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Fuzzy Multi-Objective Scenario-based Stochastic Programming to Optimize Supply Chain

F. Javadi Gargari[1], H. Amoozad-Khalili[2 *], R. Tavakkoli-Mogaddam[3]

Nowadays, the capability of cloud management suppliers is one of the important advantages for suppliers that can improve the performance and flexibility and reduce costs in companies through easy access to resources. Also, the environmental impacts of suppliers are a significant issue in today's industrialization and globalization world. This paper analyzes these subjects by fuzzy multi-objective scenario-based stochastic model. Its objective functions are minimizing the total cost, environmental impacts of suppliers, and maximizing the capability of cloud management of suppliers. Non-Dominated Sorting Genetic Algorithm- II (NSGA-II) and Multi-objective Simulated Annealing meta-heuristic (MOSA) are developed to settle this problem. Five computational experiments analyze the performance of the solution algorithms. The results illustrate that the NSGA-II algorithm provides better solutions than the MOSA algorithm for the presented model.

Keywords: *Cloud management, Multi-objective evolutionary algorithms, Quota allocation, Supply chain management, Supplier selection*.

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1. Introduction

Supplier selection as a determining section of the supply chain management has a vital role in defining enterprise success. The selection of suppliers is a multi-criteria decision-making problem that measures the performance. Hence, choosing a suitable supplier and allocating the order share for each are significant. In each supply chain, an important responsibility conferred on the purchasing department is to recognize some appropriate suppliers, considering their ability to provide the primary demands of expense, quality, technological strength, manufacture capacity, financial capability, and other options [5].
As well as, according to the current environmental crisis caused by the worrying depletion of natural resources, hazardous air emissions, loss of biodiversity, toxic waste, water pollution, and long-term harm to the ecosystem, supply chain managers must consider the extensive development

[1] Industrial Engineering Department, Alzahra University, Deh Vanak, Tehran, Iran;
E-mail: F.javadigargari@gmail.com

[2] Department of Industrial Engineering, Sari Branch, Islamic Azad University, Sari, Iran;
Email:Amoozad92@yahoo.com. *(Corresponding Author)

[3] School of Industrial Engineering, College of Engineering, University of Tehran, Tehran, Iran; E-mail: Tavakoli@ut.ac.ir

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of global environmental protection as a primer goal in their decisions [6]. Therefore, adopting sustainability and circular economy practices is necessary to move towards a society with low carbon emissions that allow mitigating the consequences of climate [12], [29]. Along these lines, the environmental impacts generated by suppliers' operations have become one of the vital aspects of their selection by customers (buyers). Thus, each supplier with a higher risk of producing negative impacts on the environment should have more difficulties in selling their products/services. In this situation, suppliers are incentivized to have an environmentally friendly behavior to have better opportunities in a competitive market [11]. Therefore, it is important to consider the environmental impacts of suppliers as one of the objectives in selecting from whom to buy and how much to buy.
On the other hand, nowadays, cloud computing has been utility for the business sector. The companies can reap the many profits of using cloud computing because it can supply buyer needs with on-demand services and low prices. Clearly, businesses have an impediment in sourcing raw materials from suppliers to provide demands such as low costs, on-time delivery, and quality of raw materials because most companies have limited budgets and shortages of supply suppliers' demands. Suppliers also require customers to supply sales conditions because suppliers require to create more benefits from selling products [4]. Indeed, the companies with cloud management have better visibility, agility, ease of use, security, and, as well as, less operation cost. Therefore, cloud computing is one of the best technologies that furnish information services and settle several problems [2].

Obviously, customers prefer to select the supplier with more cloud management capability. At last, in this research, a multi-objective model for selecting the supplier and determining the quota of each order is introduced. The proposed model of functions is to minimize the cost of purchase, environmental impacts of selected suppliers, and maximize the cloud management of selected suppliers. The presented model is considered as an NP-hard problem. Hence, two multi-objective evolutionary algorithms, Non-Dominated Sorting Genetic Algorithm-II (NSGA-II) and Multi-objective simulated Annealing meta-heuristic (MOSA) are used to solve this problem.

The main contributions of this research are summarized below:

- A Multi-Objective Mixed-Integer Fuzzy Programming model is formulated for the problem of supplier selection and order allocation.
- Environmental impacts of suppliers and cloud management of suppliers are considered as objective functions in the model.
- The hazardous environmental impacts of suppliers are introduced in the proposed model as a determinative aspect in supplier selection.
- Two multi-objective evolutionary algorithms are used to settle the problem.

