad et al, have proposed a multi-objective mathematical modeling for sustainable supply chain management. They have modeled a multi-periodic and multi-commodity supply chain [10]. An integration perspective for the development of a green and sustainable closed-loop supply chain (CLSC) network under uncertain demand is presented in [11]. A two-objective optimization model with the objectives of minimizing CO2 emissions and total operating costs is presented.

Zhou et al, have evaluated the banking system using three-stage data envelopment analysis method in uncertainty. For a comprehensive review of bank structures and identifying the specific causes of any inefficiency, three stages of banking systems are examined: capital structure, capital allocation, and profitability [12]. Given the importance of the green supply chain in all industries as well as the importance of the banking industry, this paper presents a mathematical model for the green supply chain and optimal integrated chain planning in the banking industry. Since uncertainty dominates all industries in real-world problems, some model parameters are considered fuzzy in the present study. After designing the mathematical model, metabolic algorithms such as fireworks algorithm are used to solve the model. To evaluate the performance of the proposed algorithm, its results are compared with the results of the genetic algorithm.

2. Green supply chain

In recent years, environmental pollution has become a challenging issue for commercial organizations. Business operations such as manufacturing are recognized as key players in this field [13]. These operations have increased the pressure and concern of internal and external stakeholders of the organization such as governments, workers and non-profit groups [14]. Therefore, this has led to increased demand from consumers and environmental communities for environmentally friendly products. These challenges and pressures cause companies to take serious consideration of the environmental impact of the product and the creation of green products while doing business activities. The concept of 'green' is an embodiment of environmentally friendly products, processes, systems and technologies that affect business activities [15]. Overall, the role of organizations in society and their responsibility in minimizing their impact on the environment has become more important. Green supply chain management helps organizations achieve profit and market share by reducing risks and Environmental Impacts, while increasing their ecological efficiency. Generally, creating a green supply chain and paying attention to environmental issues reduces costs and improves environmental performance and increases the credibility of the company [16].

Green Supply Chain Management was introduced by the Michigan State University Industrial Research Association in 1996. This type of management is in fact a new model of environmental protection. Managing the green supply chain in terms of product lifecycle involves all the steps from raw materials, product design and manufacturing, product sales and shipping, product use and product recycling. Using supply chain management and green technology, organizations can reduce environmental impacts and achieve optimal energy use. Environmental impact assessment supply chain activities analyze the impacts of products on the environment using a holistic approach (including analyzing the product life span from its beginning to its end). In this approach, all the ecological effects of each activity in different stages of product life such as product concept, design, preparation of raw materials, manufacturing and production, assembly, maintenance, packaging, transportation and reuse of the product in product design are considered [17]. The purpose of the green supply chain is to eliminate or minimize adverse environmental effects (air, water and soil pollution) and waste of energy resources, materials, products) from the extraction or use of raw materials to the final use and consumption of products [18]. Also providing environmental satisfaction across the supply chain and accessing new markets through the delivery of environmentally friendly products, cost savings through resource savings, fuel costs, number of hours worked, waste elimination and improving productivity and gaining competitive advantage by creating value for customers and customer satisfaction and loyalty to products and ultimately increasing profitability are the benefits of the green supply chain. The number of components of the green supply chain process varies from source to source. This process can have six components as in Figure 1 [17]:

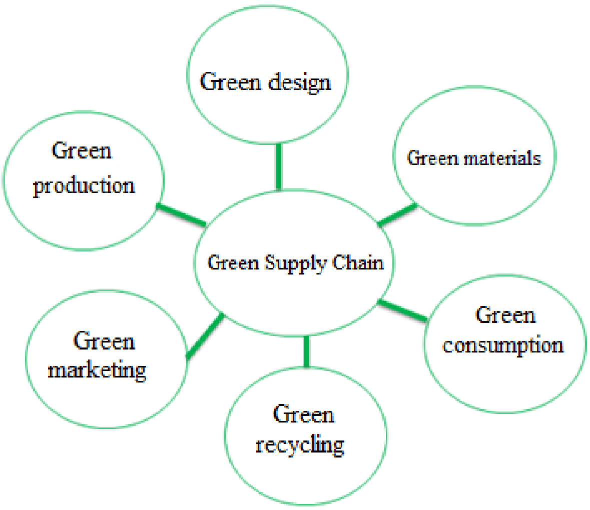

Figure 1: Overview of the green supply chain process

3. Methodology

3-1-Mathematical modeling

The issue under consideration in this article includes the three levels of central bank, bank branches and investment centers, in which the amount of investment of branches has been determined. To bring the problem closer to real-world problems, some of the model's parameters are considered fuzzy. The planning model has three goals, the goals of which are designed based on the dimensions of sustainability (economic, environmental and social).

