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Research Article

Providing a Multiproduct and Multiperiodic Model for Closed-Loop Green Supply Chain under Conditions of Uncertainty Based on a Fuzzy Approach for Solving Problem of Business Market

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Many organizations must adjust their supply chains and business environments to remain competitive and retain market share. However, despite the benefits of such developments for organizations, they can lead to supply chain disruptions in many cases. An essential aspect of modern organizations is closed-loop supply chain management, which reduces risk by coordinating processes. This paper presents a mathematical model of a closed-loop green supply chain under uncertain conditions. A detailed description of the model and current assumptions for a specific industry are provided. Consequently, the model is developed with several relevant objectives for the design of the network. Our proposed model has the following characteristics: being multiobjective, multiproduct, and multiperiodic. Our analysis indicates that the applied model can be used both to increase profitability and to reduce environmental damage. The problem was made more uncertain using fuzzy logic. Torabi and Hassini (TH) method is combined with Jiménez's proposed method to solve the problem.

1. Introduction

Today, the world is undergoing dramatic changes in all aspects. In such a complex and dynamic environment, manufacturing companies inevitably need to design and adopt strategies that improve their performance. To succeed, plenty of public, private, and even military firms and organizations must rely on their capability to deliver acceptable outputs. To this end, such creations (i.e., performance, quality, cost, innovation, delivery, and flexibility) need an organization's capability to manage the flow of data, materials, and funds internally or externally. Such a flow is considered a supply chain [1]. Therefore, supply chain management (SCM) is a crucial factor for companies. Companies and firms cannot present a profitable product, service, or process in the current business world, disregarding the integration of corporate strategies and supply chain systems [2]. In the beginning years of the 1990s, following the improvements made in manufacturing processes as well as reengineering models, plenty of industrial activists concluded that, to preserve their market presence, not only should they improve internal processes and flexibility in the organizational capabilities but also suppliers of materials and components must provide the products with the best quality and the inexpensive production cost. This is while the product distributors ought to be closely linked to policies of product market development, in which such terms as timed production and lean production were used. In lean manufacturing systems, the production is done according to the customer's tastes and orders. Thus, once the production stage is completed, the product is shipped to the customer, and the need for storage will significantly be reduced. Organizations that use lean manufacturing establish long-term relationships with suppliers of their raw materials in the form of supply chains [3].

Having such an attitude in mind, the experts have defined supply chain management (SCM) as follows: A set of measures that try to integrate service providers, manufacturers, warehouses, and vendors to produce optimally and to deliver the optimal quantities to the right places as quickly as possible. Doing this set of operations, while customer satisfaction is achieved and costs are minimized, supply chain approaches and management come into being. Modern organizations that quickly produce their products according to customers' needs have agile production systems. Besides, following the recent fast IT development and its extensive application in SCM, many essential supplies chain management activities are being undertaken in new ways [4]. In recent decades, the increase of environmental concerns and corporate social responsibility has been the subject of the green supply chain as an essential strategy for reducing ecological damage. The history of green supply chain management goes back to the early 1990s when it was first introduced at Michigan State University. With the advent of environmental management, biofriendly production strategies and the literature on green supply chain management have grown. The emergence of the green supply chain has been one of the most remarkable advances of the last decade, providing companies with opportunities to tailor their supply chain to environmental goals. A green supply chain offers an excellent chance for those concerned with such issues as stable consumption and environment-friendly business practices [5].

Marketing methods are normally thought of as metasystems that display large-scale behaviors that cannot be deduced from people or managerial activities alone. As a result, a systemic approach from a complexity viewpoint may provide more insight than standard marketing analytics based on assumptions of individual cognitive information processing and rational profit maximization. Therefore, in this study, we discuss this important topic. Due to their diverse range of products, domestic valve companies are among the leading manufacturers and industrialists. As a result, parts design and supply companies are striving to increase their performance and competitive advantage through the efficient management of their supply chains. A closed-loop green supply chain is presented in this paper as a mathematical model under conditions of uncertainty. To begin with, a detailed description of the model details is provided, including current assumptions for a specific industry. This is followed by the development of a model with several relevant objectives for the creation of the network. Specifically, our proposal consists of a single-objective, multiproduct, and multiperiodic model. Hence, our study aims to provide a multiproduct and multiperiodic model for a closed-loop green supply chain under uncertainty based on a fuzzy approach to solving problem of business market.

