Adv. Math. Fin. App., 2022, **7(**2), P. 293-312

Advances in Mathematical Finance & Applications

www.amfa.iau-arak.ac.ir
Print ISSN: 2538-5569
Online ISSN: 2645-4610
Doi: 10.22034/AMFA.2020.1881758.1326

Research Paper

A Bi Objective Optimization for Designing Sustainable Supply Chain Network Economic based Competition by Cost Management Approach

Reza Ehtesham Rasi*

Department of Industrial Management, Qazvin Branch, Islamic Azad University, Qazvin, Iran.

ARTICLE INFO
Article history:
Received 2019-11-06
Accepted 2020-02-09

Keywords:
Sustainability
Supply Chain Management
Optimization
Cost Management
Environmental

ABSTRACT

This paper presents an integrated mathematical model for cost – environmental based competition between sustainable supply chains (SCCs) with heterogeneous customers in four echelon supply with multi product. The main objective of this paper is to provide bi objective mathematical model for designing SSC network economic based competition and optimize by using meta-heuristic algorithms. Assuming the customers are heterogeneous in the above criteria i.e. cost and pollution decision making, we integrated mathematical model and formulated objectives and constraints based multi-echelon supply chain network. The main contribution of this research is to a discrete choice model is integrated into the sustainable supply chain network economic model and extends the inter supply chain competition to a new dimensions of cost and environmental. The model in this problem is solved using two metaheuristic algorithms NSGAII and MOPSO. Examples of real case study related to Emersan company is presented for model illustration and managerial insights such as profit maximization and minimize cost for Emersan company that participates in this supply chain network. Finally, NSGA-II performs better and has shorter time in terms of computational time, but MOPSO algorithm is more efficient in MID, SM, QM and DM indices. In comparison of these two algorithms, the performance of MOPSO algorithm is generally better than NSGAII by in indices.

1 Introduction

Nowadays, the intensification of the globally competitive world in a constantly changing environment will be dictated the need for appropriate responses from organizations and industrial manufacturing companies, and emphasize their flexibility with the unreliable external environment. According to Esfahbodi et al. [11], the issue of supply chain management (SCM) has become more socially and environmentally conscious and has evolved to not only embrace economic objectives but also to take social and environmental goals into account. Time-based competition in coordinating and controlling production and transportation SC network is an important strategic weapon that considers operations management academics and decision-makers in firms [19]. Sustainable procurement can have an impact on cost performance, as it involves collaboration with suppliers to acquire green materials and services

Corresponding author Tel.: +989122901128
E-mail address: *rezaehteshamrasi@gmail.com*

[8]. The role of suppliers is decisive for a firm's overall economic performance, as environmentally suppliers tend to give different price quotations to those not comparatively friendly [31]. SCM spends a lot of their time looking for ways to reduce cost. But one of the big challenges with SC is that things are often interconnected, so making a change in one area to lower cost can cause change somewhere else that actually increases the cost. Therefore, companies are seeking for cost reduction aimed at ensuring competitiveness. In manufacturing companies, SC expenses play big role in the cost of the final product [17]. Determining the cost of products can enable management to discern, which of its products is viable, which cost more, and contribute most to the bottom line. In fact, understanding the savings of product cost can be a key to improving the viability [14]. Logistics is a diverse and dynamic function that has to be flexible and change according to the various constrains and demands imposed upon it and respect to the environment, in which it works [26]. Below is the formula of logistics described theoretically: Logistics = Materials Management + Distribution. Nevertheless, logistics is a part of SC which describes the overall process and takes into account suppliers and customers. The theoretically described formula of supply chain [26]:

Supply chain = Suppliers + Logistics + Customers

Today's organizations in the national and international arena should acquire and maintain a suiTable place and for achieving to this aim, they need to use the models such as SCM to meet the competitive advantage and expectations of heterogeneous customers. An efficient SCM is one of the main factors in the survival of organizations, so that SC specialists are an inexhaustible effort to survive and maintain competitive power by using various mechanisms is seeking optimization in the chain, while using information technology (IT) on SC activities has increased the potential for value creation. In this regard, the use of modeling and solving mathematical models are using appropriate methods in terms of the type of problem that is posed, is one of the most widely used methods. Now, SC has become an important and vital factor in global markets, so that the main competition in the international realm is assumed among SCs. With the increasing environmental pollution and the importance of environment and community issues, efforts have been made to reduce the pollution and social impacts of industrial expansion as part of efforts to manage SSC. The concept of SSCM has been addressed in recent years. Decision making (DM) in SCM should be done with the estimation of different types of costs. It is high importance to understand the fundamental nature of costs in order to determine which to take into account with its particular behavior [19].

Sustainability is defined as the ability of an organization to make current decisions in such a way that these decisions do not have any detrimental effect on the future environment, society and business [12]. This definition states that sustainability has three dimensions that can be classified as the environment, economy and society dimensions. Social sustainability focuses on human rights, education and justice while economic sustainability is sought to maximize revenue through the use of minimum of assets or capital and resources [21]. In this paper, Contrary to research of [11, 31], researchers tried by rising of the sustainability concept, companies are tended to provide sustainability reports. Delivering sustainability reports allows companies to highlight the success of their programs and clarify their attitude towards customers, shareholders, employees and their counterparts. As a result, SSCM is integrating SCM with environmental and social requirements at all stages of product design, selection and supply of raw materials, production and fabrication, distribution and transfer processes, customer delivery and management of recycling and reutilization in order to maximize the amount of energy efficiency and resources associated with improving the overall SC performance.

The design of supply chain network as the most important decision at the strategic level plays an important role in the sustainability of supply chain network. The main contributions of this research are as follows:

- An integrated mathematical model proposed for cost – environmental competition between SSCs with heterogeneous customers in four echelons supply with multi product;
- A discrete choice model is integrated into the supply chain network economic model and extends the inter supply chain competition to a new dimensions of times and environmental.

The remainder of this paper is as follows: section 2 presents a literature review regarding SSCM by cost management approach to reduce cost and emissions. Section 3 describes the proposed problem and presents its mathematical formulation. The proposed algorithm based on the NSGAII and MOPSO metaheuristic is detailed in section 4. The computational results, conclusion and suggestion for future research are shown in section 5.