This study is distinguished based on the following contributions:

In the next section, a brief outline of previous research is presented. In the third section, the problem is defined, and the symbols and formulation of the problem are expressed. In Section four solution method is presented. In Section five, the solution to the algorithm is proposed, and in the sixth section, the numerical results are indicated. Finally, a summary of the paper's process and its results and suggestions for future research are cited.

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2. Literature review

Scholars have widely studied the SSOA problem in recent years. In this section, the developed mathematical models and used measures for this problem are investigated (Section 2.1). Then the developed solution algorithms for the problem are analyzed (Section 2.2). Finally, the current research gaps and our contributions are introduced (Section 2.3). Table 1 details the reviewed studies in this paper.

2.1. Measures and models

Scholars modeled the SSOA problem in different ways and considered various criteria.
For example, Alinezahd [1] presented linear programming of multi-product and multi-period complex integer closed-loop supply chain network with four floors (suppliers, factories, distribution centers, and customers) in the main chain and three layers (collection centers, inspection centers and disposal centers). Maximization profits in the closed-loop supply chain network is as a main objective. Jabbarzadeh et al. [17] introduced a new robust bi-objective optimization model for a green supply chain's integrated production and distribution planning with the postponement method. Cost and greenhouse gas emissions minimization are objective functions. Megahed and Goetschalckx [21] introduced a multi-period, multi-product, multi-echelon supply chain planning problem, and developed a mixed-integer linear programming (MIP) model considering single-objective, minimization of the total cost. Alizadeh et al. [2] presented an uncertain cold multi-cycle supply chain to minimize the cost of transportation, warehousing and total operation time and also maximize product freshness time. The model was surveyed with meta-heuristic optimization methods (strongly adjustable). Iqbal et al. [15] presented a nonlinear green supply chain for the centralized supply chain system (i.e., the three supply chainsupply chain layers make decisions jointly). The objective functions minimize the total cost and energy consumption. Tirkolaee et al. [32] developed an integrated fuzzy decision making and multi-objective programming model for the SSOA problem, which minimizes the weighted value of products by considering the suppliers' priorities and maximizing the supply chain's reliability. Singh and Singh [30] presented a system with a seasonal pattern demand rate based on collaboration for defunct cases and supplier's random lead-time under a crisp and fuzzy environment regarding the impact of inflation and time value of money. They considered the maximization of total profit as an objective function. Mohammed [23] presented a novel fuzzy TOPSIS-possibilistic multi objectives model to settle a two-stage sustainable supplier selection problem, and allocate the quantity of the appropriate goods. the objective functions are the minimization of costs, environmental impact and travel time also the maximization of social impact. Ventura et al. [34] introduced a novel supplier selection and order quantity allocation programming in a two-stage supply chain composed of appropriate suppliers and a buyer/retailer of one product. Yousefi et al. [35] a two-phase hybrid model introduced to select appropriate suppliers, allocate order, and assign prices in a supply chain based on coordination among parts. Firstly, they proposed an integrated Multi-Objective Mixed-Integer Nonlinear Programming (MOMINLP) model with objective of cost minimization and supplier evaluation. In the second phase, a model is introduced to define the proper price given both the buyer and the selected suppliers to maximize the members' utilities.

2.2. Solution approaches

As mentioned earlier, both exact and heuristic/meta-heuristic algorithms have been used for the SSOA problem. However, the latter category of solution algorithms is more efficient for the large-

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sized cases of this problem [27] and has been commonly developed. For example, Hosseini et al. [14] introduced an appropriate solution approach to the resilient supplier selection and optimal order allocation problem. Firstly, using a probabilistic graphical model, disruption scenarios of the supplier selection problem are computed. Then, a stochastic bi-objective mixed-integer programming model is proposed to support the decision-making about using of both proactive and reactive strategies in supplier selection and order allocation. Salehi and Rezaei [28] addressed uncertainty for the SSOA problem under shortfall and discounts by a fuzzy approach. They developed two solution algorithms, NSGA-II and multi-objective particle swarm optimization algorithm (MOPSO), to solve the model. The discount feature was considered for the SSOA problem by Vardi et al. [33]. Their model included three objective functions, minimizing total costs and lead times and maximizing quality. The NSGA algorithm was applied to solve the model. Javadi Gargari and Seifbarghy [18] presented a mixed-integer programming (MIP) model considering supplier disruption with a priority of reliability of suppliers. They utilized scenario-based stochastic programming (SP) approach to settle uncertainty of demand in real-world. Sobhanallahi et al. [31] also modeled the SSOA problem under discount with two objective functions: minimize total costs and maximize total purchasing costs. The NSGA-II algorithm was employed to find Pareto optimal solutions. Mohammed et al. [26] introduced a supply chain resilience (SCR) methodology about both supply and demand variations.