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

Equation (1) represents the function of the first objective, which is: maximizing job creation through investment in production centers by bank branches.

$$\min z2 = \sum_{t=1}^{T}\sum_{j=1}^{J}\sum_{i=1}^{N}(1-B_i)\sum_{sen=1}^{S}(\theta_w sp_i + \theta_h dp_i + \theta_l)x_{ijt}^{sen} \quad (2)$$

Equation (2) represents the function of the second objective, which is: minimizing the negative environmental effects caused by investment in production centers by bank branches.

$$\max z3 = \sum_{sen=1}^{S}\sum_{j=1}^{J} prob_{sen} w_{jT}^{sen} \quad (3)$$

Equation (3) represents the function of the third goal, which is: maximizing the ultimate wealth of bank branches.

$$\sum_{i=1}^{N}[(1+\tilde{c}_{buy})v_{ij0}^{sen} + x_{ji0}^{sen}] = w_{j0} + b_{j0}^{sen} \;\; ; \forall i = 1,2,\dots,N, j = 1,2,\dots,J, sen = 1,2,\dots,S \quad (4)$$

Equation (4) is the budget constraint in zero time and states that the total initial investment of the bank should be equal to the initial budget or wealth.

$$x_{ijt}^{sen} = (1 + r_{i,t-1}^{sen})(x_{i,j,t-1}^{sen} - u_{i,j,t-1}^{sen} + v_{i,j,t-1}^{sen})\; ; \forall i = 1,2,\dots,N, j = 1,2,\dots,J, sen = 1,2,\dots,S \quad (5)$$

$$x_{ij,1}^{sen} = (1 + r_l)(x_{ij,0}^{sen}) - b_{j1}^{sen} \;\; ; \forall sen \forall i = 1,2,\dots,N, j = 1,2,\dots,J, sen = 1,2,\dots,S \quad (6)$$

$$x_{ij,t}^{sen} = (1 + r_l)(x_{ij,t-1}^{sen} + \sum_{i=1}^{N}(1+\tilde{c}_{sell})u_{ij,t-1}^{sen} - \sum_{i=1}^{N}(1+\tilde{c}_{buy})v_{ij,t-1}^{sen}) - b_{j,t-1}^{sen} \times (1 + r_b) + b_{jt}^{sen}$$
$$\forall sen, t = 2,3,\dots,T-1;\; \forall i = 1,2,\dots,N, j = 1,2,\dots,J, sen = 1,2,\dots,S \quad (7)$$

$$x_{ij,T}^{sen} = (1 + r_l)(x_{ij,T-1}^{sen} + \sum_{i=1}^{N}(1+\tilde{c}_{sell})u_{ij,T-1}^{sen} - \sum_{i=1}^{N}(1+\tilde{c}_{buy})v_{ij,T-1}^{sen}) - b_{jT-1}^{sen} \times (1 + r_b) \;\; ;$$
$$\forall i = 1,2,\dots,N, j = 1,2,\dots,J, sen = 1,2,\dots,S \quad (8)$$

Constraint (9) calculates the wealth accumulated at the end of the t period under the sen scenario.

$$\sum_{i=1}^{N} x_{ijt}^{sen} = w_{jt}^{sen} \;\; ; \forall j, sen, t = 1,2,\dots,T-1;\; \forall j = 1,2,\dots,J, sen = 1,2,\dots,S \quad (9)$$

Constraint (10) calculates the utility of the bank. φ1, φ, γ and τ are the parameters that are asked of the bank.

$$weight_t = \begin{cases} \gamma(w_{jt-1}^{sen} - \tau)^{\varphi} & w_{jt-1}^{sen} \ge \tau \\ -\gamma(w_{jt-1}^{sen} - \tau)^{\varphi 1} & w_{jt-1}^{sen} \le \tau \end{cases} \; ; \forall j = 1,2,\dots,J, sen = 1,2,\dots,S, t = 2,\dots,T; \quad (10)$$