2 Literature Review

In this section, a short review of SSC network economic model is given with special regard to cost and environmental based on competition with multi products. At the end of this section, five specific papers in the literature are reviewed related to SSCM. Supply chain management (SCM) is a set of methods used to effectively and efficiently integrate suppliers, manufacturers, warehouses and vendors, in such a way that in order to minimize system costs and fulfill the needs of goods and services, produce and distribute goods and services at the right place and time [22]. In a supply chain, all steps, directly or indirectly engage in the fulfillment of customer demands. The SCs are the new battlefields for competition. Inventory is the latest reason for eliminating imbalances among different categories of suppliers. SCM is flow management between different stages in a chain with the goal of maximizing overall profitability. In this chain, suppliers usually are simultaneously members of several chains and therefore often play different roles. Thus, SCM is a multiplier system that uses IT to moderate communications between some of the key business processes of companies, as well as suppliers, consumers and their business partners to decrease costs. Most SC managers spend their time looking for ways to reduce costs. But one of the big challenges with SCs is that things are often interconnected, so making a change in one area to lower costs can cause a change somewhere else that actually increases the cost. That’s not to say that you shouldn’t look for cost-savings opportunities.

There are four decisions areas that drive most of the costs in any SC i.e. Procurement, quality, inventory and transportation costs[30].The literature review considers the mathematical optimization models, few of which consider all levels of the gas SC and most of which focused only on one or some parts of the SC in their mathematical models. At the first time Duffuaa et al. [34] studied in this area of SCM in oil and gas that developed a linear programming model for the oil and gas SC [34]. According to previous research in SCM has explored the relationships between the adoption of SSCM practices and performance implications, including operational, environmental and economic performance. Existing literature has offered insights into potential patterns of SSC initiatives for improving environmental performance [13]. The literature supporting such positive relationships is relatively strong. Zhu et al. [33] suggested that relations with suppliers aid the adoption and development of innovative environmental technologies. According to Yusuf et al. [31], performance measures are important to companies in SCs in order to evaluate performance against set objectives and identify loopholes in performance. Opinions on whether SSCM practices cause or relate to positive or negative economic performance are still mixed [32].

Fig. 1: Supply chain cost derivers [30]

Rao and Holt [24] indicated that greening the SC leads to improved economic performance. However, Bowen et al. [6] suggested that SSCM practices are not being reaped in terms of short term profitability and financial performance. The evaluation and selection of conventional SCs has been based solely on economic criteria. Price, product quality and flexibility have been some of the traditional economic criteria [3]. Nevertheless, in recent years, there has been global pressure on SCs to focus not only on economic criteria, but also on social and environmental standards. SSCM is combination of new criteria which combine environmental and social with economic criteria. Many companies seek to improve their working conditions and produce environmentally friendly goods [4]. According to [4], several definitions of SSC are presented, which may be described in a comprehensive way: material, information and capital flows management; cooperation among companies along the supply chain in the direction integrating goals from all three economic, environmental and social dimensions; as well as SSCM considers to be a management philosophy and as a set of management processes[5].Roy et al. [25], SSC involves “the management of financial and non- financial measures as well as the encouragement of good leadership practices within the SCs”. Marshall et al. [20] believe that SSC is a set of practices aimed at minimizing the environmental impacts and enhancing the social welfare of different stakeholders while contributing to the long-term financial growth of the entities within the SC. Gey et al. [29] believe that there is difference between green and SSC paradigms and contend that GSC paradigm involves practices aimed at minimizing the environmental impacts of the SC whilst SSC encompasses the triple-bottom line of environmental, social and economic objectives.

The Bright Land Report can be considered as the starting point for papers on SSC. Subsequently, in 2001- 2003, seven papers were published in the journal "Greener International Management”. Various articles are also featured in magazines such as Operations Management Magazine, International Journal of Production Research, International Journal of Production Economics, and Cleaner Magazine. This demonstrates the broad acceptance of this issue among researchers. Published articles are distributed equally in journals related to sustainable and environmental management with magazines in the field of traditional operations and SCM. While this issue in articles related to ethical and social issues remains in the minority. Also, series of articles in this area are in journals that mainly technical is in nature, but include topics related to natural resources and politics. Environmental literature consists of three journals that have provided many articles in this field. The magazine "Cleaner Production" is in the first place, then the magazines "Green Management International" and "Business and Environment Strategy" rank second and third respectively. In the operational texts, more journals have been active in this field, including: International Journal of Operations and Production Management, International Journal of

Supply Chain Management, Operations Management Magazine, Production Management and Operations Management, International Journal of Production Research, and Supply Chain Management Magazine (formerly International Journal of Purchasing and Materials Management) [28].From the point of view of methodology for conducting research, the articles in this field can be classified into five general categories:

1. Conceptual and theoretical articles such as [16], [24];
2. Case studies such as [2];
3. Surveys like [35];
4. Modeling articles like [15];
5. Literature review articles [28];

Masoumi et al. [18] provided a methodological framework for the quantifiable assessment of total cost efficiency related with a merger or acquisition in the blood banking industry, which is experiencing a volatile environment, as well as measures capturing the expected supply shortage and surplus. The network optimization pre- and post-merger models handle perishability of the life-saving product of blood, include both operational and discarding costs of waste, capture the uncertainty associated with the demand points, as well as the expected total blood supply shortage cost and the total discarding cost at demand points.Nagurney et al. [21] developed SC network game theory model consisting of retailers and demand markets with retailers competing in order to maximize profits by determining their optimal product transactions as well as cybersecurity investments subject to nonlinear budget constraints that include the cybersecurity investment cost functions.

Rasi [22] attempted to determine the value of goods sent between return processing canters in any period of time in order to minimize the total cost and time of delay within supply chain. The fuzzy approach was adopted in order to consider uncertainty in reverse logistics network. Zamanian et al. [32] a real case study of the natural gas supply chain has been investigated. Using concepts related to natural gas industry and the relations among the components of gas and oil wells, refineries, storage tanks, dispatching, transmission and distribution network, a seven-level SC has been introduced and presented schematically. They optimized a case study using a fuzzy goal programming multi-period model considering environmental and economic costs and revenue as fuzzy goals and maximize the total degree of satisfaction of goals as objective function.