Indeed, a hybrid integrated multi-attribute decision-making-possibilistic bi-objective programming model (MADM-PBOPM) was presented. Firstly, a new framework presenting pillars to define suppliers' resilience was created. Then, a DEMATEL-TOPSIS way was presented to quantify available suppliers' resilience and specify its performance. Kaur and Singh [19] proposed a new multi-stage hybrid model for optimal supplier selection and order allocation under risks and disruption. They evaluated suppliers based on a set of important criteria in Industry 4.0 environment by Data Envelopment Analysis (DEA) and AHP-TOPSIS. Mohammed et al. [25] introduced a novel method of supplier evaluation and optimal order allocation of each supplier considering green and resilience (Gresilience) characteristics. Islam et al. [16] presented a novel two-phase solution method for supplier selection and order allocation planning that a forecasting process is integrated with an optimization problem. Firstly, the demand is forecasted to settle the demand vagueness. A new Relational Regressor Chain method is defined to determine the future demand. Then, a multi-objective programming model is introduced to recognize proper suppliers and order quantities from each supplier using the forecasted demand.

2.3. Research gap

The review of conducted studies reveals that the significant cloud management of suppliers has been neglected by scholars in supplier selection and order allocation models. Cloud computing is benefited in complex networks to obtain the subject of big data management in the commerce. Processing techniques can grow insight into information management based on finding patterns that support more useful and efficient decision making. Indeed, customers prefer to select suppliers with comprehensive management that have low-cost and high-quality products with high customer orientation. Hence, we formulated the fuzzy scenario-based model to minimize cost, and environmental impacts of suppliers, as well as maximize cloud-management of suppliers.

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Table 1. Literature Review

Authors	Decision		Customer Demand		Objective function					Application		Solution Method
	SS	OA	Deterministic	Uncertain	PC	IC	QC	EI	CM	Actual Case	Example	
Islam et al. (2019)	*	*		*	*	*					*	Weighted-sum and Ɛ-constraint
Alinezahd (2019)	*	*	*		*	*	*	*		*		Commercial solver
Jabbarzadeh et al. (2019)	*	*		*	*	*		*		*		Commercial solver
Hosseini et al. (2019)	*	*		*	*						*	Fuzzy c-mean clustering (FCM) algorithm
Kaur and Singh (2019)	*	*		*	*	*				*		FAHP-TOPSIS
Megahed and Goetschalckx (2019)	*	*	*		*	*					*	Commercial solver
Salehi and Rezaei, (2019)	*	*	*									NSGA-II and MOPSO
Vardi et al. (2019)	*	*	*		*	*	*				*	GA and NSGA
Alizadeh et al. (2020)	*	*		*	*	*	*				*	NSGA-II
Singh and Singh (2020)	*	*	*		*	*					*	Commercial solver
Sobhanallahi et al. (2020)	*	*	*		*	*					*	NSGA-II
Iqbal et al. (2020)	*	*	*		*	*		*			*	Commercial solver
Tirkolaee et al. (2020)	*	*		*	*	*					*	Commercial solver
Mohammed (2020)	*	*		*	*	*	*	*			*	TOPSIS-possibilistic
Mohammed et al. (2021)a	*	*	*		*	*	*	*		*	*	TOPSIS & AHP
Mohammed et al. (2021)b	*	*		*	*	*	*	*		*		TOPSIS-possibilistic
Ventura et al. (2021)	*	*	*		*	*					*	GAMS
Yousefi et al. (2021)	*	*		*	*	*		*			*	Nash bargaining game
This Paper	*	*		*	*	*		*		*	*	NSGA-II and *MOSA*

SS: Supplier Selection, OA: Order Allocation, PC: Purchasing Cost, IC: Inventory Cost, QC: Quality Cost, EI: Environmental impacts, SD: Supplier Disruption, CM: Cloud Management

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3. Model description

The objective functions of the proposed model include minimizing costs, environmental impacts of suppliers and maximizing cloud management capability of suppliers. In this paper, the model is presented to select proper suppliers and determine the optimal share of order to each supplier underThis paper presents the model to select proper suppliers and determine the optimal share of order to each supplier under a fuzzy scenario-based condition. Due to the unreliable real world, all related parameters are considered based on triangular fuzzy number. Also, on one hand, because the effects of the supply chain on the environment vary with temperature change in the real world, in the model, some scenarios for the level of suppliers' effects on the environment are defined. On the other hand, the capability of cloud management is related to several aspects, such as the political, financial, and technological dimensions. Hence, we also introduce this parameter as a fuzzy- scenario-based method.