The relation (11 and 12) also describes the model variables.

$$x_{ijt}^{sen}, v_{ijt}^{sen}, u_{ijt}^{sen}, b_{jt}^{sen}, w_{jt}^{sen} \ge 0 ; \forall i = 1,2,\dots,N, j = 1,2,\dots,J, sen = 1,2,\dots,S, t = 1,2,3,\dots,T \quad (11)$$

$$x, v, b, w, u, W \in \{R+\} \; ; \forall i,j,t \;\; 0 \le weight_t \le 1;\; \forall t = 1,2,3,\dots,T \quad (12)$$

Several methods have been proposed to solve fuzzy mathematical planning problems. In this paper, the ranking method presented by Jimenez [19] is used. Using the Jimenez method, we convert the proposed fuzzy programming model to a definite model like it. In this case, the definitive state of constraint (4) is as follows:

$$\sum_{i=1}^{N}[(1+\alpha)\frac{c_{buy}^1 + c_{buy}^2}{2} + (1-\alpha)\frac{c_{buy}^2 + c_{buy}^3}{2})v_{ij0}^{sen} + x_{ji0}^{sen}] = w_{j0} + b_{j0}^{sen} \;\; ; \forall i = 1,2,\dots,N, j = 1,2,\dots,J, sen = 1,2,\dots,S \quad (13)$$

The definite states of constraints (7) and (8) are as follows:

$$x_{ij,t}^{sen} = (1 + r_l)\left(x_{ij,t-1}^{sen} + \sum_{i=1}^{N}(1+\alpha)\frac{c_{sell}^1 + c_{sell}^2}{2} + (1-\alpha)\frac{c_{sell}^2 + c_{sell}^3}{2}))u_{ij,t-1}^{sen} - \sum_{i=1}^{N}(1+\alpha)\frac{c_{buy}^1 + c_{buy}^2}{2} + (1-\alpha)\frac{c_{buy}^2 + c_{buy}^3}{2}))v_{ij,t-1}^{sen}\right) - b_{j,t-1}^{sen} \times (1 + r_b) + b_{jt}^{sen}$$
$$\forall sen, t = 2,3,\dots,T-1, \forall i = 1,2,\dots,N, j = 1,2,\dots,J, sen = 1,2,\dots,S \quad (14)$$

$$x_{ij,T}^{sen} = (1 + r_l)\left(x_{ij,T-1}^{sen} + \sum_{i=1}^{N}(1+\alpha)\frac{c_{sell}^1 + c_{sell}^2}{2} + (1-\alpha)\frac{c_{sell}^2 + c_{sell}^3}{2}))u_{ij,T-1}^{sen} - \sum_{i=1}^{N}(1+\alpha)\frac{c_{buy}^1 + c_{buy}^2}{2} + (1-\alpha)\frac{c_{buy}^2 + c_{buy}^3}{2}))v_{ij,T-1}^{sen}\right) - b_{jT-1}^{sen} \times (1 + r_b) \;\; ; \;\; \forall sen, t = 2,3,\dots,T-1, \forall i = 1,2,\dots,N, j = 1,2,\dots,J, sen = 1,2,\dots,S \quad (15)$$

Which we have in the above equations:

I: Includes various types of investment or bank assets (i = 1, 2, …, I)

J: Includes branch points (j = 1, 2,…, J)

T: set of planning courses (t = 1,2,…, T)

α_i : The number of job opportunities created in the production center set up by Ith investment.

x_{ijt}^{sen}: The monetary value of the asset i in Branch j is initially the period t under the sen scenario.

S: Number of scenarios and sen scenario index.

$prob_{sen}$: The probability of a sen scenario occurring.

r_{it}^{sen}: Investment returns of ith in the t period under the sen scenario.

Bi: Attraction coefficient type of investment ith, B_i= 〖B0〗_i e^(-γd^2)+α, d is the maximum Euclidean distance to the branch and γ is the absorption coefficient.

θ_h : Weight factor of hazardous materials (weight of hazardous materials in the objective function).

θ_w : Weight factor of the produced waste (weight of the waste produced in the objective function).

θ_l : Weight factor of work injury (work injury weight in the objective function).

sp_i : Average waste generated in the production center set up by ith investment.

dp_i : The average hazardous materials used in the production center set up by ith investment.

w_{jt}^{sen}: Wealth of branch j at the beginning of period t under sen scenario.