Table 1: Statistcs of research in SSCM

Row	Study type	Number of research	frequency percentage
1	Conceptual studies	177	17%
2	Research based on secondary data	229	21%
3	Case studies	180	17%
4	Mathematical Models	424	40%
5	library reviews	58	5%
Total		1068	

Gossler et al. [12] due to restricted budgets of relief organizations, costs of hiring transportation service providers steer distribution decisions and limit the impact of disaster relief. To improve the success of future humanitarian operations, it is of paramount importance to understand this relationship in detail and to identify mitigation actions, always considering the interdependencies between multiple independent actors in humanitarian logistics. In a statistical study of research on SSC and its dimensions in 2016, it is seen that studies in this area are relatively low and is needed further research. The following Table shows the thematic distribution of research on SSC from 2000 to 2015, which is extensively extracted from 1068 filtered articles. In mathematical models; mixed integer linear programming (MILP), non-linear modeling and heuristic models have the highest frequency. From the point of view of noticing the various dimensions of sustainable development, the articles in this field can be classified into three categories:

1. Articles that address environmental issues in addition to economic ones. (Most articles are this), such as [7].
2. Articles that address social issues in addition to economic ones. Such as papers [9].
3. Articles that deal with all three aspects of economic, environmental and social issues. (Few articles have been devoted to all three aspects.), Such as [37], [28].

Table 2: Overview of key scientific literature according to relevant research

Criteria	SCNE Model	Supply chain Economy Model	Risk Management	Quality Management	Environment Protection	Healthcare	Society
Masoumi et al. [18]		X				X	
Nagurney et al. [21]	X			X	X		
Rasi [22]	X	X		X			
Gossler et al. [12]	X		X		X		
Zamanian et al [32]		X			X	X	X
Wang et al [29]	X	X		X	X	X	

The contributions of the proposed model consist of both the mathematical formalization that allows for the inclusion of several complex and interlinked supply and demand features and the computational results that illustrate its practical applicability for managers and practitioners, particularly so from a strategic perspective. The interactions taking place between the different supply related processes and demand-oriented decisions by cost management approach encompass the main set of characteristics that must be considered by a firm, particularly when competing strategically within a given market. Differently from previous studies, the profit (objective) function will be simultaneously determined by supply and demand based factors: conventional sales, internet sales and staff employed by the company. In particular, internet sales, which are customer-centric, will be assumed to have three different formats: posted price, pure auction, and buy-price auction.

The logic for the inclusion of online sales is based on the customer behavioral strategy, where it is assumed that customers have full authority to choose their purchasing method (online or conventional) from the distribution centers. In this regard, Potential customers will consider multiple product attributes when maximizing their utilities. These attributes can be classified within three main categories regarding the price, quality and warranty of the products, increasing competition due to the potential demand requests placed on the different distribution centers. The framework of the paper is shown in Fig. 2.

3 Problem Statements

In this section, the problem at hand is explained. Hence, the assumptions are explicitly outlined, and the proposed mathematical model is described in detail as following.

3.1 Problem Description

The SSC network proposed in this paper is an economic model with cost and environmental based competition that consists of four echelons in the forward and reverse SSCM.Customer orientation, marketing, distribution, production planning, and procurement in organizations are working independently and in the SC paralley. Although each of these organizations has its own goals and often these goals are in contradiction with another chain, so there needs to be a way to align these different goals. But all of companies have one goal to gain shareholders and customers satisfaction. In a SC design problem, we are looking for the following outputs for the issue:

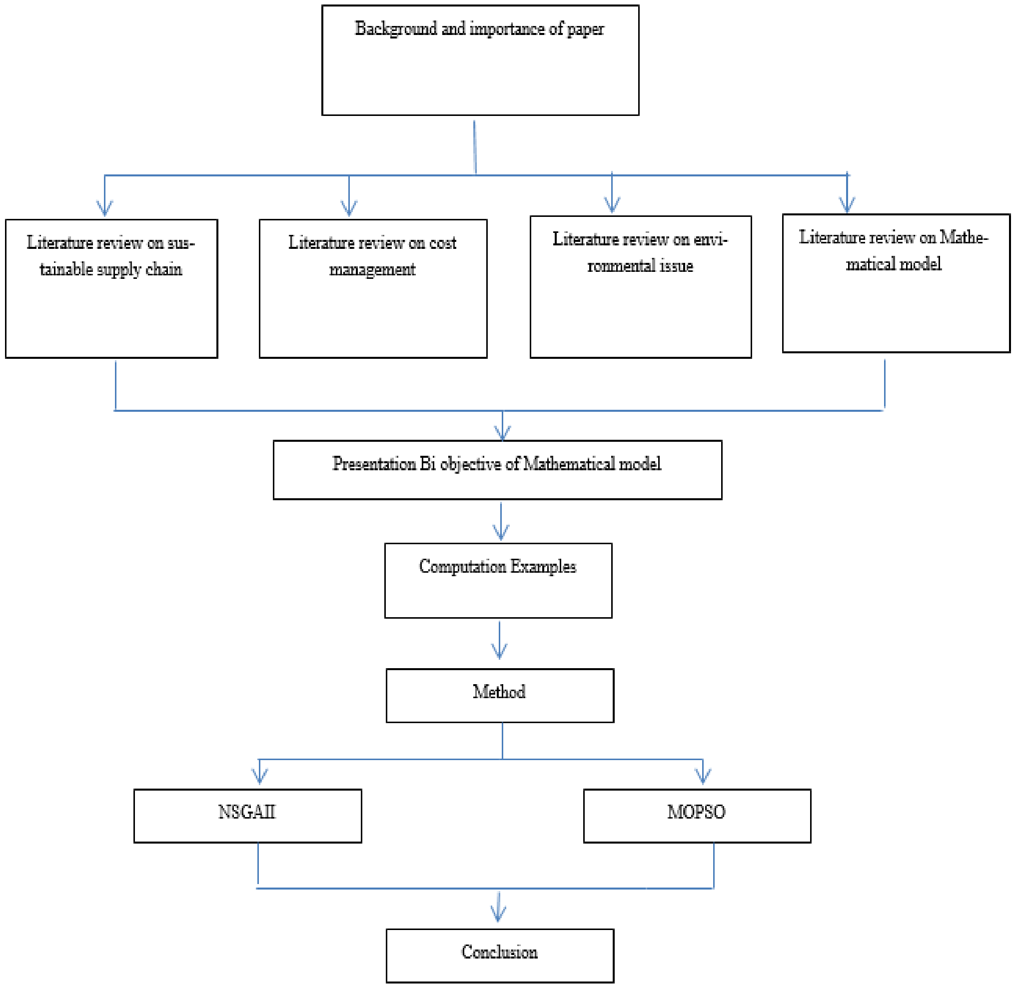

Fig. 2: The framework of the paper

Selecting suppliers, manufacturers, distribution canters, and determining the optimal transportation way for the transfer of raw materials to the factory, are moving goods to distribution canters and carrying goods, and their delivery to the customer, an optimization approach to maximize profits and pricing products with definite time-consuming demand, and finally minimizing time. Efforts have been made to model four-echelon SC networks with different assumptions; each of them has been resolved in a different way. We consider a general SC network of four different echelon including customers, distribution centres, plants, and suppliers. Customers are at the first level while at the second level there are distribution centres which transport number of products to the customers. At the third level, there are producers which provide the products for distribution centres and at the fourth level, suppliers are located which give raw materials to the producers.

Zhang & Chen [34] considered these issues in NP-Hard problems, such as multi-choice backpack problems and location-allocation issues. Amiri [1] presented a heuristic method based on the Lagrange method to minimize the cost of the network for two-echelon models. The optimal structure of the production and distribution network with operational and financial constraints was presented by Amiri [1]. Chen et al. [10] examined the design problem of an integrated CLSC network by taking into account chain costs and environmental concerns in the solar industry from the sustainability perspective. Their proposed model includes practical features, such as flow protection in each production/recycling unit whether in the direct or in the reverse flow, expansion of capacity, and recycled parts. The results of the analysis indicate that a company must adopt a proper recycling strategy or energy-saving technology to achieve an optimal economic efficiency due to regulations pertaining to carbon emissions. A multi objective genetic algorithm (GA) has been used to solve SC design problems effectively. The first attempt was made by Zhou & Wang [35] to use the GA to solve SC design model for the problem of balancing allocations to customers with disorderly and multiple distributions. Chen et al. (2017) solved the multi-criteria single-product, two-echelon SC model by using GA and hierarchical analysis method. She provided GA to minimize the total cost of transport for three-echelon distribution network. In order using GA, Chen et al. [10] offered solution to the problem of designing multi-objective SC.

The problem of this paper is to minimize all of costs and pollution of environment. In this research a multi-objective model of three-echelon SSC is presented, and it's used metaheuristic algorithms to solve it. We want to response to this question, how to provide a mathematical model to optimize cost and pollution base on competition in four echelons SSC network?

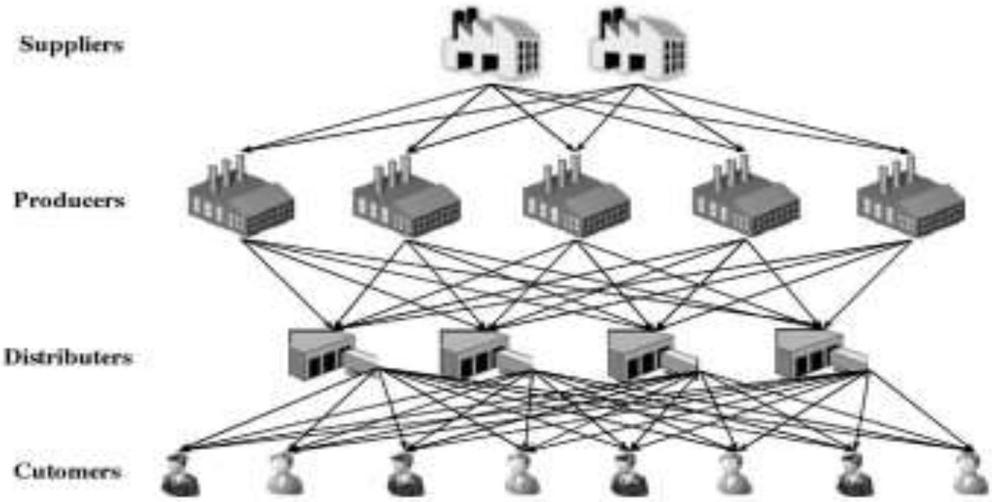

Fig. 3: Four-echelon supply chain networks

3.2 Assumptions

- A multi-echelon and multi-product problem is modelled (number of suppliers, producers, distributors, customers, products, time periods and TSs)
- Cost of making raw material and products and their transporting and holding cost.
- There is four- echelon in this SSC.
- The location and number of suppliers, manufacturers, distribution centers and retailers are specific.
- The flow of materials is only between two successive levels of network layers.
- The capacity of each facility (supplier, manufacturer, distributor and retailer) is specific.
- The amount of demand and the rest of the existing parameters are definitive.
- Each retailer can receive a product from only one wholesaler for each product.

3.3 Mathematical Formulation

Indices

- T: period, t = 1,2, ..., T
- J: Type of product produced, j = 1,2, ..., J
- I: Type of raw material, i = 1,2, ..., I
- Q: Quality of the raw material type, q = 1,2, ..., Q
- K: raw material supplier, k = 1,2, ..., K
- M: Factory of producing, m = 1,2, ..., M
- D: Distributor, d = 1,2, ..., D
- Z: retailer, z = 1,2, ..., Z.