The used indices, parameters, and variables for the proposed MOMILP are presented in Table 2.

Table 2. Definite Model Symbols.

i: supplier index	**j**: customer index
k: product index	**t**: Time period index
s: scenario index	
Parameters	
$\tilde{D}_{jk}^{t}$: Demand of product k for customer j at period t	C_{ik}^{t}: _Supplier i capacity for delivering product k at period t
$\tilde{P}_{ik}^{t}$: Unit price of product k at period t supplied by supplier i	$\tilde{e}_{ik}^{s}$: Environmental impacts of suppliers i to product product k based scenario s
$\widetilde{CL}_{ik}^{s}$: Capability of cloud management for supplier i in product k based scenario s	E: Maximum accessible level of environmental impacts for suppliers
ρ_s **:** The probability of scenario s (for Environmental impacts of suppliers and capability of cloud management for suppliers)	
Variables	
Y_{ijk}^{t}: supplier i selection variable at period t for supplying product k for customer j	${X_{ijk}^{t}}^{s}$**:** order demand of product k for customer j from supplier i at period time t based scenario s

The model is formulated as follows:
Objective functions

$$Min \sum_{s}\sum_{i}\sum_{j}\sum_{k}\sum_{t} \rho_s \; \tilde{P}_{ik}^{t} \; {X_{ijk}^{t}}^{s} \; Y_{ijk}^{t} \tag{1}$$

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$$Min \sum_s \sum_i \sum_j \sum_k \sum_t \rho_s \ \tilde{e}^s_{ik} \ X^{t\ \ s}_{ijk} \ Y^t_{ijk} \tag{2}$$

$$Max \sum_s \sum_i \sum_j \sum_k \sum_t \rho_s \ \widetilde{CL}^s_{ik} \ X^{t\ \ s}_{ijk} \ Y^t_{ijk} \tag{3}$$

The objective function (1) minimizes the total operation cost. The objective function (2) minimizes the total environmental impacts of suppliers. The objective function (3) maximizes the capability of cloud management of suppliers.

The constraints of the proposed model are expressed as below:

$$\sum_i X^{t\ \ s}_{ijk} Y^t_{ijk} = \widetilde{D}^t_{jk} \qquad \forall\, s,j,k,t \tag{4}$$

$$\sum_j \sum_k \sum_t \tilde{e}^s_{ik} \ X^{t\ \ s}_{ijk} \ Y^t_{ijk} \le E \qquad \forall\, s,i \tag{5}$$

$$\sum_i X^{t\ \ s}_{ijk} Y^t_{ijk} \le C^t_{ik} \qquad \forall\, s,j,k,t \tag{6}$$

$$X^{t\ \ s}_{ijk} \le Y^t_{ijk} \qquad \forall\, s,i,j,k,t \tag{7}$$

$$X^{t\ \ s}_{ijk} \ge 0 \qquad \forall\, s,i,j,k,t \tag{8}$$

$$Y^t_{ijk} \epsilon \begin{cases} 0 \\ 1 \end{cases} \qquad \forall\, i,j,k,t \tag{9}$$

Constraint (4) refers to providing the total customer demand for each product and per period under each scenario. Constraint (5) shows that the total environmental impacts under each scenario for each period, each customer and each product emission each the supplier should not exceed the maximum acceptable level of environmental impacts. Constraint (6) guarantees that orders of each product in each period under each scenario should not be more than the Maximum Allowable Level (Supplier's Capacity). Constraint (7) determines the allocation of the order to suppliers for the selected suppliers. Constraint (8) indicates the possible range for assigning orders to suppliers. Constraint (9) presents the binary variables.

4. Solution approach

The proposed model in this study is a fuzzy multi-objective scenario-based stochastic, stochastic programming. It can consider based on a crisp possibilistic model. As can be seen from sentences of (1)-(3), all objective functions have fuzzy parameters. Hence, according to the presented approach by Feng et al. [8], these sentences are transferred into crisp numbers, as (10)-(18).

$$Min \sum_s \sum_i \sum_j \sum_k \sum_t \rho_s \left(\frac{e^{s\ \ a}_{ik} + 4e^{s\ \ b}_{ik} + e^{s\ \ c}_{ik}}{6}\right) X^{t\ \ s}_{ijk} \ Y^t_{ijk} \tag{10}$$

$$Min \sum_s \sum_i \sum_j \sum_k \sum_t \rho_s \left(\frac{p^{t\ \ a}_{ik} + 4p^{t\ \ b}_{ik} + p^{t\ \ c}_{ik}}{6}\right) X^{t\ \ s}_{ijk} \ Y^t_{ijk} \tag{11}$$

