IJE TRANSACTIONS B: Applications Vol. 33, No. 11, (November 2020) 2252-2271

International Journal of Engineering

Journal Homepage: www.ije.ir

Designing a Sustainable Reverse Logistics Network Considering the Conditional Value at Risk and Uncertainty of Demand under Different Quality and Market Scenarios

S. Sajedi, A. H. Sarfaraz*, S. Bamdad, K. Khalili Damghani

Department of Industrial Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran

P A P E R I N F O

Paper history:
Received 06 June 2020
Received in revised form 17 July 2020
Accepted 05 September 2020

Keywords:
Closed-loop Supply Chain
Conditional Value at Risk
Fuzzy Inference System
Supply Chain Network Design
Sustainable

A B S T R A C T

In recent years, regarding the issues such as lack of natural resources, government laws, environmental concerns and social responsibility reverse and closed-loop supply chains has been in the center of attention of researchers and decision-makers. Then, in this paper, a multi-objective multi-product multi-period mathematical model is presented in the sustainable closed-loop supply chain to locate distribution, collection, recycling, and disposal centers, considering the risk criterion. Conditional value at risk is used as the criterion of risk evaluation. The objectives of this research are to minimize the costs of the chain, reducing the adverse environmental effects and social responsibility in order to maximize job opportunities. Uncertainty in demand and demand-dependent parameters are modeled and determined by the fuzzy inference system. The proposed model has been solved using multi objective particle swarm optimization algorithm (MOPSO) approach and the results have been compared with Epsilon constraint method. Sensitivity analysis was performed on the problem parameters and the efficiency of the studied methods was investigated.

***doi**: 10.5829/ije.2020.33.11b.17*

NOMENCLATURE

Indices			
I	Index of the set of fixed points for supply centers $i \in I$	$c^{s}_{jk,sen}$	The cost / distance of transporting the product s from the production center j to the distribution center k in the scenario sen
J	Index of the set of fixed points for production centers $j \in J$	$c^{s}_{kl,sen}$	The cost / distance of transporting the product s from the distribution center k to the customer center l in the scenario sen
K	Index of the set of potential points for distribution centers $k \in K$	$c^{s}_{lm,sen}$	The cost / distance of transporting each unit of the returned product s from the customer l to the collection and recovery center m in the scenario sen
L	Index of the set of fixed points for customers$l \in L$	$c^{s}_{mp,qs,sen}$	The cost / distance of transporting each unit of the returned product s with quality level qs from the collection and recovery center m to the recycling center p in the scenario sen
M	Index of the set of potential points for collection and recovery centers $m \in M$	$c^{s}_{mn,qs,sen}$	The cost / distance of transporting each unit of the returned product s with quality level qs from the collection and recovery center m to the disposal center n in the scenario sen
P	Index of the set of potential points for recycling centers $p \in P$	$c^{s}_{mj,qs,sen}$	The cost / distance of transporting each unit of the returned product s with quality level qs from the collection and recovery center m to the production center j in the scenario sen
N	Index of the set of potential points for burial and disposal centers $n \in N$	$c^{s}_{pj,sen}$	The cost / distance of transporting each unit of the returned product s from the recycling center p to the production center j in the scenario sen
		$cq^{s}_{jj,sen}$	The cost / distance of transporting each unit of the returned product s from the production center j to its own warehouse in the scenario sen

*Corresponding Author Email: *dr.ahsarfaraz@yahoo.com* (A. H. Sarfaraz)

Please cite this article as: S. Sajedi, A. H. Sarfaraz, S. Bamdad, K. Khalili Damghani, Designing a Sustainable Reverse Logistics Network Considering the Conditional Value at Risk and Uncertainty of Demand under Different Quality and Market Scenarios, International Journal of Engineering (IJE), IJE TRANSACTIONS B: Applications Vol. 33, No. 11, (November 2020) 2252-2271

S	Index of the set of products $s \in S$
T	Index of the period $t \in T$
qs	Quality levels of returned products (qs=qs_1, qs_2,…,QS)
sen	Set of scenarios (sen=1, 2,.., scenario)
Parameters	
O_k	The fixed amount of CO_2 (in kilograms) released during the establishment of the distribution center k
O'_m	The fixed amount of CO_2 (in kilograms) released during the establishment of the collection center m
O''_p	The fixed amount of CO_2 (in kilograms) released during the establishment of the recycling center p
O'''_n	The fixed amount of CO_2 (in kilograms) released during the establishment of the burial and disposal center n
w_{sen}	The probability of occurrence of the scenario sen
CEM	The amount of CO_2 (in kilograms) released from transportation of one unit of product in one kilometer
$r^{st}_{l,qs,sen}$	Return rate of product s with quality level qs from customer l during period t in scenario sen
$d^{st}_{l,sen}$	The amount of demand of product s by the customer l during period t in the scenario sen
$Price_{s,sen}$	The price of the product s delivered from the distributor to the customer in the scenario sen
$fp^{sen}_{s,qs}$	The optimal price of a unit of returned product s with quality qs in the scenario sen
$cost_{s,sen}$	The cost of producing a unit of product s in the scenario sen
$costm_{s,sen}$	The cost of collecting a unit of product s in the scenario sen
$costp_{s,sen}$	The cost of recycling a unit of product s in the scenario sen
$costn_{s,sen}$	The cost of disposing a unit of product s in the scenario sen
$value_{s,sen}$	Value added to the system after recycling a unit of product s in the scenario sen
Bj^{st}	The return rate of the product s from the collection and recovery center to the production center during period t
Bn^{st}	The return rate of the product s from the collection and recovery center to the burial and disposal center during period t
Bp^{st}	The return rate of the product s from the collection and recovery center to the recycling center during period t
f_k	Fixed cost of establishing a distribution center at location *k*
f_m	Fixed cost of establishing a collection and recovery center at location m
f_p	Fixed cost of establishing a recycling center at location *p*
f_n	Fixed cost of establishing a burial and disposal center at location *n*
$c^s_{ij,sen}$	The cost / distance of transporting the product s from the supply center i to the production center j in the scenario sen
$cq^s_{(jk,sen)}$	The cost / distance of transporting each unit of the returned product s from the warehouse of production center j to the distribution center k in the scenario sen
ca_i	Capacity of the supply center at location *i*
ca_j	Capacity of the production center at location *j*
ca_{jj}	Capacity of the warehouse of the production center at location *j*
cr_j	Capacity to rebuild products at the production center at location *j*
ca_k	Capacity of the distribution center at location *k*
ca_m	Capacity of the collection and recovery center at location *m*
ca_p	Capacity of the recycling center at location *p*
ca_n	Capacity of the burial and disposal center at location *n*
$h^s_{j,sen}$	The maintenance cost of each unit of the product s in the warehouse of the production center at location j in the scenario sen
Variables	
y_k	If the distribution center is established at location k, its value is 1, otherwise it is 0
y_m	If the collection center is established at location m, its value is 1, otherwise it is 0
y_p	If the recycling center is established at location p, its value is 1, otherwise it is 0
y_n	If the burial and disposal center is established at location n, its value is 1, otherwise it is 0
$x^{st}_{ij,sen}$	The amount of flow of the product s from the supply center i to the production center j during period t in the scenario sen
$x^{st}_{jk,sen}$	The amount of flow of the product s from the production center j to the distribution center k during period t in the scenario sen
$Q^{st}_{jj,sen}$	The amount of flow of the product s from the production center j to its own warehouse during period t in the scenario se
$x^{st}_{kl,sen}$	The amount of flow of the product s from the distribution center k to the customer l during period t in the scenario sen
$Q^{st}_{jk,sen}$	The amount of flow of the product s from the warehouse of the production center j to the distribution center k during period t in the scenario sen
$x^{st}_{lm,qs,sen}$	The amount of flow of the returned product s with the quality level qs from the customer l to the collection center m during period t in the scenario sen
$x^{st}_{mp,qs,sen}$	The amount of flow of the returned product s with the quality level qs from the collection center m to the recycling center p during period t in the scenario sen
$x^{st}_{mn,qs,sen}$	The amount of flow of the returned product s with the quality level qs from the collection center m to the burial and disposal center n during period t in the scenario sen
$x^{st}_{mj,qs,sen}$	The amount of flow of the returned product s with the quality level qs from the collection center m to the production center j during period t in the scenario sen
$x^{st}_{pj,sen}$	The amount of flow of the reused product s from the recycling center p to the production center j during period t in the scenario sen
$U^{st}_{j,sen}$	The amount of remaining inventory of the product s in the warehouse of the production center j during period t in the scenario sen
$\pi_{k,sen}$	The number of job opportunities created in the distribution center *k* in the scenario sen
$\pi_{inv,sen}$	The number of job opportunities created in reverse logistics centers in the scenario sen
Ψ_j	Average working days lost due to workplace injuries in the production center j per one unit of production

1. INTRODUCTION

Academically, the supply chain is defined as a system for converting raw materials, transporting products, and purchasing between different levels of supplier and customer [1]. In configuring logistics networks, we deal with two types of flows: 1. direct flow and 2. reverse flow. A reverse logistics network provides a flow between the used product supply market and the new product market. When the two markets overlap, a closed-loop or integrated network is created [2].

In the design of reverse logistics networks, the number of facilities required and the flow of materials between them are examined according to the structure of the supply chain [3]. Today, the main goals of customers are to receive the right goods and services in a short time, so this has changed the logistics approach of many companies In most previous studies, the design of direct and reverse logistics networks has been studied separately; but, the configuration of the reverse logistics network has a significant impact on the direct logistics network. Design separation may lead to the production of non-optimal designs. Therefore, the design of direct and reverse logistics network should be integrated [4]. Pollution and emission of greenhouse gases have a great impact on the environment, and several recent studies on the mortality rate due to greenhouse gas emissions from production units showed the importance of this issue [5]. In recent years, regarding the issues such as lack of natural resources, government laws and environmental concerns, reverse and closed-loop supply chains has been in the center of attention of researchers and decision-makers [6]. Due to the laws that have been passed by the government recently, the issue of sustainability must be considered in all companies and organizations [7]. Sustainable supply chain means creating a coordinated supply chain by integrating economic, environmental and social considerations with the business systems within a supply chain. This integration is for the efficient and effective management of materials, information and flows related to the purchase, production and distribution of products or services, and its purpose is to meet the needs of stakeholders, increase profits, create competitive advantage and chain sustainability in the short and long term [8]. These types of chains seek to balance economic, environmental, and social objective function. In addition, at the request of customers to pay attention to the dimensions of sustainability in the production of products and services, international and governmental organizations have also passed and implemented laws in this field. An examination of the expansion of these laws shows that the number of these laws and their compulsoriness will increase in the future. To maintain their competitive advantage in the future, companies need to pay attention to these rules and move toward sustaining their processes [9]. In recent years, due to increasing use of resources, increasing pollution, the current competitive market, as well as transportation costs, paying attention to the integration of reverse network problems with the forward network has created a special type of supply chain network, called sustainable closed loop supply chain [10].

Long-term and strategic decisions are effective in the design of the supply chain network, which means that changes in these decisions will lead to very high costs. Due to the constant changes in the business environment, considering the multi-product multi-period supply chains and assumptions that affect the model makes the supply chain problems more realistic and complicated [11]. Today, sustainable development and sustainability are the main issues of economic activities [1]. Sustainability dimensions for distribution and production systems include economic, environmental, and social aspects [7].

Environmental concerns have become more common recently, so one of the key issues in designing a supply chain is the effect of environmental effects created by carbon emissions, specifically known as CO_2 emissions. Considering the green supply chain can significantly address the concerns of customers and other stakeholders of the supply chain.

In addition to consider the design of the closed-loop for supply chains, it seems necessary to consider their contribution to environmental pollution. One of the main factors influencing environmental pollution is CO_2 emissions, which can be generated by continuous production of products, reproduction of returned products, transportation of products between different levels of supply chain and construction of facilities. This gas can also be produced through stored materials in warehouses, especially perishable materials that require special conditions, so considering this issue has been one of the topics of interest for researchers [4, 11–13].

Due to severe economic fluctuations and uncertainty in the amount of demand in different periods of production, organizations and managers of supply chains need to estimate the cost, revenue and conditions of production, distribution, sales, and establishment of facilities related to them and so on. They should also have a managerial view towards different situations so that they can make the best decision in the shortest possible time if the boom conditions turn into a recession or vice versa [14]. Therefore, in order to deal with the uncertainty, the scenarios of recession and boom of demand, which has been calculated as fuzzy, has been used which is considered as one of the contributions of this research.