Parameters

- C_{tiqkm}: The cost of purchasing, shipping, and transporting raw materials I of Q quality from supplier K to factory M in the period T.
- C_{tjmd} : The cost of producing, storing and delivering the product J from factory M to distributor D during period T.
- C_{tjdz} : The cost of maintaining and delivering the product J from the D distributor to the retailer Z in the T period.
- C_{tjd} : Maintenance of each unit of the product J from the distributor D in the period T.
- DA_{tjz}:The demand for the product J from the retailer Z in the period T.
- CA_{tik} : Supplier's capacity K for raw materials I in the period T
- CA_{tjm} : Capacity of factory M for product J in period T
- CA_{tjd} : Capacity of Wholesale D for product J in period T
- U_{ij} : The rate of use of each unit of product type J from the primary substance of type I
- R_{iq} : The amount of contamination caused by the primary substance of type I with the quality Q
- P_{tjz} : The product price J in retailer Z in period T

Among the above mentioned parameters, R_{iq} refers to the mass of non-renewable raw material used in the production of each product and its unit is optional.

Variables

- S_{tjz} : The number of product J sold by the retailer Z during the T period.
- X_{tiqkm} : The quantity of raw material I, with quality Q shipped from supplier K to the factory M during the period T.
- X_{tjmd} : The quantity of product J shipped from factory M to distributor D during the period T.
- X_{tjdz} : The quantity of product J shipped from the distributor D to the retailer Z in the period T.
- X_{tjd} : The quantity of product J in the distributor's warehouse D in the period T.
- W_{tjdz} : 0-1 variable for sending a product from a distributor D to a retailer Z in the period T.

Objective Function:

$$maxZ = \sum_T \sum_J \sum_Z P_{tjz} . S_{tjz} - \sum_T \sum_I \sum_K \sum_Q \sum_M C_{tiqkm} . X_{tiqkm} - \sum_T \sum_J \sum_M \sum_D C_{tjmd} . X_{tjmd} - \sum_T \sum_J \sum_D C_{tjd} . X_{tjd} - \sum_T \sum_J \sum_D \sum_Z C_{tjdz} . X_{tjdz}$$

$$minZ = \sum_T \sum_I \sum_K \sum_Q \sum_M R_{iq} . X_{tiqkm}$$

In the first objective, we want to maximize profit i.e. The total profit is equal to the total sales revenue minus "the total cost of procurement, purchasing and transporting raw materials from suppliers to factories and minus the total cost of producing, storing and delivering products from factories to distributors and minus the total cost of maintaining the product in the distributor's warehouse and finally minus the total cost of delivering the product from the distributors to retailers". In the second objective, the second objective function has been added to the problem model by reducing the level of pollutant production by selecting raw materials with lower emission rates.

Constraints of Model:

$$X_{tjdz} \leq EW_{tjdz} \quad (1)$$

The first constraint ensures that X_{tjdz} can be set when the W_{tjdz} binary variable has a value of 1 or 0. (E is a large positive number).

$$S_{tjz} \leq DA_{tjz}; \ \forall \ t, j, z \quad (2)$$

The quantity of product sold in each smaller period is less equal the amount of demand in the same period.

$$S_{tjz} \leq \sum_D (X_{tjzd}); \ \forall \ t, j, z \quad (3)$$

The quantity of product sold in each smaller period is less equal the amount of product available from the distributor to the retailer.

$$\sum_z X_{tjdz} = X_{tjd} \; ; \forall\, t, j, d \qquad (4)$$

The amount of product shipped from each distributor to each retailer is less equal to the inventory of each distributor's stock.

$$\sum_d W_{tjdz} \le 1 \; ; \forall\, t, j, z \qquad (5)$$

Each retailer can receive one product from only one wholesaler for each product.

$$\sum_z X_{tjdz} \le CA_{tjd} \; ; \forall\, t, j, d \qquad (6)$$

The amount of product shipped from each distributor to each retailer is less equal the capacity of each distributor.

$$\sum_m X_{tjmd} = X_{tjd}; \; \forall\, t, j, d \qquad (7)$$

The amount of product shipped from the factory to each distributor is equal to the amount of product available in the distributor's warehouse in each period.

$$X_{tjd} \le CA_{tjd} \; ; \forall\, t, j, d \qquad (8)$$

The quantity of product inventory in each distributor is less equal the distributor's storage capacity.

$$\sum_D X_{tjmd} \le CA_{tjm} \; ; \forall\, t, j, m \qquad (9)$$

The amount of product shipped from each factory to smaller distributors is less equal the capacity of each plant.

$$\sum_D \sum_J U_{ij}.X_{tjmd} = \sum_K \sum_Q X_{tiqkm} \; ; \forall\, t, i, m \qquad (10)$$

The amount of raw material consumed in each plant is equal to the amount of raw material shipped from the supplier to the factory.

$$\sum_M \sum_Q X_{tiqkm} \le CA_{tik}; \; \forall\, t, i, k \qquad (11)$$

The amount of raw material shipped from each supplier to smaller factories is less equal to the capacity of each supplier. The following constraints of (12-17) demonstrate nonnegative or zero or one variables and the last constraints are related to the binary (0, 1) variable.