$\tilde{c}_{buy}$: The fuzzy cost of transactions resulting from the purchase of assets at the beginning of the period.

$\tilde{c}_{sell}$: The fuzzy cost of transactions resulting from the sale of assets at the beginning of the portfolio period.

r_l: Loan rate.

r_b: Borrowing rate.

v_{ijt}^{sen}: The amount of purchase of assets i in Branch j is initially the period t under the sen scenario.

Wj0: The initial wealth of Branch j at the beginning of the period.

B0i: The maximum attraction of the type of ith investment, which is calculated based on the amount of employment and environmental benefits.

b_{jt}^{sen}: The amount of money borrowed from the central bank in Branch j is initially the period t under the sen scenario.

u_{ijt}^{sen}: The amount of sales of assets i in branch j is initially the period t under the sen scenario.

$Weight_t$: The optimal weight for the t period.

3-2- Fireworks Algorithm

The fireworks algorithm is a new smart algorithm proposed by Ying Tan in 2010 [20]. This algorithm can find the optimal solution by imitating the fireworks explosion process. For a simple introduction to this algorithm, the general optimization problem can be stated as follows:

$$\text{Minimize } f(x) \mid x_{min} \le x \le x_{max} \quad (16)$$

For the above optimization problem, the main idea of the fireworks algorithm is to initialize the M fireworks, show them in the solution space, and then select the M fireworks to continue the repetition process according to specific rules. In particular, the fireworks algorithm mainly consists of the following four sections: Explosion Operator, Mutation Operator, Mapping rule, and Selection Strategy. Among them, the explosion operator consists of three parts, namely, the intensity of the explosion, the amplitude of explosion, and the displacement operator. Mutation operators use mutation to increase population diversity. Directly, the intensity of the explosion is measured by the number of explosion sparks, while the amplitude of explosion is measured by the displacement distance. The main idea is to decide if the intensity of the explosion and the range for each fireworks are less than the value of the fitness function, greater than the intensity of the explosion, and less than the amplitude of explosion (and vice versa). The intensity of the explosion is shown as follows:

$$s_i = m \,.\, \frac{y_{max} - f(x_i) + \xi}{\sum_{i=1}^{n}(y_{max} - f(x_i)) + \xi} \quad (17)$$

That s_i is the number of sparks generated by the ith fireworks; m is a constant value that is limited to the total amount of sparks; f(x_i) is the fitness value of the ith fireworks; the amplitude of explosion was measured by the displacement distance represented by the following equation:

$$A_i = \hat{A} \,.\, \frac{f(x_i) - y_{min} + \xi}{\sum_{i=1}^{n}(f(x_i) - y_{min}) + \xi} \quad (18)$$

If A_i indicates the range of the ith fireworks, Â is a constant value, which indicates the upper limit of the explosion range. After we get the intensity and amplitude of the explosion, we randomly select z (dimensions). In this case, we have:

$$Z = \text{round}\left(d.\text{rand}(0,1)\right) \quad (19)$$

Where d is the dimension of x, and rand (0.1) is a function of producing a random number of uniform distributions between 0 and 1. For the selected dimension, the displacement equation is specified as follows:

$$\Delta x_i^k = x_i^k + \text{rand}(0, A_i) \quad (20)$$

From the above operation, we get a number of sparks and only a few can be selected for the next generation. The main idea of the selection strategy is to make sure that this spark is always selected in the recent population with the smallest amount of fit, and the n-1 residual spark is determined by the Euclidean distance between that spark and other sparks. The Euclidean distance is shown as follows:

$$R(x_i) = \sum_{j\epsilon k} d(x_i, x_j) = \sum_{j\epsilon k} \|(x_i - x_j)\| \quad (21)$$

That K is a complete set of recent populations, which not only includes fireworks but also includes the resulting sparks of explosions. To ensure variety, sparks that are farther away from other locations will most likely be selected.

The probability of selection for each spark is determined by the following equation:

$$P(x_i) = \frac{R(x_i)}{\sum_{j\epsilon k} R(x_i)} \quad (22)$$

Equation (20) suggests 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 selected sparks will be the initial position of the next iteration. Repetition determines when the stop criterion is met. The flowchart of fireworks algorithm is shown in Figure 2.