Today, environmental studies are very important and should be considered in supply chain design. In today's competitive economy, many parameters such as cost and market demand can change, so in recent years the uncertainty of cost and demand has been considered in studies [15]. In addition to being a competitive advantage, the green supply chain, which focuses specifically on environmentally friendly design, can also be a guarantor of sustainability. Green supply chain management can help reduce waste, cost, as well as improve communication with business partners and business conditions [16]. Uncertain factors cannot be ignored in order for a green supply chain to be effective enough. In many studies, this concept has been addressed as probabilistic [17]. However, it is very difficult to use probabilistic uncertainty in practice, and in many cases it is impossible to use and collect data due to time and systemic constraints. This issue causes many problems when using traditional supply [11]. For example, it is very difficult to find variable production prices in a situation where the price of raw materials fluctuates [18]. But The fuzzy logic can greatly help decision makers to deal with uncertainty [19].

Recently, environmental factors and commercial factors such as commitment have led to the consideration of risk in reverse logistics networks [20, 21]. Therefore, supply chain risks should be recognized in order for them to be managed [22, 23]. Risk sources may be environmental, organizational, or caused by the supply chain itself, so it will be very difficult to predict their impact under uncertainty. Since the sources of risk are so many and varied, it is impossible to completely eliminate them. There are also various internal and external factors and conditions that affect their intensity and weakness. Therefore, it is necessary to conduct studies that explain the various dimensions and components of this issue [24]. Understanding the risks of supply chain that decision makers face, allows managers to better detect and deal with unexpected events. Risk identification makes it possible to adapt to the uncertain conditions of a competitive environment and it will act as a strategic leverage in the process of competitiveness of organizations. The supply chain risk assessment process can help make strategic decisions and operational plans to help reduce the number of supply chain failures [24]. Conditional value at risk is one of the methods for calculating risk in financial engineering. Being linear and convex is one of the characteristics of conditional value at risk method which makes it a proper method for risk assessment [25]. Due to their complex nature, supply chains face a high degree of uncertainty that can adversely affect the quality of their performance [26]. Uncertainty in parameters can be divided into two systematic and environmental categories, which the latter are destructive factors that can affect the supply chain [14].

Therefore, in this study, uncertainty is used in relation to parameters (product quality and demand parameter). In recent years, some studies have been conducted on distribution and production systems to address the issue of sustainability [7]. But the simultaneous effect of risk and demand fuzzy uncertainty in the presence of different market scenarios and quality has not been investigated in previous studies; therefore, in this research, we will simultaneously examine these issues.

The clear distinction between a traditional supply chain and a reverse supply chain is uncertainty in quality [27]. More specifically, the relevant literature on the supply chain considers the quality as deterministic [27–29]. Therefore, one of the prominent features of this research is the existence of quality uncertainty in the reverse route. Some topics in supply chain literature, such as supply chain risk management, sustainability, pricing, and revenue management, have been less studied [30]. Therefore, in this research, a new approach is presented that includes locating the sustainable closed loop supply chain with the presence of quality uncertainty and market scenarios considering the risk. Unlike traditional (forward) supply chains, there are various uncertainties in the reverse supply chain, such as price, quality, time, and rate of returned products [12].

This study is organized in five sections. In the second section, the related literature will be reviewed. In the third section, while stating the main problem of the research, modeling of the problem and also the approach used to estimate the uncertain demand will be presented. In the fourth section, numerical examples and results and sensitivity analysis of some model parameters will be presented. Finally, in the fifth section, conclusions and future research proposals will be expressed.

2. LITERATURE REVIEW

In this section, a review of previous literature on the design of a green closed-loop logistics network, risk modeling in the supply chain, and uncertainty modeling in the supply chain are examined, and at the end, the main innovations of this study are presented and analyzed.

2.1. Green Closed-loop Supply Chain

The study of Liu et al. [31] was one of the first studies that investigated the emission of greenhouse gases in marine units. In this study, traditional multi-criteria decision-making (MCDM) methods were developed using group fuzzy entropy and cloud technique [5]. In the last decade, the closed loop supply chain has attracted a lot of attention due to considering returned products, environmental factors, and customer rights. In this regard, it can be concluded that an effective closed loop supply chain covers environmental factors along with considering economic factors [32].

Karampour et al. [1] investigated at an alternative method to reduce fuel consumption and emissions of pollutants in a supply chain, which can shift the Vendor Managed Inventory (VMI) to the Green VMI (GVMI). So they designed a two-echelon bi-objective green supply chain with a vendor and a number of retailers, which aimed to increase chain profits and reduce carbon emissions through transportation. The proposed model was solved with Nondominated Sorting Genetic Algorithm (NSGA-II), Multi-Objective of Keshtel Algorithm (MOKA) and Multi-Objective of Red Deer Algorithm (MORDA), and finally a comparison between the three methods showed that the MORDA method performed better than the other two methods. Iqbal et al. [33] provided a mathematical model for minimizing energy consumption in a green chain. In their proposed supply chain, discarded materials were taken back from customers and returned to the collection centers to be recycled and reused as second-hand materials. Wang et al. [34] presented a mathematical model for pricing in a green supply chain. Their supply chain was considered to be reverse, including producers, distributors, customers and collection centers. The results indicated that the final price of the product was not affected by the collection method. Safaeian et al. [35] presented a 4-objective model to select the best supplier, and the order allocation operation was considered due to the incremental discount in a fuzzy environment in the presence of uncertainty. The fuzzy method used was Zimmermann, and to reduce the risk, demand was considered uncertain. The four objectives of this model were to reduce costs, increase service levels, increase product quality and reliability. Finally, the model was solved using the NSGAII method.

Wang and Li [36] presented an integer linear programming model for the design of reverse logistics networks, in which repair and reconstruction options were considered simultaneously. Considering risk as fuzzy was one of the innovations of their research. They considered minimizing risk and transportation costs simultaneously. Samuel et al [14] designed a deterministic mathematical model for a supply chain network under different carbon emission policies. They considered the quality of returned products in a closed-loop supply chain considering the different carbon emission policies. Finally, their proposed model was solved with a robust optimization approach.

Fathollahi-Fard et al. [37] provided a green home health care supply chain which started from the pharmacy and continued to the patient's home. In this supply chain, scheduling and routing were considered as a competitive advantage for organizations providing this type of service. Locating the nearest pharmacy and allocating it to the customer were two of the most important factors in this supply chain. Finally, the model was solved with the Simulated Annealing algorithm and the Epsilon constraint method was used to examine the solutions in small-scale. Baptista et al. [38] proposed a multi-period multi-stage stochastic mixed zero-one optimization model for establishment and expansion of reverse logistics processing networks to maximize profits. Among the innovations of their proposed model were simultaneous consideration of various uncertainties such as demand, production cost, volume of returned products, and risk management.

Yun et al. [39] designed a sustainable closed loop supply chain with economic, environmental and social criteria. Their objectives included minimizing total costs, minimizing the amount of carbon dioxide emissions, and maximizing social impact. Three types of distribution channels were considered in this study, including normal delivery, direct delivery and direct shipment. Finally, the model was solved by a hybrid genetic algorithm. Rabbani et al. [40] presented a multi-objective, multi-period model for location and allocation in a sustainable supply chain. Considering the different technologies for vehicles that lead to different costs, including the cost of carbon dioxide emissions, was one of the contributions of this research. In order to deal with the uncertainty of the problem, Hybrid Robust Possibilistic Programming-II (HRPP-II) approach was used. Finally, a case study was solved with the Epsilon constraint approach. Roghanian and Cheraghalipour [41] presented a multi-objective mathematical model to reduce costs and reduce CO_2 emissions in the food supply chain. Among their research innovations were the consideration of all levels of decision-making, including the production of products, distribution, inventory, sustainability, the consideration of several vehicles in order to overcome shortages, as well as the location of facilities. Taleizadeh et al. [42] examined the supply chain design problem under uncertainty in demand and by integrating supply chain design and production planning for chain components. They adopted a robust optimization approach. To solve the model, they used a heuristic method to break down the main problem into two sub-problems. Uncertainty was considered as scenario-based, and considering the uncertainty of product quality was one of their research innovations.

Mehranfar et al. [7] designed a sustainable production-distribution system using mixed integer programming and used a hybrid metaheuristic method based on Whale optimization algorithm and simulated annealing to solve it. It was one of the first studies that used this approach to solve problems.

2. 2. Quantitative Modeling of Risk in Supply Chain

The most basic research that has examined sustainability in a closed-loop supply chain considering risk is for Rahimi and Ghezavati [43]. They offered a multi-period multi-objective linear programming model for a closed-loop supply chain considering risk and uncertainty. The objectives of this study included increasing profits and social effects as well as reducing environmental effects. Soleimani and Govindan [25] used a two-stage stochastic model to examine the effecof risk in a closed-loop supply chain using conditional value at risk. Khalili-Damghani and Ghasemi [44] provided a three-level supply chain based on conditional value at risk. In their model, suppliers and producers sought to increase profits, and retailers sought to increase their profits by considering conditional value at risk.

2. 3. Modeling Uncertainty in Supply Chain

There are several ways to consider uncertainty, one of which involves fuzzy sets. Usually when the information available is ambiguous, fuzzy set theory can be used to consider uncertainty in the real world. Uncertainty is widely used in supply [12]. Chen et al. [45] conducted a study assuming uncertainty in demand.

Fathollahi-Fard et al. [19] modeled a multi-warehouse multi-period bi-objective home healthcare problem in a fuzzy environment. Jimenez fuzzy was used to control the uncertainty of travel time and patient satisfaction. Then, the model was solved by meta-heuristic methods and the results showed the proper performance of the model. Petrovic et al. [46] considered demand as uncertain in their study. El-Sayed et al. [47] used stochastic programming to determine the uncertainty of the problem parameters. Pishvaee et al. [48] used fuzzy mathematical programming for modeling. Ali et al. [49], while modeling a reverse supply chain, examined its application to air conditioning products. The uncertainty in the considered sustainable supply chain was fuzzy; in fact supply chaimn modeling (SCM) is extensively discussed in literature [50–65]. Locating collection and recycling centers was one of the most important objectives of this study. Abdi et al. [66] modeled a two-objective closed loop supply chain using two-stage stochastic programming and applied robust method to control the uncertainties related to product production, customer demand, product price, and product return rate. Considering the objective function of cost and financial risk was among the contributions of this research. Finally, the model was solved using Whale Optimization Algorithm (WOA), Particle Swarm Optimization (PSO), Genetic Algorithm (GA) and Simulated Annealing (SA) methods and their results were compared.

Nezhadroshan et al. [50] studied a humanitarian logistics due to the need for emergency services in the case of disaster. Considering the robust uncertainty, resilience and various earthquake scenarios were among the contributions of this research. In their study, warehouses and distribution centers could be reopened and the inventory level of warehouses, distribution centers and the flow between facilities were determined by the model.

Table 1 categorizes and summarizes the literature review of the most relevant studies in the field of supply chain modeling in terms of the solution approach, the type of modeling, the type of objective functions, and attention to risk.

The research gap observed in the literature is as follows. The only study that examined the effect of risk as a part of the objective function on the closed-loop supply chain, considering environmental effects, is the

TABLE 1. Summary of literature review

Ref.	Approach				Risk	Model Type		Network Type		Objective		
	2stage	Stochastic	Fuzzy	Probabilistic		Deterministic	Non Deterministic	Direct	Reverse	Economic	Social	Environment
[33]		*					*	*	*	*		*
[49]			*				*		*	*		
[34]	*			*			*	*	*			*
[66]	*		*		*			*	*	*		
[36]			*		*		*	*		*		
[24]						*		*	*	*	*	*
[4]						*		*	*	*		*
[51]		*			*		*	*	*	*		
[14]				*			*	*	*			*
[42]				*			*	*	*			*
[43]	*	*			*		*	*			*	*
[52]		*					*	*	*			*
[53]			*				*	*	*	*		*
[15]		*					*	*	*			*
[25]	*				*		*	*	*			

study of Rahimi and ghezavati [43]. Therefore, considering risk in the objective function with effective methods such as conditional value at risk is one of the issues that have received less attention. Therefore, in this paper, a multi-period multi-product multi-objective green closed-loop supply chain network design model is developed for locating distribution, collection, recycling, and burial centers by considering the conditional value at risk and scenario-based demand uncertainty; and it is estimated using fuzzy theory and fuzzy expert system alongside product quality scenarios.