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$$Max \sum_s \sum_i \sum_j \sum_k \sum_t \rho_s \left(\frac{CL_{ik}^{s\ a} + 4CL_{ik}^{s\ b} + CL_{ik}^{s\ c}}{6}\right) X_{ijk}^{t\ \ s} Y_{ijk}^{t} \tag{12}$$

S.t.

$$\sum_i X_{ijk}^{t\ \ s} Y_{ijk}^{t} = \left(\frac{D_{jk}^{t\ a} + 4D_{jk}^{t\ ab} + D_{jk}^{t\ ac}}{6}\right) \qquad \forall\, s, j, k, t \tag{13}$$

$$\sum_j \sum_k \sum_t \left(\frac{e_{ik}^{s\ a} + 4e_{ik}^{s\ b} + e_{ik}^{s\ c}}{6}\right) X_{ijk}^{t\ \ s} Y_{ijk}^{t} \le E \qquad \forall\, s, i \tag{14}$$

$$\sum_i X_{ijk}^{t\ \ s} Y_{ijk}^{t} \le C_{ik}^{t} \qquad \forall\, s, j, k, t \tag{15}$$

$$X_{ijk}^{t\ \ s} \le Y_{ijk}^{t} \qquad \forall\, s, i, j, k, t \tag{16}$$

$$X_{ijk}^{t\ \ s} \ge 0 \qquad \forall\, s, i, j, k, t \tag{17}$$

$$Y_{ijk}^{t} \in \begin{cases} 0 \\ 1 \end{cases} \qquad \forall\, i, j, k, t \tag{18}$$

5. Solution algorithms

The introduced model in this research is classified into the Set Covering Location Problem (SCLP) that is recognized as NP-hard [9].

Typically, there are two main solution approaches to unravel multi-objective mixed integer programming problems, exact and heuristic/meta-heuristic algorithms [25]. Several exact solution algorithms such as the LP-metric [23] and weighed sums methods [3] have been proposed to find Pareto optimal solutions for the SSOA problem. However, considering that the exact solution algorithms might require a long computational time for solving large-size problems, those cannot tackle the large-size problem cases [7].

As the large-sized cases of SSOA problems are identified as NP-hard problems, heuristic/meta-heuristic algorithms are the best options for solving these problems [9]. In contrast, heuristic/ meta-heuristic solution algorithms can make near-optimal solutions for large-sized problems in lowercan make near-optimal solutions for large problems in less time. In this regard, several metaheuristic algorithms, such as Genetic Algorithm (GA) [33] and Simulated Annealing (SA) [22], memetic algorithms [13] have been developed for this problem. Hence, according to several papers, meta-heuristic optimization algorithms are a better approach to solving the multi-objective NP-hard models [10]. In this paper, we used two MOEAs, Multi-objective Simulated Annealing meta-heuristic (MOSA) and Non-Dominated Sorting Genetic Algorithm-Ⅱ (NSGA-Ⅱ), to settle the presented model.

5.1. Non-dominated Sorting Genetic algorithm-II

The NSGA-II algorithm is an elitist population-based metaheuristic algorithm. The pseudo-code of the NSGA-II algorithm is presented in Figure 1.