2. Literature Review

The main idea behind the green supply chain is to reduce waste. Recently, green supply chain management has been considered a preventive approach to improving environmental performance and plays an essential role in traditional supply chain management.

Several practitioners and scholars have concentrated on integrated procurement production planning simulation in the latest days, and several integrated procurement production inventory model works have been issued. The creation of the integrated procurement manufacturing cell should take into account the world's complicated concerns. In addition, a dependable optimization technique for optimum solutions should be available. A thorough evaluation of the literature on the subject of supply chain management informs and leads future research. In 1992, Goyal and Deshmukh [6] examined 39 works published from 1976 to 1992 on the IPP topic. Several systematic literature reviews on the supply chain have recently been published, together with inventory models for low-quality items [1], consequence and supply chain disruption management [7], empirical model and numerical simulations of the huge influence [8], and the role of big data analytics in supply chain management [9]. Following Goyal and Deshmukh's evaluations, there are no studies on IPP concerns. As a result, by examining published studies from 1992 to 2021, our research bridged the gap.

Fahimnia et al. [10] presented a green and adaptable supply chain network model. Guo and Liang [11] employed the cooperative game theory contracting model to investigate a cost-sharing solution for lowering carbon emissions in the green supply chain. Luo et al. [12] built a multistage game model with many scenarios to assess changing laws impacting elements like green after-sales services, product greenness, and equilibrium pricing to address the knowledge issue of green programs provided by manufacturers in two competing green supply chains. Han et al. [13] and Jing and Meng [14] proposed a contract model for a dual-channel green supply chain, claiming that revenue-sharing and cost-sharing contracts may achieve system coherence. Wang and Zheng [15]. The MILP model was created by Zhou et al. [16] to assist decision-makers in planning oil pipeline supply chain networks. [17] Yang et al. After that, Shang et al. [18, 19] looked into the green production of substations as well as the optimization of urban road transportation networks.

Unlike the conventional ecological management style, the concept of green SCM presumes a company's complete responsibility or duty for its products, beginning from the extraction and procurement of raw materials to reaching the final product and waste [20]. In recent years, many researchers have focused on the green supply chain. In what follows, we briefly discuss some of the achievements. According to Yang et al. [21], the issue of supply chain network design involves strategic decisions that significantly impact the configuration and tactical and operational decisions. The network proposed in this study had three levels in the forward direction (suppliers, production and distribution, and middle customers) and three groups in the opposite direction (collection and inspection centers and disposal). It was the objective function of the profit maximization model. To solve the problems of the mentioned model, we proposed translating the mixed linear programming model into a deterministic model. Our proposed model resulted in an agreeable solution according to the experimental data. Chio [22] provided a robust optimization model for closed-loop supply chain design whose purpose was to minimize costs by considering the environmental effects of greenhouse gas emissions. Bental and Nemirovsky provided a robust optimization approach that relies on a recent theory to handle some parameters' uncertainty. Then, according to the nondeterministic parameters of the robust counterpart, a deterministic model was written to find the robust answers.

Four different policies were proposed to consider carbon emissions, and each was examined according to the provided example. Finally, each decision-maker was given the right to choose one of the existing policies according to the current conditions and their results. Ranjbarian and Khatami Firozabadi [23] conducted their study in the metro equipment industry, and a group of experts in the field was selected as a sample. A questionnaire was used to collect the research data. The relationships among the main variables of the model and the pattern of causal relationships among the criteria have been identified using the fuzzy DEMATEL technique. The matrix obtained from the DEMATEL technique (the internal communication matrix) shows the causal relationships among the factors and the effectiveness of the variables. Modeling the relationships among the research variables shows that senior management support is the most influential factor.

On the other hand, focusing on customers is the most affected one. The desired factor's degree of influence shows that it interacts more with other elements in the system. Accordingly, senior management support has the most interaction with different criteria. Customer focus is second only to process control and supplier interaction. Finally, senior management support, process control, focus on customers, and interaction with suppliers were disabled.