3. DEFINITION OF THE PROBLEM

In this study, a green closed-loop supply chain is presented considering the quality of returned products, risk and fuzzy demand uncertainty under different scenarios. Figure 1 shows the conceptual model.

According to Figure 1, the demand is estimated using the fuzzy inference system and the method used is Mamdani inference system due to its successful use in many previous studies. Then the risk is added to the model as a part of the cost objective function using the conditional value at risk approach. In the supply chain considered in this study, the flow of returned products is determined based on their quality, then after solving the model, sensitivity analysis is performed on basic parameters such as alpha and lambda and by keeping the other parameters constant, its effects on the values of the objective function is investigated.

3. 1. Fuzzy Inference System

In this section, Mamdani and Asilian's [60] inference system is used due to its simple structure, acceptable results, simplicity of interpreting the results, and its success in previous studies [52-55]. In this study, a fuzzy inference engine has been designed to estimate the demand and its related scenarios. The fuzzy system used includes three operational stages, which are described in Figure 2.

3. 1. 1. Identifying Input Indicators

To deal with the proposed uncertainty, the fuzzy inference system approach is used to estimate demand. Factors influencing demand uncertainty include price, quality, environmental effects, advertising, and availability. These factors are based on the studies of Prasad and Sounderpandian [64], Attaran and Attaran [65] and Bhardwaj and Palaparthy [52].

3. 1. 2. Fuzzification

In this research, there are two scenarios of stagnation and boom for demand. In the proposed fuzzy system, the demand estimation criteria identified in the previous stage are the same for both the stagnation scenario and the boom scenario. They are considered as FIS inputs, and fuzzification operations are performed on them. In this stage, we consider membership functions for each input variable so that deterministic inputs become fuzzy and enter the fuzzy inference system.

3. 1. 3. Fuzzy Rules

Rules are the main part of the FIS model. Fuzzy rules are determined as if-then based on expert opinions. A fuzzy rule can be as "**if** x_1 is a_1 **AND** x_2 is b_1 **THEN** y is c_1" so $x_1, x_2$are variables and y is the desired variable and a, b and c are linguistic variables, which are mentioned in Table 2.

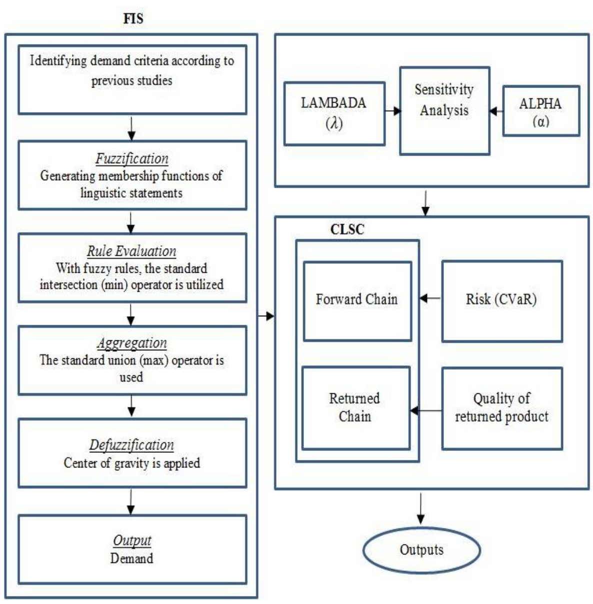

Figure 1. Conceptual model

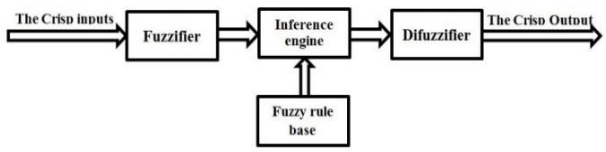

Figure 2. The Mamdani's FIS adapted from Amindoust et al. [58]

TABLE 2. FIS setting

Feature	Description
Fuzzy type	Mamdani
Number of experts	9
Complete rulebase	486
Input of each rule	5
Output	1
Linguistic features of inputs	3
Defuzzification method	COA(Center of area)

3. 1. 4. Inference Engine The main function of the fuzzy inference engine is adapting the rules to the inputs and to integrate the considered fuzzy sets according to the fuzzy rules.

3. 1. 5. Defuzzification It is converting fuzzy outputs to deterministic information. Among four parts of a fuzzy system, computing defuzzification has the most complexity in terms of computation, and it is Defuzzifier that finally determines the numerical value. Common defuzzification methods include: the center of area method (COA), bisector of area method (BOA), mean of maximum method (MOM), smallest of maximum method (SOM), and the largest of maximum method (LOM). In this research, the center of gravity method is used.

4. DETERMINING DEMAND WITH FUZZY MODEL

Some basic concepts should be defined to design a fuzzy demand estimation model, so these concepts are examined in the following sections.

4. 1. Determining the Membership Degree in the Proposed Model The membership degrees used in the Fuzzy Inference System (FIS) of this research are in both trapezoidal and triangular forms. Trapezoidal fuzzy numbers are shown as$\widetilde{w} = (a, b_1, b_2, c)$ according to Figure 3. Also, trapezoidal numbers are defined as relation. Based on relation, if $b_1 = b_2$, trapezoidal fuzzy numbers will become triangular fuzzy numbers.

$$\mu_{\widetilde{w}}(x) = \begin{cases} 0 & x < a \\ \frac{x-a}{b_1-a} & a \leq x \leq b \\ \frac{x-c}{b_2-c} & b < x \leq c \\ 0 & x > c \end{cases} \quad (1)$$

4. 1. 1. Membership Function of Inputs and Outputs At this stage, the membership function of inputs and outputs are used in the FIS system. The linguistic terms used in this study are "low", "average" and "high" according to Figure 4. These variables are equivalent to fuzzy numbers in the range of 500-1500 for demand in the stagnation scenario and the range of 1500 to 3000 for demand in the boom scenario, which are shown in Table 2.

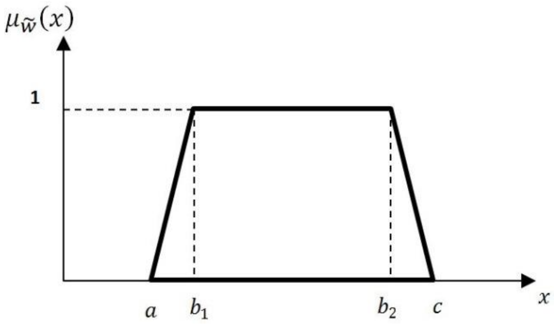

Figure 3. The trapezoidal fuzzy membership function

4. 1. 2. Membership Function for Criteria Weights As mentioned in this study, there are 5 criteria for estimating demand and the linguistic terms to describe them are "low", "average" and "high". To determine the importance of weight of these variables, they are equated with trapezoidal fuzzy numbers in the range between zero and one. Figure 5 shows three fuzzy sets, and the weights of the linguistic variables are shown in Tables 3 and 4.

4. 2. Fuzzy Operators Mamdani and Larsen implication relations use the min and multiplier operators, respectively, to obtain the truth value of each

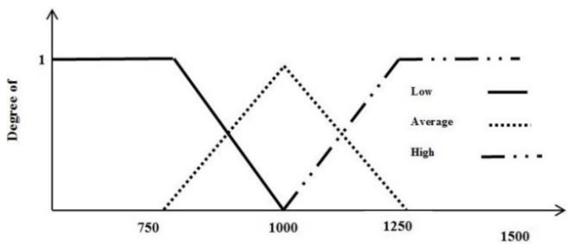

Figure 4. The triangular fuzzy membership function for stagnation scenario

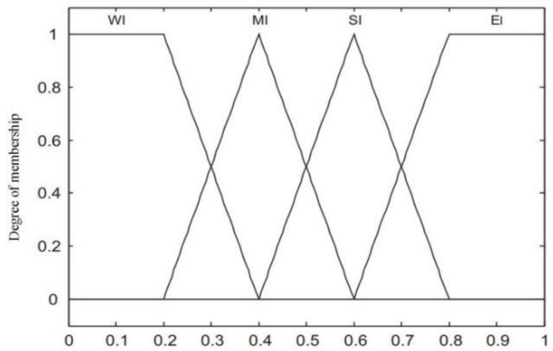

Figure 5. Membership functions for the weights of criteria

TABLE 3. The linguistic terms for demand evaluation

Scenario	Linguistic Terms	Fuzzy Set
	Low	**(500,750,1000)**
Stagnation	Average	**(750,1000,1250)**
	high	**(1000,1250,1500)**
	Low	**(1500,1750,2000)**
Boom	Average	**(1750,2000,2500)**
	high	**(2000,2500,3000)**

TABLE 4. The linguistic weighting terms for criteria

Linguistic Terms	Fuzzy Set
Weak importance (WI)	(0,0,0.2,0.4)
Moderate importance (MI)	(0.2,0.4,0.4,0.6)
Strong importance (SI)	(0.4, 0.6, 0.6,0.8)
Extreme importance (EI)	(0.6, 0.8, 1,1)

rule. Equations (1) and (2) show Mamdani and Larsen implication relations, respectively.

$$R(U,V) = \min[\mu_A(u), \mu_B(u)] \quad (2)$$

$$R(U,V) = \mu_A(u).\mu_B(u) \quad (3)$$

4. 3. Implementing the Fuzzy Rule-based System

As shown in Figure 5, the inputs of the fuzzy inference system include the criteria of price, quality, environmental effects, advertising, and availability, and the output of the system is the predicted amount of demand. Also, the rules for estimating demand in boom and stagnation scenarios are stated in Table 5.

In this study, the Mamdani implication relation has been used to obtain the truth value of each rule. As shown in Figure 5, the inputs to the fuzzy inference system include the criteria of price, quality, environmental effects, advertising, and availability, and the output of the system is the predicted amount of demand. Figure 6 shows mamdani FIS model.

Defuzzification is the process of converting a fuzzy set to a definite number. Therefore, the input of the defuzzification process is a fuzzy set (the result of the aggregation of output fuzzy sets) and its output is a number. There are various methods such as the center of gravity, bisector, mean of maximum, smallest of maximum, and the largest of maximum for defuzzification. However, the center of gravity method is the most commonly used method [56]. In this study, COA method was used for defuzzification. Equation (3) is the defuzzification relation based on the center of gravity.

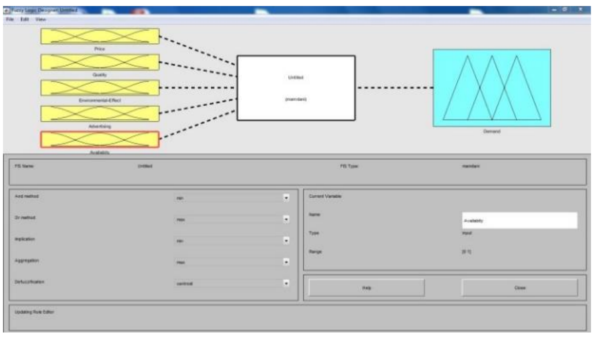

Figure 6. Mamdani FIS model

$$X_{COA} = \frac{\int_1^n \mu_i(x_i)xdx}{\int_1^n \mu_i(x_i)dx} \quad (4)$$

where x_i is a member of the set X, which is defined as $X = x_1, x_2, \dots, x_n$. The membership value (μ) indicates the degree of membership of each member of x_i in the fuzzy set X, which is shown as $X = x_1(\mu_1), x_2(\mu_2), \dots, x_n(\mu_n)$.

It is worthwhile to say that after multiplication of criteria and sub-criteria weights by customer's demand in the boom and stagnation scenario, the range of demand ([500-1500] in stagnation scenario and [1500,3000] in boom scenario) is reduced. So, the obtained results do not satisfy the aims of designed rules and causes inadequate precision for the FIS outputs. To tackle this problem, the FIS inputs are normalized for remaining in the previous scale of inputs. This methodology must be repeated for each candidate scenario.