$$S_{tjz} \ge 0, \quad Int \quad \forall\, t, j, z$$

$$X_{tiqkm} \ge 0 \quad \forall\, t, i, q, k, m$$

$$X_{tjmd} \ge 0, \quad Int \quad \forall\, t, j, m, d$$

$$X_{tjd} \ge 0, \quad Int \quad \forall\, t, j, d$$

$$X_{tjdz} \ge 0, \quad Int \quad \forall\, t, j, d, z$$

$$W_{tjdz} = \{0, 1\}$$

4 The Metaheuristic Algorithms

In this research, optimal solutions cannot be achieved using basic methods, and the solution of the developed model cannot be reached with the final solution using appropriate software. The reason is that such methods in the face of these problems, especially in large dimensions, encounter problems such as time consuming, falling into local optimizations and inability to exit, so this is part of the NP-hard issues group. The problem in this research goes under the rubric of NP-hard category, which cannot be solved by applying exact methods. To solve such problems, heuristic and meta-heuristic methods based on optimization of hybrid problems were applied. In multi-objective optimization, there are several different objective functions that tend to be minimized or maximized related to each other simultaneously. Often these goal functions are located at the opposite point, so that one of them improves if the other deteriorates. Therefore, in such problems, sets of optimal responses are obtained that are called optimal Pareto points or Pareto curve. To obtain the Pareto frontier, objective function values must be calculated for all solutions. One of the axes is the cost function values; another is pressure function values. Then the calculated points will be located from a scatter diagram. The line that is fitted to the points will be the Pareto curve. In this study, the values of the objective functions are calculated.The objective functions are said to be conflicting, and there exists a (possibly infinite) number of Pareto optimal solutions. A solution is called non dominated, Pareto optimal, Pareto efficient or no inferior, if none of the objective functions can be improved in value without regrading some of the other objective values. Without additional subjective preference information, all Pareto optimal solutions are considered equally good (as vectors cannot be ordered completely). Researchers study multi-objective optimization problems from different viewpoints and, thus there exist different solution philosophies and goals when setting and solving them. The goal may be to find a representative set of Pareto optimal solutions, and/or quantify the trade-offs in satisfying the different objectives, and/or finding a single solution that satisfies the subjective preferences of a human decision maker (DM).
Solving a multi-objective optimization problem is sometimes understood as approximating or computing all or a representative set of Pareto optimal solutions. To improve NPD activities in a SC network the proposed multi-objective model has to be solved. Since, the model was presented in this study is bi-objectives and have many uncertain parameters, and because of its high complexity and also it is NP-hard; the metaheuristic algorithm has been used to solve it. In this study, in order to evaluate two validation processes, valid mathematical models presented by leading researchers in mathematical modeling of SSC problems have been used as the basis of the model design. In order to solve the mathematical model, the meta-heuristic non-dominated sorting genetic algorithm (NSGAII) and multi objective particle swarm optimization (MOPSO) algorithms are utilized, which has been one of the most widely used multi-objective optimization methods in recent years. Five test problems of different sizes (small, medium and large) will be generated and solved by these two meta-heuristics (both of them coded in MATLAB 2019b version) as well as using the General Algebraic Modeling System (GAMS) software. According to previous studies, in this paper we want to compare the algorithms. Therefore four indices are used which are presented as below.

4.1 Criteria for Comparison of Multi-Objective Algorithms

In general, to solve a multi-objective problem, an algorithm deals with two contradictory goals, including convergence to Pareto optimal solutions and variation among the set of solutions that have two distinct and somewhat opposite objectives in multi-objective evolutionary algorithms. Therefore, user expects a good multi-objective optimization algorithm to find solutions close to the actual optimal solution with the same uniformity throughout the Pareto optimal region. If we can find a criterion by which we obtain the closeness of the final solutions to Pareto optimal solutions, and also another criterion by which we can determine the density of the solutions, then we can measure the performance of the two algorithms. In this research, four evaluation criteria have been investigated as following:

Mean Ideal Distance Index (MID): This criterion is used to calculate the mean distance of the Pareto responses of the best obtained for each objective function. As we can see, the lower the benchmark, the more efficient of the algorithm will be as following:

$$MID = \frac{\sum_{i=1}^{n} \sqrt{\left(\frac{f_{1i} - f_1^{best}}{f_{1\,total}^{Max} - f_{1\,total}^{Min}}\right)^2 + \left(\frac{f_{2i} - f_2^{best}}{f_{2\,total}^{Max} - f_{2\,total}^{Min}}\right)^2}}{n}$$

In the above equation, n is equal to the number of Pareto points, $f_{i.total}^{max}$ and $f_{i.total}^{min}$ equal to the maximum and minimum values of the target functions among all the algorithms being compared, respectively. Also, (f_2^{best}, f_1^{best}) is the coordination of the ideal point.

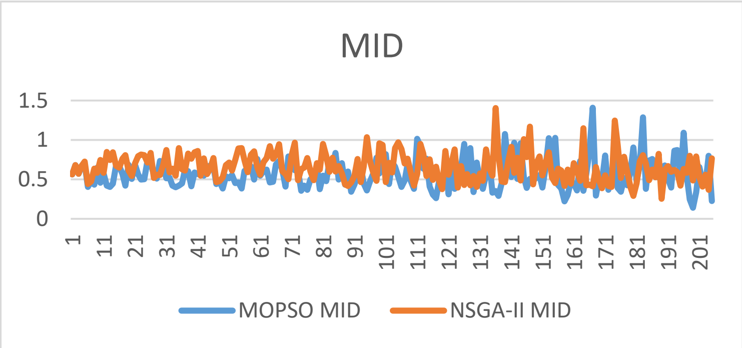

Fig. 4: MID Index NSGAII vs MOPSO

Spacing Metric Index (SM): This indicator shows the uniform distribution of Pareto's solutions in the solution space. This index is calculated as follows:

$$SM = \frac{\sum_{i=1}^{n-1} |d_i - \bar{d}|}{\bar{d}(n-1)}$$

Where n is equal to the number of Pareto points, d_i is equal to the Euclidean distance between the two Parto-side solutions in the solution space and $\bar{d}$ equal to the mean of d_i distances. With the SM index being smaller, the algorithm will perform better.

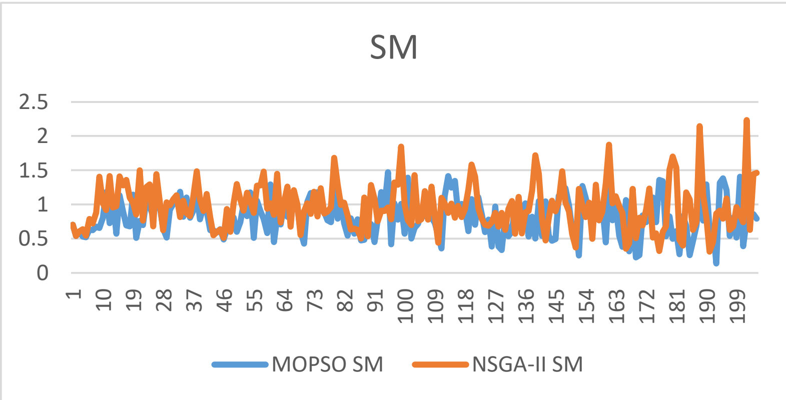

Fig. 5: SM Index NSGAII vs MOPSO

Quality Metric: The index of quality is such that all of the Pareto responses obtained by each of the algorithms are considered for each problem set, and then the selection of the non-dominated sorting for all the solutions is done. Finally, the quality of each algorithm is equal to the Pareto response specific to that algorithm of the whole Pareto's response. A higher quality means the better performance of the algorithm.