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```
Input:
    1. N'
    2. g                                  (N' member evolved g generation to solve f_k(x))
    3. f_k(x)
Initialize Population (P');
Generate random population- size (N');
Evaluate Objective Values;
Assign Rank (Level) based on Pareto-sort;
Generate Child Population;
Binary Tournament Selection;
Recombination and Mutation;
For  i = 1  to g  do
        For each Parent and Child in Population do
            Assign Rank (Level) based on Pareto-sort;
            Generate sets of non-dominated solutions;
            Determine Crowding distance;
            Loop (inside) by adding solutions to next generation starting from the first front until
            N' individuals;
          End
          Select points on the lower front with high crowding distance;
          Create next generation;
          Binary Tournament Selection;
          Recombination and Mutation;
End
```

Figure 1. The pseudo-code of the NSGA-II algorithm

5.1.1. Parameters of NSGA-II

For the population-based metaheuristic algorithms (Such as: NSGA-II), the initial solutions and operators play an essential role in the productivity of the algorithm. In this paper, the initial solutions of the NSGA-II algorithm are randomly generated. Also, the search progress in the NSGA-II algorithm is accomplished by three fundamental breeding operations (selection, crossover, and mutation).

- Selection: In this paper, a binary tournament is utilized. For this operator, two individuals are randomly selected from the population and then are compared with others. The best dominant individual is nominated as the first parent. A similar process is accomplished to find all parents.
- Crossover: The crossover operator in this paper is a uniform crossover. At first, two parents are selected. If the parents' chromosome valume is more than the probability of combination, the first offspring get the gene at index i from parent 1, and the second offspring get the identical index from parent 2. But if it is not, this process is reversed. This type of crossover operator is demonstrated in Fig. 2.

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Choromosome 1 (Parent 1)	1	0	0	1	0
Choromosome 2 (Parent 2)	0	0	1	1	1
Random Numbers String	0.52	0.68	0.89	0.13	0.94
Probability of Combination (0.72)	<0.72	<0.72	>0.72	<0.72	>0.72
Offspring 1	0	0	0	1	0
Offspring 2	1	0	1	1	1

Figure 2. Crossover operation

- Mutation: For the mutation operator, after selecting for a chromosome for each genome of the chromosome, a random number is created. Should this number be less than the mutation rate, the genome will be altered randomly; otherwise, the genome will not mutate. The mutation operator is shown in Fig. 3.

Choromosome (Parent)	1	0	0	1	0
Random Numbers String	0.69	0.22	0.51	0.11	0.09
Probability of Mutation (0.28)	>0.28	<0.28	>0.28	<0.28	<0.28
Offspring	1	1	0	0	1

Figure 3. Mutation operation

5.2. Multi-objective Simulated Annealing meta-heuristic

Multi-objective Simulated Annealing meta-heuristic algorithm is a randomized search of the solution space to find an optimal solution [20]. In the MOSA algorithm, the material is warmed and then slowly is cooled. The material sizes are impacted by cooling rate. with this mechanism, alterations in energy power are simulated until a frozen steady state is attained. In this paper, into the number of iterations (K), the temperature is fixedthe temperature is fixed into the number of

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iterations (K). Then, it is decreased by a cooling rate (α) (α ∈ (0,1)). The pseudo-code of the MOSA algorithm is presented in Figure 4.