4. 5. Introducing the Research Problem

In this research, a four-level supply chain network includes suppliers, producers, distribution centers, and customers in direct route and includes collection, recycling, and disposal centers. This model is multi-product and multi-period. Distribution, collection, recycling and disposal centers can be reopened. Overproduction in factories is transported to the producer's warehouse, and both the producer and the warehouse can send the products directly to the distribution centers. Suppliers, collection and recycling centers are responsible for providing components and raw materials to production equipment. New products are sent from factories to customers through distribution centers to meet their demand, and the reverse supply chain process begins with customer returned products. The decisive role in the flow of returned products is played by their quality, so that the returned products are disassembled according to their quality in the collection centers and high quality parts (qs_1) are sent to production centers, reproducible parts (qs_2) are sent to recycling centers, and non-usable parts (qs_3) are sent to the disposal centers. It should be noted that the demand parameter in the proposed model is considered as uncertain and to deal with the proposed uncertainty, the fuzzy inference system approach is used to estimate demand.

Therefore, the research steps are as follows. First, the values of uncertainty in demand are estimated using the fuzzy inference system approach and the identified factors. After mathematical modeling, the problem is solved using the multi-objective particle swarm meta-heuristic approach. Finally, sensitivity analysis are performed on the results. Figure 7 shows the research steps.

In the following, based on the definition of the problem, the mathematical model is designed and the components of the model are described. In this research,

TABLE 5. The fuzzy rule base matrix based on scenarios

	Criteria					
Scenario	**Price**	**Quality**	**Environmental Effects**	**Advertising**	**Availability**	**Demand**
	low	medium	low	medium	High	High
Market boom	low	High	medium	High	medium	High
	medium	medium	low	High	High	medium
	High	low	High	low	medium	low
Market stagnation	High	medium	medium	medium	low	low
	medium	low	High	low	medium	low

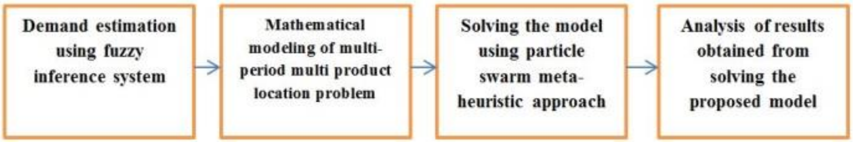

Figure 7. Research steps

the model determines the optimal amount of product delivery to the market based on the market situation and related scenarios. In this study, two modes are considered for different scenarios. The first scenario is boom and the second scenario is low boom of the market. Each of these scenarios will affect product demand and lead to a change in demand. And the probability of occurrence of both scenarios is equal.

In this study, two objective functions are considered. In the first objective function, we seek to reduce costs, and in the second objective function, we seek to minimize environmental effects and carbon dioxide emissions. Figure 8 shows the proposed supply chain structure.

4. 6. Model Assumptions

- Uncertainty in parameters such as demand is considered as scenario-based.
- The model is multi-product and multi-period and the shortage is not allowed in the model.
- Each seller can be served by all warehouses and each warehouse can be served by all distribution centers.
- Each product can be taken back in one period and each returned product can only be recycled, collected and disposed or sent to supply, production and distribution centers in that same period.
- Each unit of distance is considered equal to one unit of cost.

4. 7. The Main Structure of the Mathematical Model

Value at risk is a measure of financial risk, which is widely used in the financial industry [62]. For the decision variable x selected from the set X, for each $x\epsilon X$, loss is $T = L(x, y)$ where x is the decision variable and y is the random variable, and in the significance level $\alpha\epsilon(0{,}1)$ for the value at risk , loss of T is defined as follows [44].

$$VaR_\alpha(x) = \min\{\gamma | p\{y | L(x,y) \le \gamma\} \ge \alpha\} \quad (5)$$

Due to not being convex and addable, the VaR criterion is not appropriate. Therefore, the conditional value at risk (CVaR) criterion is used, which is expressed as follows [30]:

$$CVaR_\alpha(x) = \varphi_\alpha(x) = E\{L(x,\varepsilon) | L(x,\varepsilon) \ge VaR_\alpha(x)\} = \frac{1}{1-\alpha}\int_{L(x,y)\ge VaR_\alpha(x)} L(x,y) f(y) dy \quad (6)$$

where f(y)is density function of ε. Rockafellar and Uryasev [54] proved that to minimize CVaR, it is sufficient to minimize the following function:

$$CVaR_\alpha(x) = F_\alpha(x,y) = \gamma + \frac{1}{1-\alpha} E[[L(x,\varepsilon) - \gamma]^+] \quad (7)$$

In the above formula, the addition operator is as follows:

$$[t]^+ = \max\{0, t\} \quad (8)$$

The decision maker may consider a tolerance of previous loss (β), which this constraint is shown in Goh and Meng [55] as follows:

$$CVaR_\alpha(x) \le \beta \quad (9)$$

4. 7. 1. Risk Modeling

In general, the two indicators of cost minimization (profit maximization) and loss minimization are important for decision makers. To determine these two criteria simultaneously in a model, we use a risk aversion rate, $\lambda\epsilon(0{,}1)$, and the linear combination of this criterion and the cost criterion $f(x, y)$ in the objective function is expressed as follows ($h_l(x, y)$ represent the constraints of the problem):

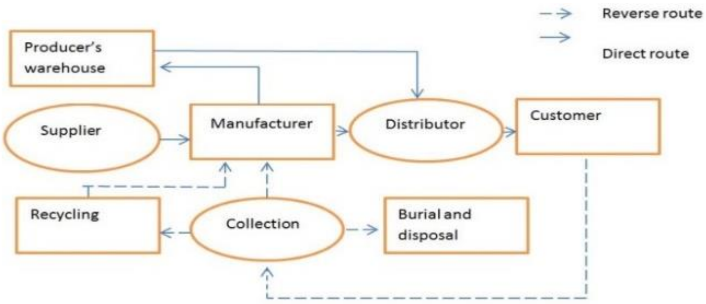

Figure 8. Proposed supply chain structure

$$Min(1-\lambda)E[f(x,y)+\lambda\, CVaR\alpha(x)$$
$$E[h_l(x,y)]=0 \quad l=1,2,\dots,$$
$$j\ E[h_l(x,y)]\le 0 \quad l=j+1,\dots,$$
$$k\ CVaRax\le \beta x\in X \tag{10}$$

By placing the formula of CVaR in the above model, we will have:

$$min(1-\lambda)\,E[f(x,y)]+\lambda(\gamma+\frac{1}{1-\alpha}E[[L(x,\varepsilon)-\gamma]^+)$$
$$E[h_l(x,y)]=0 \quad l=1,2,\dots,j$$
$$E[h_l(x,y)]\le 0 \quad l=j+1,\dots,k \tag{11}$$
$$\gamma+\frac{1}{1-\alpha}E[[L(x,\varepsilon)-\gamma]^+\le\beta \qquad (x,\gamma)\epsilon X*R$$

Zhou et al. [48] rewrote the above function and made it linear:

$$F_\alpha(x,y)=\gamma+\theta\sum[L(x,y)-\gamma]^+ \qquad where\,\theta=((1-\alpha)sen)^{-1} \tag{12}$$

$$T_s=L(x,\varepsilon)-\gamma \tag{13}$$

and the final model, considering the risk and cost, is presented as follows:

$$min(1-\lambda)\,E[f(x,y)]+\lambda(\gamma+\theta\sum_{s=1} T_s) \tag{14}$$

St:

$$E[h_l(x,y)]=0 \quad l=1,2,\dots,j$$
$$E[h_l(x,y)]\le 0 \quad l=j+1,\dots,k$$
$$T_s\ge L(x,\varepsilon)-\gamma \quad s=1,2,\dots,S \tag{15}$$
$$T_s\ge 0 \quad Z_s\epsilon R \quad s=1,2,\dots,S$$
$$(\gamma+\theta\sum_{s=1} T_s)\le\beta \qquad (X,\gamma)\epsilon X*R$$

The objective function of cost minimization:

$$min\,z\,1=(\sum_{k\in K} f_k y_k+\sum_{m\in M} f_m y_m+\sum_{p\in P} f_p y_p+\sum_n f_n y_n)+w_{sen}$$
$$(\sum_t \sum_{sen} (\sum_{s\in S}\sum_{i\in I}\sum_{j\in J} c^s_{ij,sen}x^{st}_{ij,sen}+$$
$$\sum_{s\in S}\sum_{j\in J} cq^s_{jj,sen}Q^{st}_{jj,sen}+$$
$$\sum_{s\in S}\sum_{j\in J}\sum_{k\in K} c^s_{jk,sen}x^{st}_{jk,sen}+$$
$$\sum_{s\in S}\sum_{ij\in J}\sum_{k\in K} cq^s_{jk,sen}Q^{st}_{jk,sen}+ \tag{16}$$
$$\sum_{s\in S}\sum_{k\in K}\sum_{l\in L} c^s_{kl,sen}x^{st}_{kl,sen}$$
$$+\sum_{sen\in Sen}(\sum_{s\in S}\sum_{l\in L}\sum_{m\in M} c^s_{lm,sen}x^{st}_{lm,sen}+$$
$$\sum_{s\in S}\sum_{m\in M}\sum_{p\in P} c^s_{mp,sen}x^{st}_{mp,sen}$$
$$+\sum_{s\in S}\sum_{m\in M}\sum_{n\in N} c^s_{mn,sen}x^{st}_{mn,sen}+$$
$$\sum_{s\in S}\sum_{m\in M}\sum_{j\in J} c^s_{mj,sen}x^{st}_{mj,sen}+$$
$$\sum_{s\in S}\sum_{p\in P}\sum_{j\in J} c^s_{pj,sen}x^{st}_{pj,sen}+$$
$$\sum_{s\in S}\sum_{p\in P}\sum_{i\in I} c^s_{pi,sen}x^{st}_{pi,sen}+$$
$$\sum_{s\in S}\sum_{j\in J} h^s_{j,sen}U^{st}_{j,sen})$$
$$\sum_{t\in T}\sum_{sen\in senario}\sum_{s\in S}\sum_{j\in J}$$
$$(cos\,t_{s,sen}\,(Q^{st}_{jj,sen}+\sum_{k\in K} x^{st}_{jk,sen})))$$

The first objective function includes minimizing the cost of establishing facilities, the cost of transporting the flow of materials between centers, the cost of storing materials in the producer's warehouse, the cost of returning the product, the cost of collecting, the cost of recycling, the cost of burial and disposal, and the cost of production for each product. The second objective function:

$$Minz_2=TE+FE\ FE=\sum_{k\in K} y_k.\,o_k+\sum_{m\in M} y_m.\,o'_m+\sum_{p\in P} y_p.\,o''_p+\sum_{n\in N} y_n.\,o'''_n\ TE=\sum_{sen\in Sen} w_{sen}.CEM$$
$$\sum_{s\in S}\sum_{i\in I}\sum_{j\in J} c^s_{ij,sen}x^{st}_{ij,sen}+$$
$$\sum_{s\in S}\sum_{j\in J} cq^s_{jj,sen}Q^{st}_{jj,sen}$$
$$+\sum_{s\in S}\sum_{j\in J}\sum_{k\in K} c^s_{jk,sen}x^{st}_{jk,sen}+$$
$$\sum_{s\in S}\sum_{ij\in J}\sum_{k\in K} cq^s_{jk,sen}Q^{st}_{jk,sen}+ \tag{17}$$
$$\sum_{s\in S}\sum_{k\in K}\sum_{l\in L} c^s_{kl,sen}x^{st}_{kl,sen}$$
$$+\sum_{s\in S}\sum_{l\in L}\sum_{m\in M} c^s_{lm,sen}x^{st}_{lm,sen}+$$
$$\sum_{s\in S}\sum_{m\in M}\sum_{p\in P} c^s_{mp,sen}x^{st}_{mp,sen}$$
$$+\sum_{s\in S}\sum_{m\in M}\sum_{n\in N} c^s_{mn,sen}x^{st}_{mn,sen}+$$
$$\sum_{s\in S}\sum_{m\in M}\sum_{j\in J} c^s_{mj,sen}x^{st}_{mj,sen}+$$
$$\sum_{s\in S}\sum_{p\in P}\sum_{j\in J} c^s_{pj,sen}x^{st}_{pj,sen}+$$
$$\sum_{s\in S}\sum_{p\in P}\sum_{i\in I} c^s_{pi,sen}x^{st}_{pi,sen}]$$

The second objective function consists of two sections. The first section minimizes the adverse environmental effects (released carbon dioxide) caused by the establishment of potential centers. The second part of the objective function also minimizes the adverse environmental effects (released carbon dioxide) caused by the transportation and flow of products.

$$max\,z\,3=\sum_{t\in T}\sum_{sen}(\sum_{k\in K}\pi_{k,sen}y_k+\sum_{m\in M}\pi_{inv,sen}y_m+\sum_{p\in P}\pi_{inv,sen}y_p+\sum_{n\in N}\pi_{inv,sen}y_n)-$$
$$\sum_{t\in T}\sum_{sen}\left(\sum_{j\in J}\sum_{s\in S}\left(\psi_j(Q^{st}_{jj,sen}+\sum_{k\in K} x^{st}_{jk,sen})\right)\right)$$

The third objective function is expressed in the form of social responsibility as above. The first phrase of the objective function indicates the number of job opportunities created in the facilities with the ability to reopen, such as distribution, collection, recycling and burial and disposal centers. The second phrase indicates the workplace injuries in the above centers.