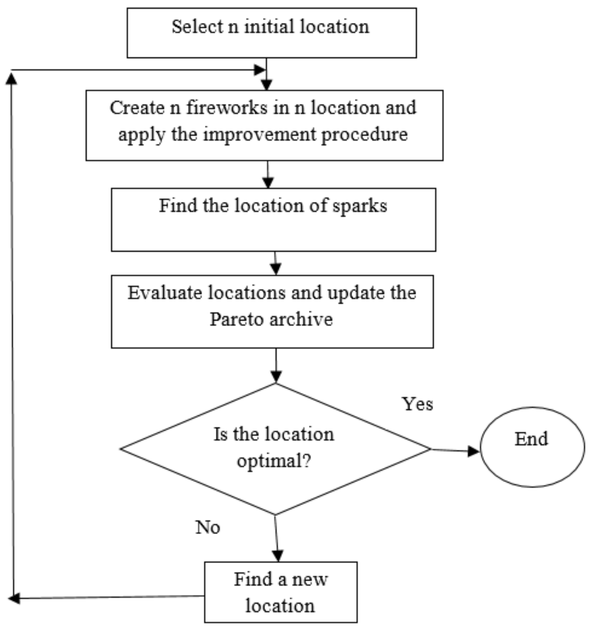

Figure 2: Flowchart Fireworks Algorithm

3-3- Genetic algorithm

Genetic algorithm is a special type of evolutionary algorithms that uses evolutionary biology techniques such as heredity and mutation. This algorithm was first introduced in the twentieth century. This algorithm is a population-based meta-heuristic algorithm that works with a population of responses in each iteration. Each response in the population of responses in this algorithm is called a chromosome.

This algorithm starts with a population of responses and generates new responses using mutation, crossover, and reproduction operators. Each section of this algorithm is briefly described below.

Primary population production: As mentioned, the genetic algorithm is a population-based algorithm. In fact, in each iteration or generation, this algorithm deals with a population of responses. The population size should be the same in all repetitions of the algorithm. First, a population of primary responses must be generated.

Mutation: In each repetition of the algorithm, a percentage of the responses are selected and a neighborhood search operator will be applied to these responses, which is called the mutation operator. The number of responses selected to apply this operator depends on the mutation rate. The mutation rate is between 0 and 1 and is the input parameter of the algorithm. For example, if the mutation rate is 0.2, 20% of the population's responses will be selected for the mutation operator.

Crossover: Another genetic algorithm operator is the crossover operator, which is applied to two responses or two selected parents and produces two children. The number of responses selected for the crossover operator depends on the crossover rate. The crossover rate is a number between 0 and 1 and is part of the input parameters of the algorithm. If the crossover rate is 0.6, 60% of the responses in the population that have never been operated on are selected to apply the crossover operator.

Generational renewal: A number of responses in the population, on which the two mutation operators and the intersection have not been applied, will be passed on to the next generation without any change. The number of these responses also depends on the generation rate.

Parent selection: As stated in the crossover operator explanation, to perform this operator, two responses are selected as parents and given to this operator. There are several ways to choose a parent.

Fitness function: This function is calculated for each of the responses and is a criterion for comparing the responses. In this paper, to evaluate the performance of the fireworks algorithm, its results are compared with the well-known genetic algorithm NSGA-II. The flowchart of the genetic algorithm is shown in Figure 3.