```
Input:  population, number iterations, α (cooling factor)
max_fitness = maximal_fitness(population);
min_fitness = minimal_fitness(population);
diversity = max_ fitness − min_ fitness ;
temperature = 1 / diversity;
new_population = create_empty_population();
i = 1;
while (i ≤ size(population)) do
solution = get_solution(population, i);
if ( fitness(solution, population) ≠ max_fitness ) then
new_solution = multi_objective_simulated_annealing_algorithm(solution, temperature,
number_iterations, α, population);
else
new_solution = solution;
end if
add_solution(new_population, new_solution);
i = i + 1;
end while
population = new_population;
End
```

Figure 4. *The pseudo-code of the MOSA algorithm*

6. Computational results

In this section, five numerical problem is solved that the heuristic algorithms are coded by MATLAB 2013 software. The experiments are divided into three categories (small, medium, and large) based on the number of suppliers and products (Table 3). The parameter values are randomly selected in uniform fashion (Table 4). The algorithm is performed by software MATLAB R2017a and runs on a 2.20 GHz Intel(R) Core i7 machine with 16 GB RAM. To tune the parameters of the algorithms, a Trial and Error process was completed by the suggested values in Table 5

Table 3. Size of experiments

	Experiment	I	J	k	T
Small	1	3	3	3	3
	2	4	4	4	4
	3	6	6	6	6
	4	8	8	8	8
	5	10	10	10	10
Medium	6	12	12	12	12

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	7	14	14	14	14
	8	16	16	16	16
	9	18	18	18	18
	10	20	20	20	20
	11	25	25	25	25
	12	30	30	30	30
Large	13	35	35	35	35
	14	40	40	40	40
	15	50	50	50	50

Table 4. Parameters values for all examples

Parameter	**Range**
${e_{ik}^{1}}^{a}$, ${CL_{ik}^{1}}^{a}$, ${P_{ijk}^{t}}^{a}$	[1000, 1500]
${e_{ik}^{1}}^{b}$, ${CL_{ik}^{1}}^{b}$, ${P_{ijk}^{t}}^{b}$	[2000, 2500]
${e_{ik}^{1}}^{c}$, ${CL_{ik}^{1}}^{c}$, ${P_{ijk}^{t}}^{c}$	[3000, 3500]
${e_{ik}^{2}}^{a}$, ${CL_{ik}^{2}}^{a}$	[5000, 5500]
${e_{ik}^{2}}^{b}$, ${CL_{ik}^{2}}^{b}$	[6000, 6500]
${e_{ik}^{2}}^{c}$, ${CL_{ik}^{2}}^{c}$	[7000, 7500]
E	10000
ρ_s	0.50
C_{ik}^{t}	[10000, 15000]
${D_{jk}^{t}}^{a}$	[1000, 1500]
${D_{jk}^{t}}^{b}$	[1800, 2100]
${D_{jk}^{t}}^{c}$	[2500, 3000]

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Table 5. Levels of parameters of the NSGA-II and

	parameters	Levels			
		1	2	3	4
NSGA-II	Number of generations	300	**400**	500	600
	Population	150	200	**250**	300
	(Probability of combination, probability of mutation)	(0.65,0.05)	(0.70,0.0.04	(**0.75,0.03**)	(0.80,0.02)
	evolutionary rate	0.010	0.015	0.020	**0.025**
MOSA	Initial temperature	**150**	120	70	50
	Cooling rate (α)	0.95	**0.90**	0.85	0.80
	Number of iterations (K)	100	**90**	80	70

Table 6. Final obtained values of objective functions

NO	MOSA				NSGA-II			
	Z_1	Z_2	Z_3	Run time(S)	Z_1	Z_2	Z_3	Run time(S)
1	45221	37337	56247	64	44784	36113	57145	63
2	45103	36109	58199	65	43980	35967	58986	61
3	45896	35221	51011	62	44992	34024	52323	59
4	45781	38195	55199	69	45017	37145	56012	64
5	49854	36478	57502	71	49002	35869	58104	67
6	50129	37120	59011	74	49784	36358	59845	71
7	50993	37887	60545	83	50070	37120	61773	74
8	52476	38095	61452	81	50981	37864	62411	69
9	53899	39001	62070	92	51225	38425	63329	77
10	54078	39946	63457	97	51918	39052	64128	83
11	56121	41007	63992	105	52546	40819	65401	88
12	57378	41899	64230	113	53419	40758	66085	94

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13	58410	42113	66001	125	54207	41009	67948	109
14	59207	43140	66748	133	55143	41952	68112	117
15	60184	44657	67254	147	56230	42541	69485	125
Mean	52315	39214	60861	92	50220	38334	62072	81