Constraints:

$$\sum_{k\in K} x^{st}_{kl,sen} = d^{st}_{l,sen} \forall l \in L, \forall s \in S, t \in T, sen \in scenario \quad (18)$$

$$\sum_{m\in M} x^{st}_{lm,qs,sen} = r^{s}_{l,qs,sen}\left(\sum_{s\in S} \sum_{l\in L} x^{st}_{kl,sen}\right) \forall l \in L, \forall s \in S, t \in T, qs, sen \in scenario \quad (19)$$

Constraints (18) and (19) ensure that the total demand of customers may not be met in the direct flow, and that all returned products will be collected from customer centers in the reverse flow.

$$\sum_{qs_1} \sum_{j\in J} x^{st}_{mj,qs,sen} = Bj^{st} \sum_{qs} \left(\sum_{l\in L} x^{st}_{lm,qs,sen}\right) \forall m \in M, \forall s \in S, t \in T, \forall sen \in scenario \quad (20)$$

$$\sum_{m\in M} x^{st}_{lm,qs,sen} = r^{s}_{l,qs,sen}\left(\sum_{s\in S} \sum_{l\in L} x^{st}_{kl,sen}\right) \forall l \in L, \forall s \in S, t \in T, qs, sen \in scenario \quad (21)$$

$$\sum_{qs_3} \sum_{n\in N} x^{st}_{mn,qs,sen} = Bn^{st} \sum_{qs} \left(\sum_{l\in L} x^{st}_{lm,qs,sen}\right) \forall m \in M, \forall s \in S, t \in T, \forall sen \in senario \quad (22)$$

$$\sum_{j\in J} \left(x^{st}_{jk,sen} + Q^{st}_{jk,sen}\right) = \sum_{l\in L} x^{st}_{kl,sen} \forall k \in K, \forall s \in S, t \in T, \forall sen \in scenario \quad (23)$$

$$\sum_{qs_2} \sum_{m\in M} x^{st}_{mp,qs,sen} = \sum_{j\in J} x^{st}_{pj,sen} \forall p \in P, \forall s \in S, t \in T, \forall sen \in senario \quad (24)$$

$$\sum_{i\in I} x^{st}_{ij,sen} + \sum_{qs_1} \sum_{m\in M} x^{st}_{mj,qs,sen} + \sum_{p\in P} x^{st}_{pj,sen} = \sum_{k\in K} x^{st}_{jk,sen} + Q^{st}_{jj,sen} \forall j \in J, \forall s \in S, t \in T, \forall sen \in scenario \quad (25)$$

$$\sum_{qs_1} \sum_{j\in J} x^{st}_{mj,qs,sen} + \sum_{qs_2} \sum_{p\in P} x^{st}_{mp,qs,sen} + \sum_{qs_3} \sum_{n\in N} x^{st}_{mn,qs,sen} = \sum_{qs} \sum_{l\in L} x^{st}_{lm,sen} \forall m \in M, \forall s \in S, t \in T, \forall sen \in scenario \quad (26)$$

$$U^{st}_{j,sen} = Q^{st}_{jj,sen} - \sum_{k\in K} Q^{st}_{jk,sen} \forall j \in J, \forall s \in S, t \in T, \forall sen \in senario \quad (27)$$

Constraints (20) to (27) relate to flow balance constraints in the nodes.

$$\sum_{k\in K} Q^{st}_{jk,sen} \le Q^{s}_{jj,sen} \forall j \in J, \forall s \in S, t \in T, \forall sen \in senario \quad (28)$$

Constraint (28) ensures that the amount of outflow from the warehouse of the production center is less than the total inflow to the warehouse.

$$\sum_{s\in S} \sum_{j\in J} x^{st}_{ij,sen} \le ca_i \forall i \in I, t \in T, \forall sen \in senario \quad (29)$$

$$\sum_{s\in S} \sum_{k\in K} x^{st}_{jk,sen} + \sum_{s\in S} Q^{st}_{jj,sen} \le ca_j \forall j \in J, t \in T, \forall sen \in senario \quad (30)$$

$$\sum_{s\in S} \sum_{l\in L} x^{st}_{kl,sen} \le ca_k y_k \forall k \in K, t \in T, \forall sen \in senario \quad (31)$$

$$\sum_{qs_1} \sum_{s\in S} \sum_{j\in J} x^{st}_{mj,qs,sen} + \sum_{qs_3} \sum_{s\in S} \sum_{n\in N} x^{st}_{mn,qs,sen} + \sum_{qs_2} \sum_{s\in S} \sum_{p\in P} x^{st}_{mp,qs,sen} \le ca_m y_m \forall m \in M, t \in T, \forall sen \in senario \quad (32)$$

$$\sum_{s\in S} \left(\sum_{qs_1} \sum_{m\in M} x^{st}_{mj,qs,sen} + \sum_{p\in P} x^{st}_{pj,sen}\right) \le cr_j \forall j \in J, t \in T, \forall sen \in senario \quad (33)$$

$$\sum_{qs_3} \sum_{s\in S} \sum_{m\in M} x^{st}_{mn,qs,sen} \le ca_n y_n \forall n \in N, t \in T, \forall sen \in senario \quad (34)$$

$$\sum_{qs_2} \sum_{s\in S} \sum_{m\in M} x^{st}_{mp,qs,sen} \le ca_p y_p \forall p \in P, t \in T, \forall sen \in senario \quad (35)$$

$$\sum_{s\in S} U^{st}_{j,sen} \le ca_{jj} \forall j \in J, t \in T, \forall sen \in senario \quad (36)$$

Relations (29) to (36) ensure that the flow is only between points in which a facility has been established and that the total flow in each facility does not exceed its capacity.

$$\sum_{k\in K} y_k \ge 1 \quad (37)$$

$$\sum_{m\in M} y_m \ge 1 \quad (38)$$

$$\sum_{p\in P} y_p \ge 1 \quad (39)$$

$$\sum_{n\in N} y_n \ge 1 \quad (40)$$

Relations (37) to (40) ensure that at least one of the potential centers is active.

$$Bj^{st} + Bp^{st} + Bn^{st} = 1 \forall s \in S, t \in T \quad (41)$$

Relation (41) ensures that the sum of the coefficients of the returned products is 1.

$$y_m, y_k, y_p, y_n \in \{0,1\} \forall m \in M, \forall k \in K, \forall p \in P, \forall n \in N, t \in T \quad (42)$$

$$x^{st}_{ij}, x^{st}_{jk}, Q^{st}_{jj}, U^{st}_{j}, x^{st}_{kl}, Q^{st}_{jk}, x^{st}_{lm}, x^{st}_{mj}, x^{st}_{mp}, x^{st}_{mn} \ge 0 \ \forall i \in I, \forall j \in J, \forall k \in K, \forall l \in L, \forall m \in M, \forall n \in N, \forall p \in P, t \in T \quad (43)$$

Constraints (42) and (43) are logical and obvious constraints related to problem decision variables.

5. SOLUTION METHOD

Solution method is as follow:

5. 1. Multi-objective Particle Swarm Solution Algorithm Figure 9 shows the structure of MOPSO optimization algorithm.

5. 2. Adjusting the Coefficients Managers look for better ways or solutions for improvement, which will help them manage the entire organization. Metaheuristic algorithms are easy, cost-effective, and important tools that allow researchers and managers to solve problems [56]. PSO method is one of the best problem solving techniques among swarm-based methods [56, 66].

In the MOPSO algorithm, the equations describing the behavior of the particles are as follows, in which Equations (44) and (45) determine the velocity and position of particle i at the moment $t+1$.

$$V^i[t+1] = wV^i[t] + c_1 r_1\left(x^{i,best}[t] - x^i[t]\right) + c_1 r_1\left(x^{g,best}[t] - x^i[t]\right) \quad (44)$$

$$x^i[t+1] = x^i[t] + V^i[t+1] \quad (45)$$

where $x^i[t]$ is the position of the particle i at time t, $V^i[t]$ is the velocity of the particle i at time t, $x^{i,best}[t]$ is the best position of the particle i at time t. Also, w is the inertia coefficient, r_1 and r_2 are random numbers between zero and one with uniform distribution, and c_1 and c_2 are the personal and global learning coefficients, respectively. The inertia coefficient w is an important parameter in particle swarm optimization algorithm, which has a direct effect on the convergence of the algorithm. In other words, it controls the effect of previous velocity on current velocity. A proper value for w creates a balance between local search and global search and often reduces the number of iterations needed for convergence to a proper solution. Pishvaee et al. [48] proposed the value of Equation (46) for the value of inertia.

$$w = w_{max} - \frac{w_{max} - w_{min}}{iter_{max}} \quad (46)$$

where w_{max} is the initial value of the inertia coefficient, w_{min} is the final value of the inertia coefficient, and $iter_{max}$ is the maximum number of iterations of the algorithm. Through this relation, the value of w is considered as large in initial stages to conduct a complete, global search of the search space. Then, during the implementation of the algorithm, the value of w is gradually reduced to bring the algorithm closer to the convergence boundary. According to Relation (46), the values of $iter_{max} = 500$, $w_{min} = 0.4$ and $w_{min} = 1.2$ are considered for each of the parameters. Also, 100 particles are used for searching the solution space.

5. 3. Displaying the Particles As can be seen in the Figure 10, in this study, the integer values are used to display the amount of remaining inventory of the product s in the warehouse of the production center j during period t in the scenario sen.

5. 4. Generation of Initial Solutions For the generation of initial particles, a quasi-random method is designed to use those particles between the two modes of minimum and maximum number of deliveries. The steps of this process for the generation of initial particles are as follows [57]:

All components of the first particle are considered equal to 1. This particle is the particle with the highest number of deliveries and always feasible. In other words, the first particle represents the mode in which we produce in all periods and send in all periods for all retailers.

We put the first and second particle as the first and second parent. Then, using the scattering crossover operator, we create the other required particles. To perform the scattered crossover operator, first a zero and one random array the same size as the particle is created.

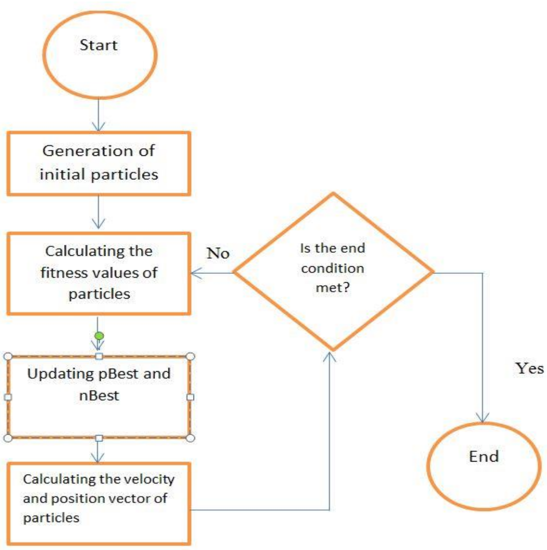

Figure 9. Structure of solution algorithm [48]

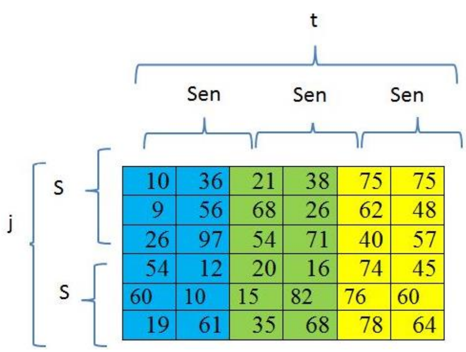

Figure 10. An example of displaying the particles

If the component i of the random array is 1, the component i of the child particle (new particle) will be equal to the component i of the parent 1 (the first particle), otherwise it will be equal to the component i of the parent 2 (the second particle). The operation of the scattered crossover operator is presented in Figure 11.