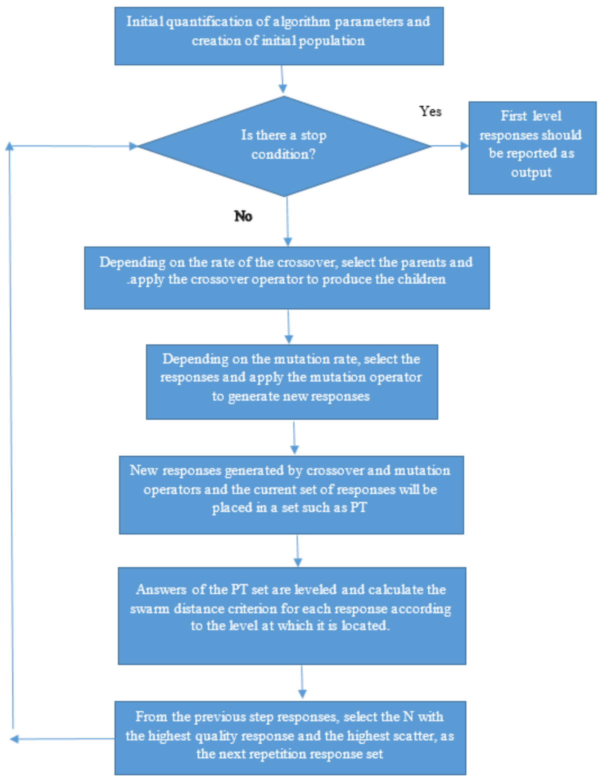

Figure 3: Flowchart of the genetic algorithm

4- Data analysis

4-1- Sample issues

To solve the model, sample issues were designed based on Sepah Bank branches in Tehran, whose number is 219. Sample issues in small, large and medium sizes are presented below. It should be noted that the issues are subdivided into 219 branches of Sepah Bank in Tehran. To set the parameters of the algorithms, the values of each of these parameters are examined in three levels, which are shown in Tables 1 to 3.

Table 1- Small size issues

Number of courses	Number of assets	Number of branches	Number
6	4	10	1
6	6	10	2
6	8	10	3
6	10	10	4
6	12	10	5
6	4	15	6
6	6	15	7
6	8	15	8
6	10	15	9
6	12	15	10

Table 2. Medium size issues

Number of courses	Number of assets	Number of branches	Number
6	4	20	1
6	6	20	2
6	8	20	3
6	10	20	4
6	12	20	5
6	4	30	6
6	6	30	7
6	8	30	8
6	10	30	9
6	12	30	10

Table 3- Large size issues

Number of courses	Number of assets	Number of branches	Number
6	10	50	1
6	10	70	2
6	10	100	3
6	10	120	4
6	10	140	5
6	10	160	6
6	10	180	7
6	10	190	8
6	10	200	9
6	10	219	10

4-2- Setting the parameters of the algorithms

MINITAB software has been used to adjust some of the proposed algorithm parameters. To perform the analysis, a criterion called GAP was used, which is shown below:

$$GAP = (\frac{a\lg_{sol} - best_{sol}}{best_{sol}}) \times 100 \qquad (23)$$

In which, algsol: the value of the objective function obtained by combining the desired parameters and bestsol: the best value of the objective function obtained from the implementation of the algorithm.

The GAP criterion is calculated for each algorithm and finally its graph is plotted. The levels of the parameters of the genetic algorithm and the fireworks algorithm and orthogonal for adjusting the parameters of the genetic algorithm and the fireworks algorithm are shown in Tables 4 to 7, respectively.

Table 4-Levels of genetic algorithm parameters

Repetition of the algorithm	Mutation rate	Crossover rate	Population size
150	0.006	0.75	70
300	0.009	0.85	150
500	0.01	0.95	200

Table 5- Levels of fireworks algorithm parameters

Repetition of the algorithm	Spark control parameter (m)	Upper limit of the amplitude of explosion	Population size
150	0.5	5	70
300	1	10	150
500	2	15	200

Table 6 - Orthogonal for adjusting the parameters of the genetic algorithm

GAP value	Repetition of the algorithm	Mutation rate	Crossover rate	Population size	Test number
0.965	150	0.006	0.75	70	1
0.158	300	0.009	0.85	70	2
0.971	500	0.01	0.95	70	3
0.957	500	0.009	0.75	150	4
0.485	150	0.01	0.85	150	5
0.800	300	0.006	0.95	150	6
0.142	300	0.01	0.75	200	7
0.422	500	0.006	0.85	200	8

Table 7 - Orthogonal for adjusting the parameters of the fireworks algorithm

GAP value	Repetition of the algorithm	Spark control parameter (m)	Upper limit of the amplitude of explosion	Population size	Test number
0.888	150	0.5	5	70	1
0.427	300	1	10	70	2
0.112	500	2	15	70	3
0.131	500	1	5	150	4
0.485	150	2	10	150	5
0.800	300	0.5	15	150	6
0.942	300	2	5	200	7
0.134	500	0.5	10	200	8
0.967	150	1	15	200	9

The results of MINITAB software for the effect of the average genetic algorithm are shown in Figure 4.