$$\frac{\text{Algorithm of each non}-\text{dominated sortings}}{\text{total number of non}-\text{dominated sortings}}$$

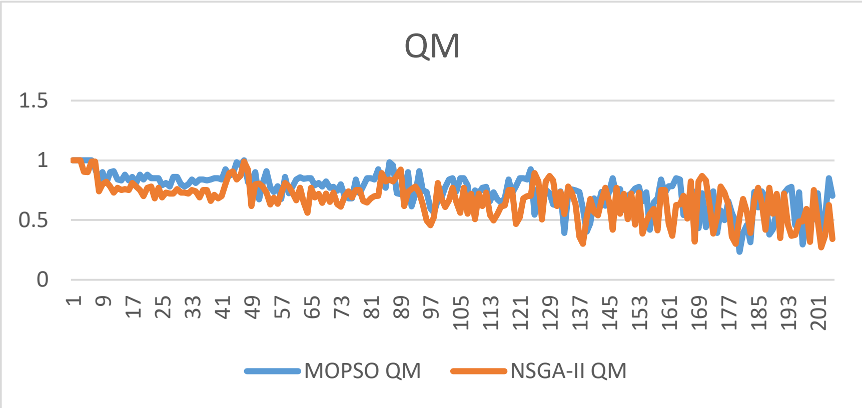

Fig. 6: QM Index NSGAII vs MOPSO

Diversification Metric (DM): This parameter shows the breadth of Pareto's responses to an algorithm and can be calculated by the following equation. The higher DM index is better algorithm.

$$DM = \sqrt{\left(\frac{\max_i f_{1i} - \min_i f_{1i}}{f_{1\,total}^{Max} - f_{1\,total}^{Min}}\right)^2 + \left(\frac{\max_i f_{2i} - \min_i f_{2i}}{f_{2\,total}^{Max} - f_{2\,total}^{Min}}\right)^2}$$

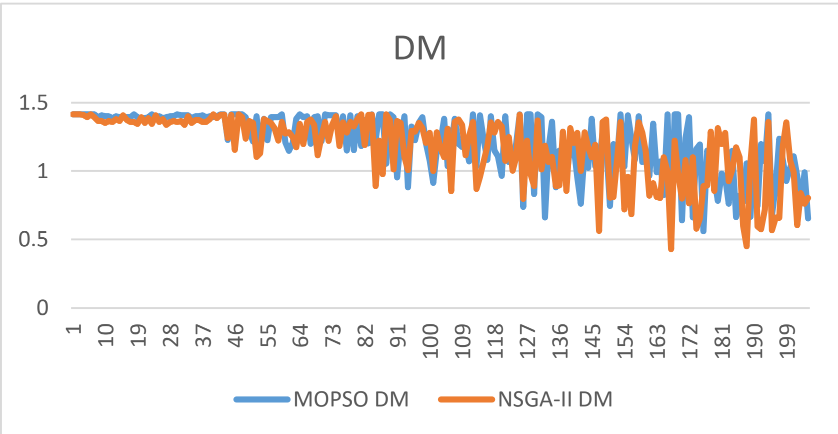

Fig. 7: DM Index NSGAII vs MOPSO

At the final step, we compared time of NSGAII vs MOPSO which we can find it as Fig.8.

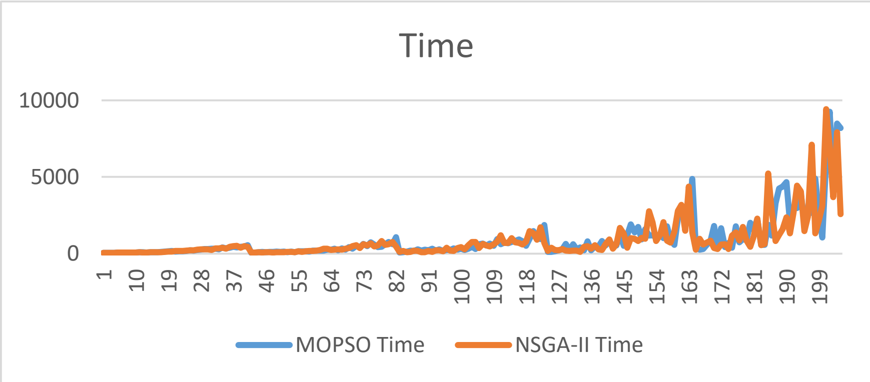

Fig. 8: Calculation time of NSGAII vs MOPSO

4.2 Analysis of Case Study Results

In this paper to implement of mathematical model and approve validity of the model, we used a real case study. This case is about Emersun group. Emersun is a big company of world-class technologies seeks to supply Iranian households and home appliances. Emersun was started to produce 20 years ago. Raw materials from Emersun factory are demanded from suppliers in China and Korea. Emersun use distribution centres to distribute finished goods to deliver them to final customers. So the definition of the problem and its related mathematical model was implemented in this step in order to obtain the results, the algorithm-related code was implemented in MATLAB 2019a software and the result was extracted in Excel Tables. The number of Runs is very high and therefore some of the result is presented in the following Table 3.

Table 3: Results of solving the mathematical model

t	1	1	1	1	1	1
z	6	7	8	9	10	11
MOPSO Time	44.12667	50.13481	49.24927	52.27444	55.20541	62.00993
NSGA-II Time	43.73261	44.12795	48.9481	46.72015	53.59358	59.87906
MOPSO MID	0.564915	0.680308	0.573867	0.667967	0.692436	0.403532
MOPSO SM	0.704628	0.540872	0.604202	0.532658	0.523195	0.63315
MOPSO QM	1	1	1	1	1	1
MOPSO DM	1.414	1.414	1.414	1.414	1.414	1.414
NSGA-II MID	0.564915	0.680308	0.573867	0.667967	0.727058	0.443885
NSGA-II SM	0.704628	0.540872	0.604202	0.63977	0.546462	0.789634
NSGA-II QM	1	1	1	0.904681	0.901125	0.988663
NSGA-II DM	1.414	1.414	1.414	1.4107	1.39305	1.414214

In Table 3, t is the time period and z is the number of retailers. The input of the time period is independent and the other inputs are dependent on the z value, so that they increase or decrease with Z changing. The time spent implementing each algorithm at each level is calculated by the software and the comparison indices (as mentioned earlier) are also represented separately for each algorithm. In the following, the computational process of the mean values of the previous Table 3 is calculated in a separate Table. This is done in order to validate and to decide which algorithm has a better performance index. The results are visible as below:

In the following, we have a sample of the Pareto front graphs related to NSGAII (t = 5, z = 10) and a sample of Pareto front graphs related to PSO algorithm (t = 5, z = 10). According to the obtained Pareto fronts, the superiority of NSGAII algorithm has over MOPSO, the breadth and convergence of responses are clearly evident.