5. 5. Stop Criterion The maximum number of iterations for all problem modes is considered as 500.

5. 6. Computational Results Epsilon constraint method is one of the well-known approaches for dealing with multi-objective problems. It solves this type of problems by transferring all the objective functions except one of them to the constraints at each stage. The Pareto boundary can be created by the ε constraint method [50]. In this method, we always optimize one of the objectives, provided that we define the highest acceptable limit for other objectives in the form of constraints, so that [57]:

$$\begin{aligned} & min\, f_1(x) \\ & x \in X \\ & f_2(x) \le \varepsilon_2 \\ & \vdots \\ & f_n(x) \le \varepsilon_n \end{aligned} \tag{47}$$

Table 6 shows the results of solving the model in small and medium scale. This table compares the results of the Epsilon constraint approach and particle swarm optimization. It should be noted that examples 1 to 4 are small scale and examples 5 to 8 are medium scale. The results of solving each of the two approaches are also listed in Table 6.

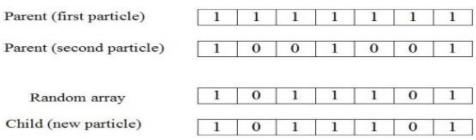

Figure 11. Performing the scattered crossover operator

According to Table 6, the mean error for all examples is below one percent. As it is obvious, the mean error percentage for objective function values is below one percent. Due to the small difference of error between the two algorithms, the accuracy of the performance and efficiency of the multi-objective particle swarm algorithm is proved, and the multi-objective particle swarm algorithm can be trusted to solve large scale problems. The results of the solution indicate that the growth rate of the solving time of the exact solution algorithm is much higher than that of the meta-heuristic algorithm. The mean solving time of the Epsilon constraint approach is 2047.25 seconds and the mean solving time of the particle swarm approach is 19 seconds. Therefore, according to the results of Table 6, we can trust the particle swarm algorithm to solve large scale problems as well as predict its good performance. Figure 12 shows the Pareto points obtained from numerical samples. The red points are the Pareto points for the particle swarm approach.

5. 7. Metrics to Evaluate Proposed Algorithm To evaluate the accuracy of the proposed particle swarm algorithm, two metrics of MID and SM are presented.

Spacing: This metric calculates the standard deviation between the solutions and the Pareto points. This metric is defined as Equation (48):

$$SM = \frac{\sum_{i=1}^{n-1} \left| d_i - \bar{d} \right|}{(n-1)\bar{d}} \tag{48}$$

N is the number of Pareto points, d_i is the Euclidean distance between the two adjacent Pareto points, and $\bar{d}$ is the average Euclidean distance of the solution points. The closer this value is to zero, the closer the Pareto points and the better the performance of the algorithm will be.

Mean ideal distance (MID): Calculates the convergence rate of Pareto points to the ideal point (0.0). This metric is defined as Equation (49):

TABLE 6. Comparative results of solution in small and medium scale

Epsilon Constraint				MOPSO				Error		
f_1	f_2	f_3	Time(s)	f_1	f_2	f_3	Time(s)	f_1	f_2	f_3
805	415	289	1	805	415	289	1	0	0	0
838	421	311	48	843	426.9	301	3	0.005967	0.01329	0.0332
952	429	314	53	956	432	304	7	0.004202	0.00582	0.0329
876	451	328	104	993	457	325	16	0.133562	0.01226	0.0092
1753	769	639	1799	1779	773	634	31	0.014832	0.00523	0.0079
1809	861	755	2131	1891	866	747	35	0.045329	0.00552	0.0107
1915	921	816	3313	1929	942	815	39	0.007311	0.02272	0.0012
2232	1151	996	8929	2234	1169	984	58	0.000896	0.01555	0.0122

$$MID = \frac{\sum_{i}^{n}\sqrt{\left(\frac{f_{1i}-f_{1}^{best}}{f_{1,total}^{\max}-f_{1,total}^{\min}}\right)^{2}+\left(\frac{f_{2i}-f_{2}^{best}}{f_{2,total}^{\max}-f_{2,total}^{\min}}\right)^{2}+\left(\frac{f_{3i}-f_{3}^{best}}{f_{3,total}^{\max}-f_{3,total}^{\min}}\right)^{2}}}{n} \quad (49)$$

f_{ji} is the value of j-th objective function for i-th Pareto front. $f_{j,total}^{max}$ and $f_{j,total}^{min}$ are respectively the highest and lowest values of the j-th objective function among the Pareto points. So the lower the MID value is, the better the performance of the algorithm will be.

Table 7 shows the metrics for small and medium scale problems. The resuls show that the mean of MID and SD metrics are 0.338 and 3.971 resecptivly. Therefore, the results of the solution can be trusted and the algorithm can be used to solve in large scale problems.

5. 8. Numerical Example

In this problem, the number of suppliers, producers and distributors is 5, the number of customer centers is 6, the number of collection, recycling and disposal centers is 5, the number of products is 2, the number of periods is 2, the number of scenarios is 2, and the number of quality levels is 3. Because it is a two-objective problem, the solutions are reported for 1 point of a specific Pareto point of a numerical example. The method of selecting a Pareto point is that due to the fact that the cost factor (first objective function) is more important than social responsibility (second objective function), the Pareto point is selected for product number 1, which has the lowest cost. It should be noted that the amount of gamma calculated for the desired Pareto point is 66750. Some of the input parameters of the problem are in Table 8.

The results of solving the model in MATLAB 2018 software are as follows. Table 9 shows the Pareto points resulting from solving the proposed model. In this table, ten points (in large scale problem) are examined and the solving time indicates the appropriate performance of the proposed algorithm.Table 10 shows values of location of distribution, collection, recycling and disposal centers, Tables 11 and 12 show the amount of flow of the product from supply centers to production centers and the amount of flow of the product from the production centers to the distribution centers respectively.

5. 9. Sensitivity Analysis

In this section, we analyze the sensitivity of the important parameters of the

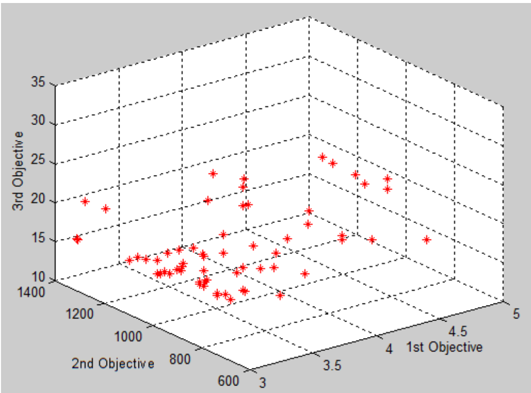

Figure 12. Pareto front

TABLE 7. Metrics for small and medium scale problems

MID	SD
0	0
0.217	2.584
0.244	2.845
0.257	3.168
0.27	3.621
0.441	5.11
0.468	5.138
0.475	5.335

TABLE 8. Problem parameters for α=0.95, β=1000000, λ=0.6

Parameters	Uniform distribution function for each period
$d_{l,sen}^{st}$	500-3000
$cost_{s,sen}$	150-200
Bp^{st}	0.3-0.6
f_m	450-600
$c_{ij,sen}^{s}$	50-100
ca_i	400-500
Ca_p	400-500
O_k, O'_m, O''_p, O'''_n	200-300
CEM	0.2-0.4

TABLE 9. Pareto points obtained from solving the model

No	f_1	f_2	f_3	Time(s)	MID	SD
1	57313	2126	1825	2	0.358	2.649
2	57346	2135	1831	6	0.362	2.741
3	57167	2265	1832	7	0.389	3.002
4	56739	2283	1828	14	0.402	3.325
5	57627	2253	1827	19	0.415	3.778
6	57332	2260	1830	23	0.586	5.267
7	57316	2296	1831	26	0.613	5.295
8	57301	2835	1832	28	0.62	5.492
9	57321	2553	1829	32	0.649	5.681
10	57432	2568	1835	36	0.688	5.903

TABLE 10. Values of location of distribution, collection, recycling and disposal centers

Distribution Center	Collection Center	Recycling Center	Disposal Center	Center Number
1	1	0	1	1
1	1	1	0	2
1	1	0	1	3
1	1	0	1	4
1	0	1	0	5

TABLE 11. The amount of flow of the product from supply centers to production centers ($x_{ij,sen}^{st}$)

(I,j)/(sen,t)	(sen1,t1)	(sen1,t2)	(sen2,t1)	(sen2,t2)
(i1,j1)	265	523	662	650
(i1,j4)	534	634	1264	698
(i2,j3)	631	582	1482	1058
(i2,j2)	649	638	1560	750
(i3,j5)	635	602	716	1409
(i3,j4)	565	598	856	785
(i4,j1)	489	645	1078	716
(i4,j4)	649	552	941	705
(i5,j3)	573	586	798	1088
(i5,j4)	450	562	789	1390

TABLE 12. The amount of flow of the product from the production centers to the distribution centers ($x_{jk,sen}^{st}$)

(I,j)/(sen,t)	(sen1,t1)	(sen1,t2)	(sen2,t1)	(sen2,t2)
(k1,j2)	565	631	1438	895
(k1,j3)	675	504	875	1301
(k2,j1)	444	473	935	843
(k2,j2)	600	629	872	787
(k3,j5)	453	485	1384	1323
(k3,j4)	552	585	765	682
(k4,j4)	382	435	897	638
(k4,j3)	482	492	867	787
(k5,j1)	468	459	1256	956
(k5,j2)	453	510	796	861

model and examine the effects of changing them on the variables and objective functions. As shown in Figure 13 shows the amount of changes of the first objective function relative to the values of the alpha variables. As can be seen, higher amounts of alpha lead to higher costs. This increase is not linear and uniform, and the biggest change occurs in the increase from 0.8 to 0.9, which is much greater than the previous period, indicating that the alpha level of more than 0.8 will lead to more costs.

Figure 14 shows changes in risk aversion rate (λ) relative to cost. As can be seen, the cost has a completely linear relationship with the decision-maker's risk aversion rate; so the more risk tolerant the decision maker, the lower the value of the objective function will be, and we need to spend more to avoid the risk as much as possible. So, decision-maker only seeks to reduce costs, and also, if λ is assumed to be 1, it means that the probable loss has much more importance for the decision-maker than cost reduction.