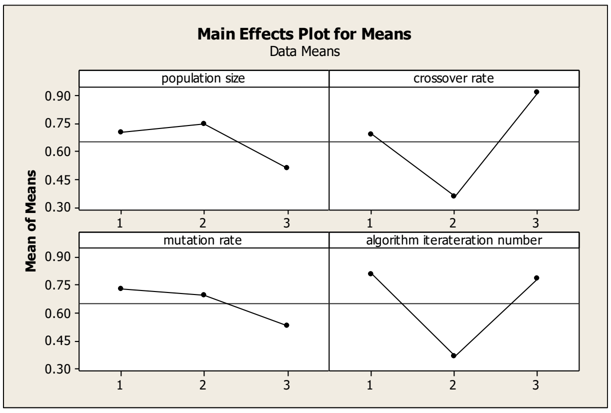

Figure 4: Effect of the average genetic algorithm

Level 3 is more effective for mutation rate and level 2 is more effective for crossover rate; level 3 is more effective for population size and level 2 is for repeating algorithm. Therefore, values of 200 for population size, 300 for algorithm repetition, 0.01 for mutation rate, and 0.85 for crossover rate are considered. The results of MINITAB software for the effect of the average fireworks algorithm are shown in Figure 5.

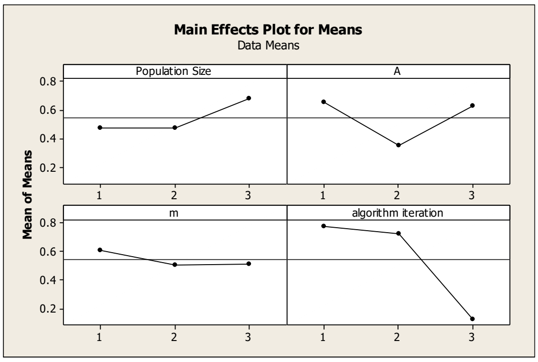

Figure 5: Effect of the average fireworks algorithm

Level 2 is more effective for algorithm control parameters; level 2 is more effective for population size and level 3 is more effective for repeating algorithms. Therefore, values of 200 for population size, 500 for algorithm repetition, value 10 for upper limit of the amplitude of explosion (A) and value 1 for control parameter of number of sparks (m) are considered.

4-3- Comparative indicators

To evaluate the quality and dispersion of multi-objective meta-heuristic algorithms, three indicators are considered in this paper for comparison.

A- Quality Index: This index compares the quality of pareto responses obtained by each method. In fact, it summarizes all the Pareto responses obtained by both methods and determines what percentage of the level 1 responses belong to each method. The higher this percentage, the higher the quality of the algorithm.

B- Spacing Index: This criterion tests the uniformity of the distribution of the obtained pareto responses at the boundary of the responses. This index is defined as follows:

$$s = \frac{\sum_{i=1}^{N-1} \left| d_{mean} - d_i \right|}{(N-1) \times d_{mean}} \quad (24)$$

In the above equation, di represents the Euclidean distance between two adjacent non-defeated responses and d_{mean} represents the mean of di values.

C- Diversity index: This index is used to determine the amount of non-defeated responses found on the optimal boundary. The definition of diversity index is as follows:

$$D = \sqrt{\sum_{i=1}^{N} \max(\left\| x_t^i - y_t^i \right\|)} \quad (25)$$

In the above equation, $\left\| x_t^i - y_t^i \right\|$ indicates the Euclidean distance between two adjacent x_t^i and y_t^i responses on the optimal boundary.

4-4- Model solution results

In this study, in order to more accurately compare the performance of the multi-objective fireworks algorithm and NSGA-II, comparative results to solve issues of small, medium and large sizes based on the indicators are shown in Tables 8 to 10.

Table 8- Results of issues solving with small size

Prob.	FIREWORKS					NSGA-II				
	Quality metric	Spacing metric	Diversity metric	cpu time	Number of pareto responses	Quality metric	Spacing metric	Diversity metric	cpu time	Number of pareto responses
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