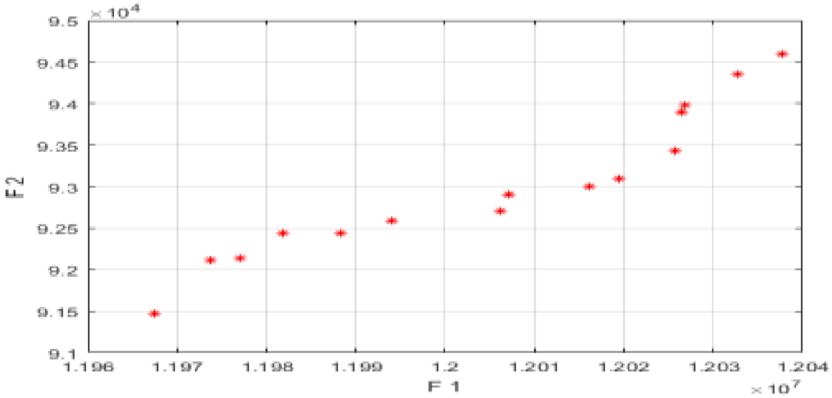

Fig. 9: Pareto Front Genetic Algorithm

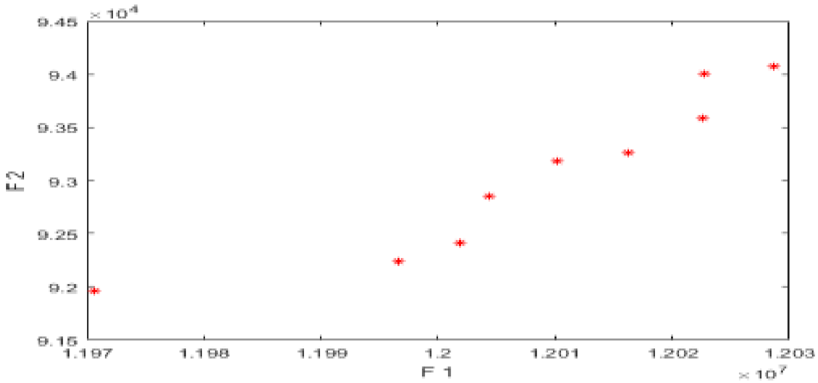

Fig. 10: Pareto Particle Swarm Algorithm

Table 4: Average indices for each algorithm

Parameter	Mean
MOPSO Time	916.0618
NSGA-II Time	840.9007
MOPSO MID	0.568205
MOPSO SM	0.810167
MOPSO QM	0.740543
MOPSO DM	1.21045
NSGA-II MID	0.658108
NSGA-II SM	0.962056
NSGA-II QM	0.673221
NSGA-II DM	1.174201

5 Conclusions and Future Research

According to Table 4, the NSGA-II algorithm performs better and has a shorter time in terms of computational time, but MOPSO algorithm is more efficient in the MID, SM, QM and DM indices. To solve the above problem in this paper has been used MATLAB Programming (R2019b) on a notebook with 5 gigabytes of R Intel memory i7 ™ Core is implemented. In this study, bi-objective mixed-integer linear programming model was proposed to optimize SSCM. The model's objectives have two dimensions: economic and environmental, and each one's functions do not affect the others, but also complement them. Although these dimensions are naturally related to one another, and affect the other dimension's performance; but, it is necessary to make an integrated decision and manage how each of these dimensions is implemented in a way that yields the highest returns. For the economic dimension, the total cost index; and for the environmental dimension, the indicator of the amount of pollution generated by the raw material were considered. The model was chosen for the reason that in the literature, economic and environmental dimensions are rarely considered simultaneously, and most studies were presented as a single objective research. Customers are looking for a commodity at low price, but not at any price, that they are looking for low-cost commodity but without any negative social and environmental impacts, which is why the sustainability debate has become a competitive advantage for businesses. The problem model was optimized by using MOPSO and NSGA-II algorithms, and by changing the parameter numbers, the values of the target functions and related Pareto fronts were obtained. By comparing the results of two algorithms in Tables and charts of above, it can be concluded that the performance of the MOPSO algorithm is generally better in terms of comparison indices.

The model is used in this study have four echelons in SSC including supplier, producer, distributor and retailers. Future research may increase or decrease the number of supply chain levels and use novel fuzzy DEA or network DEA models based on general fuzzy measure in which the attitude of DMUs could be determined by the optimistic-pessimistic parameters presented by Peykani et al [36, 37, 44]. In this research, the cost and emission of carbon were considered as two independent factors; in future research, the cost factor can be considered as time dependent. We suggest that the future studies adjusTable FDEA model could be adapted to many other models to include negative data [38]. The novel robust DEA models could be applied to other real-world problems such as supply chain management and energy, transportation, power, communication, and health care [39, 40, 41]. Also, the robust DEA model could be formulated based on network DEA models for performance measurement of DMUs with network structure. Finally, we suggest other researchers to use new algorithm and apply random dataset generation to overcome the problems arising from violations of the inclusion of observations axiom in DEA settings with ordinal or internal data [42]. And further above compute efficiency interval of units with interval input and output that while some indicators can also be negative therefore we suggest to compared to efficiency interval of models [43]. Future research focus on optimization model to minimize bias and variance of predictions that was presented by Shahhosseini et al. [45]

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