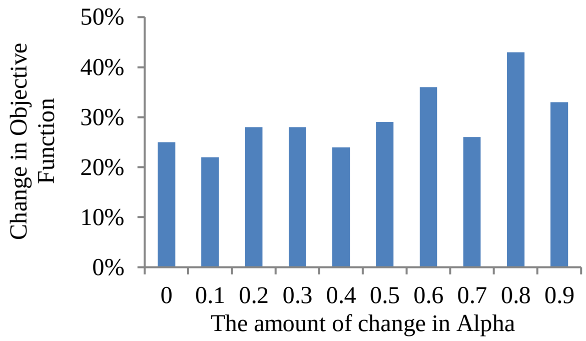

Figure 13. Sensitivity analysis of the objective function relative to alpha values

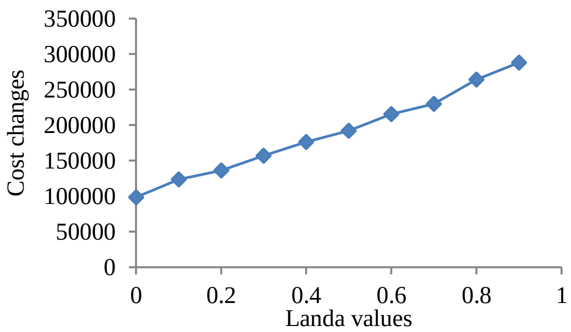

Figure 14. Cost changes relative to different λvalues

6. CONCLUSION

In today's competitive world, reducing production costs and improving productivity are among the top priorities in the thoughts and production policies of industrial managers, and every company is trying to provide the best solutions to meet the above needs. Therefore, at each period, new approaches to inventory management and control, and distribution of products are proposed, including planning to reduce transportation costs and reduce risk in the supply chain. Therefore, managers must attach the same importance to the reverse supply chain as they do to the direct supply chain. Paying attention to the social dimension in a supply chain, especially in the conditions of market instability and continuous market orientation towards recession and boom, can have many benefits for organizations and chain managers. For example, when the market is booming, with proper modeling and forecasting of the market conditions in times of recession, the unemployment rate, dismissal and even workplace injuries can be reduced greatly. This is the social responsibility of a company towards society, because such a forecast reduces crime, corruption and delinquency rates and so on and it can raise the level of hope and welfare in society. Therefore, in this study, a multi-objective mathematical model for locating and distributing products in a closed-loop supply chain has been presented considering risk and environmental factors. Considering the uncertainty of quality and uncertainty of demand along with minimizing risk and environmental impacts are among the main innovations of this research. Fuzzy inference system has been used to deal with uncertainty of demand, and this parameter has been estimated using 5 identified factors. The results of solving the model indicate that the mean of the Pareto points obtained from the first objective function is 57289.4, the mean of the Pareto points for the second objective function is 2357.4 and the third objective function is 1830. Finally, examining the error rate of the particle swarm approach and its much lower solving time than the Epsilon constraint method shows its high efficiency. The results of sensitivity analysis indicate that higher amounts of alpha lead to higher costs. . This increase is not linear and uniform, and the biggest change occurs in the increase from 0.8 to 0.9, which is much greater than the previous period. The downward trend of the sensitivity analysis chart of the number of distribution centers relative to cost indicates that the increase in the capacity of centers will reduce costs. The reason is that with the increase in capacity, the need to establish new centers is greatly reduced. From a managerial point of view, it is recommended that managers should always have an estimate of demand in boom and recession periods. Also using the proposed model, they can have a very good view of the future of the supply chain by choosing the desired level of risk in CVaR through changing alpha values and its weighted parameter, i.e., lambda. So, the proposed model is very flexible for managers in order to improve the supply chain.

The following are recommended for future studies:

- Considering a competitive game between supply chain members (for example, distributor and producer) in the proposed model
-Considering other objectives in the model: for example, maximizing supply chain resilience or minimizing delivery time
- Problem solving with a two-level planning approach
- Considering multi-modal transport models, such as considering trucks, containers, or rail and air transportation.
- Use of other uncertainty approaches, for example, robust optimization approach

7. REFERENCES

1. Karampour, M. M., Hajiaghaei-Keshteli, M., Fathollahi-Fard, A. M., and Tian, G. "Metaheuristics for a bi-objective green vendor managed inventory problem in a two-echelon supply chain network." ***Scientia Iranica***, (2020). (In press) https://doi.org/10.24200/sci.2020.53420.3228
2. Zailani, S., Iranmanesh, M., Foroughi, B., Kim, K., and Hyun, S. S. "Effects of supply chain practices, integration and closed-loop supply chain activities on cost-containment of biodiesel." ***Review of Managerial Science***, (2019), 1–21. https://doi.org/10.1007/s11846-019-00332-9
3. Fathollahi-Fard, A. M., Ranjbar-Bourani, M., Cheikhrouhou, N., and Hajiaghaei-Keshteli, M. "Novel modifications of social engineering optimizer to solve a truck scheduling problem in a cross-docking system." ***Computers and Industrial Engineering***, Vol. 137, (2019), 106103. https://doi.org/10.1016/j.cie.2019.106103
4. Yavari, M., and Zaker, H. "Designing a resilient-green closed loop supply chain network for perishable products by considering disruption in both supply chain and power networks." ***Computers and Chemical Engineering***, Vol. 134, (2020), 106680. https://doi.org/10.1016/j.compchemeng.2019.106680
5. Sahebjamnia, N., Goodarzian, F., and Hajiaghaei-Keshteli, M. "Optimization of multi-period three-echelon citrus supply chain problem." ***Journal of Optimization in Industrial Engineering***, Vol. 13, No. 1, (2020), 39–53. https://doi.org/10.22094/JOIE.2017.728.1463
6. Ghasemi, P., and Talebi Brijani, E. "An Integrated FAHP-PROMETHEE Approach For Selecting The Best Flexible Manufacturing System | Ghasemi | European Online Journal of Natural and Social Sciences." ***European Online Journal of Natural and Social Sciences***, Vol. 3, No. 4, (2014), 1137–1150. Retrieved from http://european-science.com/eojnss/article/view/815
7. Mehranfar, N., Hajiaghaei-Keshteli, M., and Fathollahi-Fard, A. M. "A Novel Hybrid Whale Optimization Algorithm to Solve a Production-Distribution Network Problem Considering Carbon Emissions." ***International Journal of Engineering, Transactions C: Aspects***, Vol. 32, No. 12, (2019), 1781–1789. https://doi.org/10.5829/ije.2019.32.12c.11
8. Goodarzian, F., and Hosseini-Nasab, H. "Applying a fuzzy multi-objective model for a production–distribution network design problem by using a novel self-adoptive evolutionary algorithm." ***International Journal of Systems Science: Operations and Logistics***, (2019). https://doi.org/10.1080/23302674.2019.1607621
9. Shirazi, H., Kia, R., and Ghasemi, P. "Ranking of hospitals in the case of COVID-19 outbreak: A new integrated approach using patient satisfaction criteria." ***International Journal of Healthcare Management***, (2020), 1–13. https://doi.org/10.1080/20479700.2020.1803622
10. Babaeinesami, A., and Ghasemi, P. "Ranking of hospitals: A new approach comparing organizational learning criteria." ***International Journal of Healthcare Management***, (2020). https://doi.org/10.1080/20479700.2020.1728923
11. Zhen, L., Huang, L., and Wang, W. "Green and sustainable closed-loop supply chain network design under uncertainty." ***Journal of Cleaner Production***, Vol. 227, (2019), 1195–1209.

https://doi.org/10.1016/j.jclepro.2019.04.098

12. Soleimani, H., Govindan, K., Saghafi, H., and Jafari, H. "Fuzzy multi-objective sustainable and green closed-loop supply chain network design." ***Computers and Industrial Engineering***, Vol. 109, (2017), 191–203. https://doi.org/10.1016/j.cie.2017.04.038
13. Giri, B. C., Mondal, C., and Maiti, T. "Analysing a closed-loop supply chain with selling price, warranty period and green sensitive consumer demand under revenue sharing contract." ***Journal of Cleaner Production***, Vol. 190, (2018), 822–837. https://doi.org/10.1016/j.jclepro.2018.04.092
14. Samuel, C. N., Venkatadri, U., Diallo, C., and Khatab, A. "Robust closed-loop supply chain design with presorting, return quality and carbon emission considerations." ***Journal of Cleaner Production***, Vol. 247, (2020), 119086. https://doi.org/10.1016/j.jclepro.2019.119086
15. Mohammed, A., and Wang, Q. "The fuzzy multi-objective distribution planner for a green meat supply chain." ***International Journal of Production Economics***, Vol. 184, (2017), 47–58. https://doi.org/10.1016/j.ijpe.2016.11.016
16. Aziziankohan, A., Jolai, F., Khalilzadeh, M., Soltani, R., and Tavakkoli-Moghaddam, R. "Green supply chain management using the queuing theory to handle congestion and reduce energy consumption and emissions from supply chain transportation fleet." ***Journal of Industrial Engineering and Management***, Vol. 10, No. 2Special Issue, (2017), 213–236. https://doi.org/10.3926/jiem.2170
17. Yang, D., and Xiao, T. "Pricing and green level decisions of a green supply chain with governmental interventions under fuzzy uncertainties." ***Journal of Cleaner Production***, Vol. 149, (2017), 1174–1187. https://doi.org/10.1016/j.jclepro.2017.02.138
18. Mirmohammadi, S. H., and Sahraeian, R. "A novel sustainable closed-loop supply chain network design by considering routing and quality of products." ***International Journal of Engineering, Transactions B: Applications***, Vol. 31, No. 11, (2018), 1918–1928. https://doi.org/10.5829/ije.2018.31.11b.16
19. Fathollahi-Fard, A. M., Ahmadi, A., Goodarzian, F., and Cheikhrouhou, N. "A bi-objective home healthcare routing and scheduling problem considering patients' satisfaction in a fuzzy environment." ***Applied Soft Computing Journal***, Vol. 93, (2020), 106385. https://doi.org/10.1016/j.asoc.2020.106385
20. Baryannis, G., Validi, S., Dani, S., and Antoniou, G. "Supply chain risk management and artificial intelligence: state of the art and future research directions." ***International Journal of Production Research***. Vol. 57, No. 7, (2019), 2179-2202. https://doi.org/10.1080/00207543.2018.1530476
21. Jiang, G., Wang, Q., Wang, K., Zhang, Q., and Zhou, J. "A Novel Closed-Loop Supply Chain Network Design Considering Enterprise Profit and Service Level." ***Sustainability***, Vol. 12, No. 544, (2020), 1–21. https://doi.org/10.3390/su12020544
22. Ghasemi, P., Khalili-Damghani, K., Hafezolkotob, A., and Raissi, S. "Uncertain multi-objective multi-commodity multi-period multi-vehicle location-allocation model for earthquake evacuation planning." ***Applied Mathematics and Computation***, Vol. 350, (2019), 105–132. https://doi.org/10.1016/j.amc.2018.12.061
23. He, R., Xiong, Y., and Lin, Z. "Carbon emissions in a dual channel closed loop supply chain: the impact of consumer free riding behavior." ***Journal of Cleaner Production***, Vol. 134, No. Part A, (2016), 384–394. https://doi.org/10.1016/j.jclepro.2016.02.142
24. Ghasemi, P., Khalili-Damghani, K., Hafezalkotob, A., and Raissi, S. "Stochastic optimization model for distribution and evacuation planning (A case study of Tehran earthquake)." ***Socio-Economic Planning Sciences***, Vol. 71, (2020), 100745. https://doi.org/10.1016/j.seps.2019.100745
25. Soleimani, H., and Govindan, K. "Reverse logistics network design and planning utilizing conditional value at risk." ***European Journal of Operational Research***, Vol. 237, No. 2, (2014), 487–497. https://doi.org/10.1016/j.ejor.2014.02.030
26. Polo, A., Peña, N., Muñoz, D., Cañón, A., and Escobar, J. W. "Robust design of a closed-loop supply chain under uncertainty conditions integrating financial criteria." ***Omega (United Kingdom)***, Vol. 88, (2019), 110–132. https://doi.org/10.1016/j.omega.2018.09.003
27. Jeihoonian, M., Kazemi Zanjani, M., and Gendreau, M. "Closed-loop supply chain network design under uncertain quality status: Case of durable products." ***International Journal of Production Economics***, Vol. 183, (2017), 470–486. https://doi.org/10.1016/j.ijpe.2016.07.023
28. Aras, N., Aksen, D., and Gönül Tanuğur, A. "Locating collection centers for incentive-dependent returns under a pick-up policy with capacitated vehicles." ***European Journal of Operational Research***, Vol. 191, No. 3, (2008), 1223–1240. https://doi.org/10.1016/j.ejor.2007.08.002
29. Das, K., and Chowdhury, A. H. "Designing a reverse logistics network for optimal collection, recovery and quality-based product-mix planning." ***International Journal of Production Economics***, Vol. 135, No. 1, (2012), 209–221. https://doi.org/10.1016/j.ijpe.2011.07.010
30. Asgari, N., Nikbakhsh, E., Hill, A., and Farahani, R. Z. "Supply chain management 1982-2015: A review." ***IMA Journal of Management Mathematics***, Vol. 27, No. 3, (2016), 353-379. https://doi.org/10.1093/imaman/dpw004
31. Liu, X., Tian, G., Fathollahi-Fard, A. M., and Mojtahedi, M. "Evaluation of ship's green degree using a novel hybrid approach combining group fuzzy entropy and cloud technique for the order of preference by similarity to the ideal solution theory." ***Clean Technologies and Environmental Policy***, Vol. 22, No. 2, (2020), 493–512. https://doi.org/10.1007/s10098-019-01798-7
32. Garg, K., Kannan, D., Diabat, A., and Jha, P. C. "A multi-criteria optimization approach to manage environmental issues in closed loop supply chain network design." ***Journal of Cleaner Production***, Vol. 100, (2015), 297–314. https://doi.org/10.1016/j.jclepro.2015.02.075
33. Iqbal, M. W., Kang, Y., and Jeon, H. W. "Zero waste strategy for green supply chain management with minimization of energy consumption." ***Journal of Cleaner Production***, Vol. 245, (2020), 118827. https://doi.org/10.1016/j.jclepro.2019.118827
34. Wang, T., and Li, Q. "Endogenetic Risk Analysis of the Replenishment Supply Chain in Large Fresh Supermarket." ***World Scientific Research Journal***, Vol. 6, No. 1, (2020), 165–172. https://doi.org/10.6911/WSRJ.202001_6(1).0024
35. Safaeian, M., Fathollahi-Fard, A. M., Tian, G., Li, Z., and Ke, H. "A multi-objective supplier selection and order allocation through incremental discount in a fuzzy environment." ***Journal of Intelligent and Fuzzy Systems***, Vol. 37, No. 1, (2019), 1435–1455. https://doi.org/10.3233/JIFS-182843
36. Wang, J., Jiang, H., and Yu, M. "Pricing decisions in a dual-channel green supply chain with product customization." ***Journal of Cleaner Production***, Vol. 247, (2020), 119101. https://doi.org/10.1016/j.jclepro.2019.119101
37. Fathollahi-Fard, A. M., Govindan, K., Hajiaghaei-Keshteli, M., and Ahmadi, A. "A green home health care supply chain: New modified simulated annealing algorithms." ***Journal of Cleaner Production***, Vol. 240, (2019), 118200. https://doi.org/10.1016/j.jclepro.2019.118200
38. Baptista, S., Barbosa-Póvoa, A. P., Escudero, L. F., Gomes, M. I., and Pizarro, C. "On risk management of a two-stage stochastic mixed 0–1 model for the closed-loop supply chain design problem." ***European Journal of Operational Research***, Vol. 274, No. 1, (2019), 91–107. https://doi.org/10.1016/j.ejor.2018.09.041
39. Yun, Y., Chuluunsukh, A., and Gen, M. "Sustainable Closed-