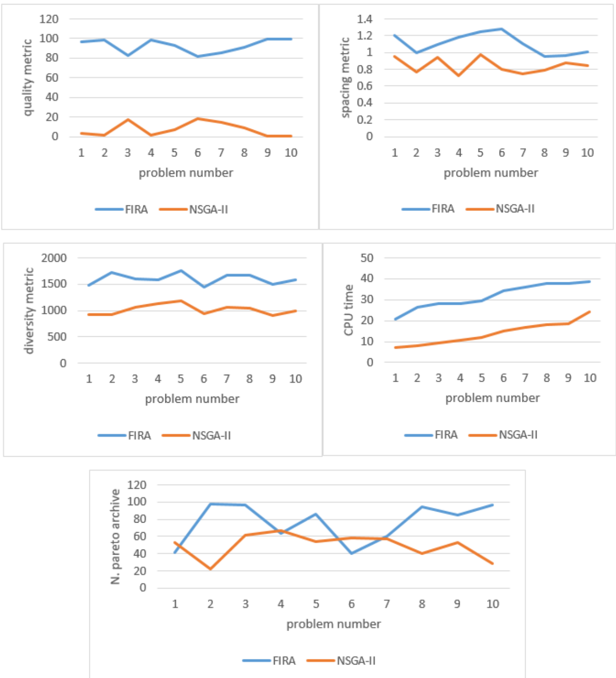

Figure 6: Wiktionary,Quality metric, Spacing metric, Diversity metric, cpu time, Number of pareto responses, for small size issues.

Table 9- Results of issues solving with medium size

Prob.	FIREWORKS					NSGA-II				
	Quality metric	Spacing metric	Diversity metric	cpu time	Number of pareto responses	Quality metric	Spacing metric	Diversity metric	cpu time	Number of pareto responses
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

Table 10- Results of issues solving with large size

Prob.	FIREWORKS					NSGA-II				
	Quality metric	Spacing metric	Diversity metric	cpu time	Number of pareto responses	Quality metric	Spacing metric	Diversity metric	cpu time	Number of pareto responses
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

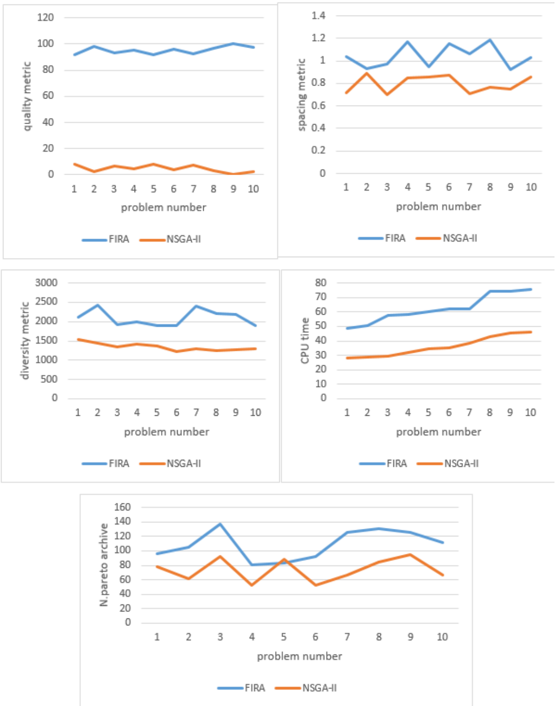

Figure 7: Wiktionary,Quality metric, Spacing metric, Diversity metric, cpu time, Number of pareto responses, for medium size issues

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

The comparative results in Tables 8 to 10 and the values for the comparative indicators show that the fireworks algorithm in all cases has a higher ability to produce higher quality responses than the NSGA-II algorithm. The fireworks algorithm is able to generate higher scattered responses than the NSGA-II algorithm. Also, the NSGA-II algorithm produces higher uniformity responses than the fireworks algorithm.

5. Conclusion

Green banking is a type of banking that pays attention to environmental and social factors while performing banking operations. This type of banking is also called ethical banking, which, in addition to profitability goals, also aims to protect the environment. In this paper, the green banking supply chain optimization model is discussed. First, a multi-objective mathematical model was presented, and then fireworks and genetic algorithms were used to solve the model. Research shows that fireworks algorithms have a higher ability to generate higher quality responses than NSGA-II algorithms in all cases. Also, the fireworks algorithm is able to produce higher scattered responses than the NSGA-II algorithm, or in other words, the fireworks algorithm has a greater ability to explore and extract the area to be answered than the NSGA-II algorithm. The NSGA-II algorithm produces higher uniformity responses than the fireworks algorithm. Running time values indicate that the multi-objective fireworks algorithm has a higher resolution time. Because based on the proposed structure of the proposed method, this method intelligently searches many points in the response space in each iteration. Obviously, this method takes more computational time than the NSGA-II method.

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