According to the results in Table 6, the run time of all examples by MOSA is further than NSGA-II. In fact, the NSGA-II is faster than MOSA to discover the near-optimal solutions. Also, the NSGA-II provided more appropriate solutions than MOSA based on values of the objective function. The mean value of the first objective function, minimizing the total operating costs, for the NSGA-II, and MOSA are 50220 and 52315, respectively. For minimizing the environmental impacts of selected suppliers as the second objective, the NSGA-II lower values in comparisons with MOSA. So that the mean value of this function for NSGA-II is 38334 that is less than the mean value of MOSA with the amount of 39214, respectively. Furthermore, the superiority of NSGA-II is also evident in the third function. Indeed, the mean value of the function for the introduced NSGA-II is equal to 62072, which is 1211 units more than the mean value of MOSA algorithm. It can be understood that the NSGA-II algorithm creates better answers comparison with MOSA for the fuzzy- scenario based problem for solving supplier selection and order allocation model.

6.1. Managerial implication

Today competitive world highlights the necessity of optimal supplier selection and order allocation for most industrial and commercial companies. This paper focuses on increasing customer satisfaction and moderating costs in the supply chain under uncertainty. The proposed model is helpful for decision-makers' managerial boards to increase satisfaction in receiving their order and control uncertainty. In this model, uncertainty is considered, and controlled by presenting the fuzzy multi-objective scenario-based stochastic programming. As well as, cloud computing in complex networks is used to find the issue of big data management in businesses. Processing techniques are capable of obtaining insight to achieve the management of the data by finding patterns that support more impressive and efficient decision-making. Hence, customers trust the supplier with more power of cloud management. So, in this paper, suppliers' cloud management is considered an objective function.

7. Sensitivity analysis

In this section, attempts have been made to demonstrate the confirmation of the presented model. So, it is essential to check the model by altering the value of several parameters. The changes are listed, and the results are shown graphically in Fig.5 and Fig.6 .

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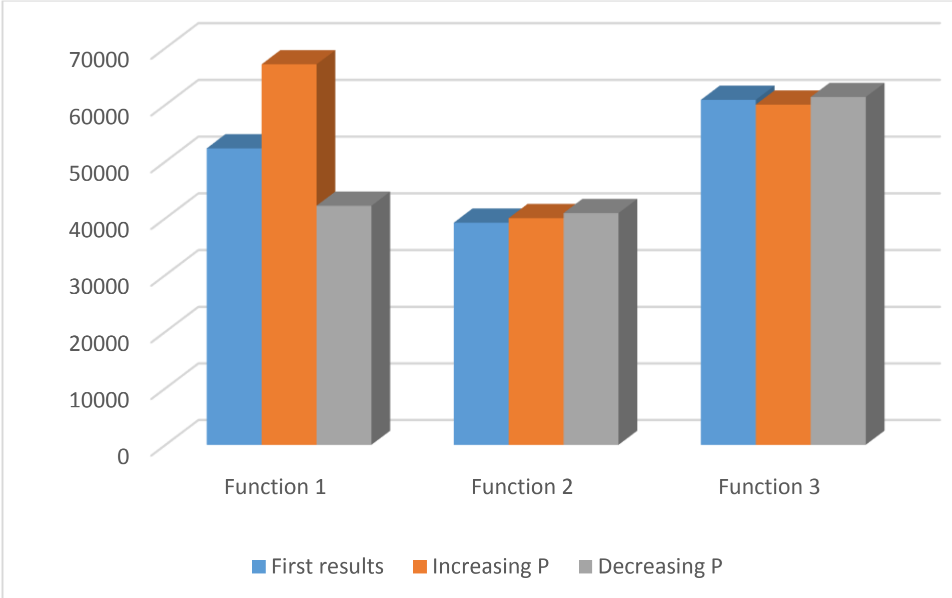

Figure 5. The results of functions with alteration values of P

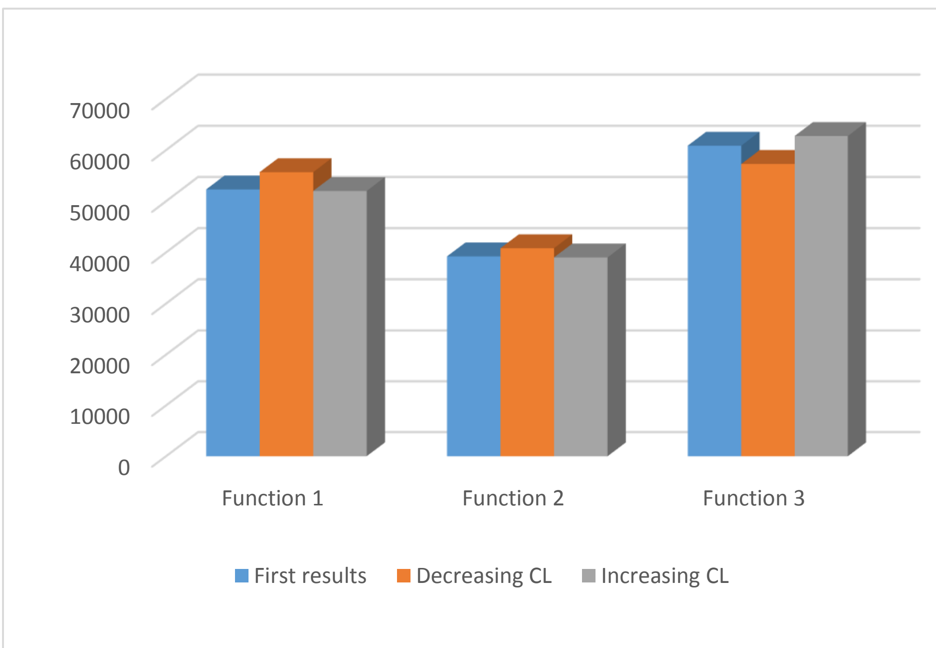

Figure 6. The results of functions with alteration values of CL

Obviously, in these examples, the value of functions changes with proportional of fluctuation for parameters. Indeed, all of them correctly respond to any alteration. Increasing and decreasing the values of P virtually impact relevant function. As well as, the changing of CL is an expected

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reaction on function 3. Eventually, it is distinct that the validity of modeling is proved with this analysis.

8. Conclusions

In this paper, we proposed a fuzzy multi-objective scenario-based stochastic programming for the problem of supplier selection and order allocation. The introduced model includes three objective functions: minimizing environmental of suppliers, total cost and, as well as, maximizing capability of cloud management of suppliers. Due to the progress of technology, cloud management capability is a vital approach for suppliers to have coherent control of cost, time and product quality. Hence, considering this ability is important for customers in selecting suppliers. Also, because of globalization and industrialization, nowadays, the environmental impacts of the supplier are a significant matter for customers. Two multi-objective evolutionary algorithms, MOSA and NSGA-II were used to settle this model that is classified into NP-hard problems. The results indicated that the NSGA-II algorithm creates a better answer than MOSA for this problem.

8.1. Limitations and future studies

One of the primary limitations of this paper is, using the proposed model with numerical examples. Therefore, it is highly recommended to perform this model for actual industrial cases in future studies. Another limitation of this study is the undefined disruptions. Indeed, Accordingly, in future studies, it is proper that disruptions are defined in a certain or uncertain mode.

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