Loop Supply Chain Design Problem: A Hybrid Genetic Algorithm Approach." ***Mathematics***, Vol. 8, No. 84, (2020), 1–19. https://doi.org/10.3390/math8010084

40. Rabbani, M., Hosseini-Mokhallesun, S. A. A., Ordibazar, A. H., and Farrokhi-Asl, H. "A hybrid robust possibilistic approach for a sustainable supply chain location-allocation network design." ***International Journal of Systems Science: Operations and Logistics***, Vol. 7, No. 1, (2020), 60–75. https://doi.org/10.1080/23302674.2018.1506061

41. Roghanian, E., and Cheraghalipour, A. "Addressing a set of meta-heuristics to solve a multi-objective model for closed-loop citrus supply chain considering CO2 emissions." ***Journal of Cleaner Production***, Vol. 239, (2019), 118081. https://doi.org/10.1016/j.jclepro.2019.118081

42. Taleizadeh, A. A., Alizadeh-Basban, N., and Niaki, S. T. A. "A closed-loop supply chain considering carbon reduction, quality improvement effort, and return policy under two remanufacturing scenarios." ***Journal of Cleaner Production***, Vol. 232, (2019), 1230–1250. https://doi.org/10.1016/j.jclepro.2019.05.372

43. Rahimi, M., and Ghezavati, V. "Sustainable multi-period reverse logistics network design and planning under uncertainty utilizing conditional value at risk (CVaR) for recycling construction and demolition waste." ***Journal of Cleaner Production***, Vol. 172, (2018), 1567–1581. https://doi.org/10.1016/j.jclepro.2017.10.240

44. Khalili-Damghani, K., and Ghasemi, P. "Uncertain Centralized/Decentralized Production-Distribution Planning Problem in Multi-Product Supply Chains :Fuzzy Mathematical Optimization Approaches." ***Industrial Engineering & Management Systems***, Vol. 15, No. 2, (2016), 156–172. Retrieved from https://www.dbpia.co.kr/Journal/articleDetail?nodeId=NODE06699601

45. Chen, C. L., Yuan, T. W., and Lee, W. C. "Multi-criteria fuzzy optimization for locating warehouses and distribution centers in a supply chain network." ***Journal of the Chinese Institute of Chemical Engineers***, Vol. 38, No. 5–6, (2007), 393–407. https://doi.org/10.1016/j.jcice.2007.08.001

46. Petrovic, D., Xie, Y., Burnham, K., and Petrovic, R. "Coordinated control of distribution supply chains in the presence of fuzzy customer demand." ***European Journal of Operational Research***, Vol. 185, No. 1, (2008), 146–158. https://doi.org/10.1016/j.ejor.2006.12.020

47. El-Sayed, M., Afia, N., and El-Kharbotly, A. "A stochastic model for forward-reverse logistics network design under risk." ***Computers and Industrial Engineering***, Vol. 58, No. 3, (2010), 423–431. https://doi.org/10.1016/j.cie.2008.09.040

48. Pishvaee, M. S., Farahani, R. Z., and Dullaert, W. "A memetic algorithm for bi-objective integrated forward/reverse logistics network design." ***Computers and Operations Research***, Vol. 37, No. 6, (2010), 1100–1112. https://doi.org/10.1016/j.cor.2009.09.018

49. Ali, S. S., Paksoy, T., Torğul, B., and Kaur, R. "Reverse logistics optimization of an industrial air conditioner manufacturing company for designing sustainable supply chain: a fuzzy hybrid multi-criteria decision-making approach." ***Wireless Networks***, Vol. 26, No. 8, (2020), 5759–5782. https://doi.org/10.1007/s11276-019-02246-6

50. Nezhadroshan, A. M., Fathollahi-Fard, A. M., and Hajiaghaei-Keshteli, M. "A scenario-based possibilistic-stochastic programming approach to address resilient humanitarian logistics considering travel time and resilience levels of facilities." ***International Journal of Systems Science: Operations and Logistics***, (2020), 1-27. https://doi.org/10.1080/23302674.2020.1769766

51. Ma, L., Liu, Y., and Liu, Y. "Distributionally robust design for bicycle-sharing closed-loop supply chain network under risk-averse criterion." ***Journal of Cleaner Production***, Vol. 246, (2020), 118967. https://doi.org/10.1016/j.jclepro.2019.118967

52. Sunil, B., and Indrani, P. "ICFAI Journal of Supply Chain Management." ***ICFAI Journal of Supply Chain Management***, Vol. 5, No. 3, (2008), 59–68. Retrieved from https://biblioteca.sagrado.edu/eds/detail?db=bsu&an=35272238

53. Zhou, Y. ju, Chen, X. hong, and Wang, Z. run. "Optimal ordering quantities for multi-products with stochastic demand: Return-CVaR model." ***International Journal of Production Economics***, Vol. 112, No. 2, (2008), 782–795. https://doi.org/10.1016/j.ijpe.2007.04.014

54. Rockafellar, R. T., and Uryasev, S. "Conditional value-at-risk for general loss distributions." ***Journal of Banking and Finance***, Vol. 26, No. 7, (2002), 1443–1471. https://doi.org/10.1016/S0378-4266(02)00271-6

55. Goh, M., and Meng, F. "A stochastic model for supply chain risk management using conditional value at risk." In Managing Supply Chain Risk and Vulnerability: Tools and Methods for Supply Chain Decision Makers (pp. 141–157). Springer London., 2009. https://doi.org/10.1007/978-1-84882-634-2_8

56. Fathollahi-Fard, A. M., Hajiaghaei-Keshteli, M., and Tavakkoli-Moghaddam, R. "Red deer algorithm (RDA): a new nature-inspired meta-heuristic." ***Soft Computing***, Vol. 24, No. 19, (2020), 14637–14665. https://doi.org/10.1007/s00500-020-04812-z

57. Xia, W., and Wu, Z. "An effective hybrid optimization approach for multi-objective flexible job-shop scheduling problems." ***Computers and Industrial Engineering***, Vol. 48, No. 2, (2005), 409–425. https://doi.org/10.1016/j.cie.2005.01.018

58. Mohammed, F., Selim, S. Z., Hassan, A., and Syed, M. N. "Multi-period planning of closed-loop supply chain with carbon policies under uncertainty." ***Transportation Research Part D: Transport and Environment***, Vol. 51, (2017), 146–172. https://doi.org/10.1016/j.trd.2016.10.033

59. Fazli-Khalaf, M., Mirzazadeh, A., and Pishvaee, M. S. "A robust fuzzy stochastic programming model for the design of a reliable green closed-loop supply chain network." ***Human and Ecological Risk Assessment***, Vol. 23, No. 8, (2017), 2119–2149. https://doi.org/10.1080/10807039.2017.1367644

60. Fallah-Tafti, A., Vahdatzad, M. A., and Sadegheiyeh, A. "A comprehensive mathematical model for a location-routing-inventory problem under uncertain demand: A numerical illustration in cash-in-transit sector." ***International Journal of Engineering, Transactions B: Applications***, Vol. 32, No. 11, (2019), 1634–1642. https://doi.org/10.5829/ije.2019.32.11b.15

61. Ghasemi, P., Khalili-Damghani, K., Hafezolkotob, A., and Raissi, S. "A decentralized supply chain planning model: a case study of hardboard industry." ***International Journal of Advanced Manufacturing Technology***, Vol. 93, No. 9–12, (2017), 3813–3836. https://doi.org/10.1007/s00170-017-0802-3

62. Jung, H., and Jeong, S. J. "Managing demand uncertainty through fuzzy inference in supply chain planning." ***International Journal of Production Research***, Vol. 50, No. 19, (2012), 5415–5429. https://doi.org/10.1080/00207543.2011.631606

63. Amindoust, A., Ahmed, S., Saghafinia, A., and Bahreininejad, A. "Sustainable supplier selection: A ranking model based on fuzzy inference system." ***Applied Soft Computing Journal***, Vol. 12, No. 6, (2012), 1668–1677. https://doi.org/10.1016/j.asoc.2012.01.023

64. Prasad, S., and Sounderpandian, J. "Factors influencing global supply chain efficiency: Implications for information systems." ***Supply Chain Management***, Vol. 8, No. 3, (2003), 241–250. https://doi.org/10.1108/13598540310484636

65. Attaran, M., and Attaran, S. "Collaborative supply chain management: The most promising practice for building efficient and sustainable supply chains." ***Business Process Management***

Journal, Vol. 13, No. 3, (2007), 390–404. https://doi.org/10.1108/14637150710752308

66. Abdi, A., Abdi, A., Fathollahi-Fard, A. M., and Hajiaghaei-Keshteli, M. "A set of calibrated metaheuristics to address a closed-loop supply chain network design problem under uncertainty." ***International Journal of Systems Science: Operations and Logistics***, (2019). https://doi.org/10.1080/23302674.2019.1610197

Persian Abstract

چکیده

در سال‌های اخیر با توجه به پیدایش مسائلی مانند کمبود منابع طبیعی، قوانین دولتی و نگرانی‌های زیست محیطی، زنجیره تامین‌های بازگشتی و حلقه بسته در مرکز توجه محققین و تصمیم‌گیرندگان این حوزه قرار گرفته است، بنابراین در این مقاله یک مدل ریاضی چندهدفه، چند کالایی و چنددوره‌ای در زنجیره تامین حلقه بسته پایدار جهت مکانیابی مراکز توزیع، جمع‌آوری، بازیافت و دفن با در نظر گرفتن معیار ریسک ارائه شده است. از ارزش در معرض خطر شرطی بعنوان معیار اندازه‌گیری ریسک استفاده شده است. اهداف این پژوهش عبارتند از کمینه کردن هزینه‌های زنجیره، به همراه کاهش اثرات نامطلوب زیست محیطی و در نظر گرفتن مسئولیت اجتماعی به منظور بیشبنه کردن فرصت‌های شغلی می‌باشد.عدم قطعیت در تقاضا و پارامترهای وابسته به تقاضا، توسط سیستم استنتاج فازی مدلسازی و مشخص می‌گردد. مدل پیشنهادی با استفاده از رویکرد الگوریتم ذرات چند هدفه حل گردیده است ونتایج با روش اپسیلون محدودیت مقایسه شده‌اند. تحلیل حساسیت بر روی پارامترهای مساله انجام شده است و کارایی روش‌های مورد مطالعه بررسی شده‌اند.