The supply chain network design issue involves strategic decisions that significantly impact the configuration and tactical and operational decisions. Gong et al. [24] presented an optimization model with a multiobjective nature having green supply chain criteria and then solved the problem using the NSGAII algorithm. Their results were compared to previous studies, showing the model's suitability. Romin [20] presented a multiobjective nonlinear programming model with greenness criteria and solved the model using the ECLSC algorithm. The results indicated that the model was useable in real-world applications. Pishvaee et al. [25] designed a stochastic integer programming model and then solved it using a heuristic algorithm. The results of their study indicated that the proposed model was following real-world conditions and developments in reducing environmental factors. According to Shi et al. [26], hierarchical structures of closed-loop green supply chains with operations are very similar to those in the real world. They designed an appropriate model according to the existing criteria and solved it using the ANP method. A careful examination of the results obtained in these researches shows their use of multicriteria decision-making methods for solving green SCM problems and their neglect of the closed-loop supply chain through waste recycling and sale of scrap.

Rahbani et al. [27] presented the multiobjective black widow optimization method, a metaheuristic approach for solving multiobjective optimization problems. The study's findings showed that the NSGAII algorithm performs better in small and medium-scale test issues, but the proposed technique performed better in large-scale test problems than the other two methods.

Pirnagh et al. [28] created a statistical equation for designing an integrated closed-loop supply chain network that combines two-problem localization difficulties and flow optimization. The suggested paradigm was created to lower network costs while increasing customer response. The cost criteria for building centers in this concept are unclear; stochastic programming is utilized to overcome the model's difficulties. In virtually all circumstances, NSGAII surpasses Multiobjective Particle Swarm Optimization in obtaining the optimal tradeoff approaches, according to the outcome of the Comparative indicators. Mohammad & Duffuaa [29] suggested an effective Tabu search method for multiproduct, multiobjective, multistage supply chain design challenges. The algorithm's desirable qualities were devised, programmed, and tested. For small-scale, medium-scale, and large-scale examples of multiobjective supply chain issues, the performance of the proposed algorithm was compared with those obtained from an enhanced method.

2.1. Research Gap. So far, no study has provided a multiproduct and multiperiodic model for closed-loop green supply chain under conditions of uncertainty based on a fuzzy approach for solving problem of business market. Thus, our study is the first to do this.

2.2. Problem Statement. Nowadays, many organizations must adjust their supply chains and business environments to remain competitive and retain market share. However, despite the benefits of such developments for organizations, they can lead to supply chain disruptions in many cases. An important aspect of modern organizations is closed-loop supply chain management, which reduces risk by coordinating processes. To this end, we provided a multiproduct and multiperiodic model for closed-loop green supply chain under conditions of uncertainty based on a fuzzy approach for solving problem of business market.

3. Methods and Materials

This research proposes the application of fuzzy sets in designing a mixed closed-loop supply chain network in an utterly unclear environment. The proposed network of this study has three levels in the forward direction (suppliers, production and distribution, and middle customers) and three groups in the reverse order (collection and inspection centers and destruction). The objective function of the model aims to maximize profits. We first make the mixed linear programming into a deterministic model to solve the problem. We show that the proposed solution method is suitable using the experimental data.

The supply chain for domestic valves includes suppliers, factories, and retailers. The chain has the steps described in the following. Suppliers send raw materials (e.g., cartridge, brass, hose, and mesh) to domestic valve factories to convert them into domestic valves. Manufacturers produce various models of faucets for the kitchen, bathroom, and toilet. The artificial valves are shipped to retailers who sell them. In replacing worn-out valves, customers who wish to purchase them can buy new ones at a discount if they deliver their worn-out valves to retailers. The collected, worn-out valves are sent to manufacturing plants or scrap dealers. The factories meet these worn-out valves and use the brass metal to make novel domestic valves. This replacement scheme transforms the usual supply chain of domestic valves into a closed one. Figure 1 shows the closed-loop supply chain of the proposed domestic valves.

In Figure 1, type 2 (resp., type 1) retailers implement (resp., do not implement) the replacement plan. Retailers implementing a replacement plan have two types of customers: customers who are willing to use a replacement plan and those who do not wish to use a replacement plan. Each supplier can provide several types of raw materials and may require a limited supply of any kind of them. Factories produce various types of products.

Manufacturers have three types of warehouses: one for raw materials, one for manufactured products, and one for worn-out valves, each with limited capacity. Customers of type 2 retailers who use a replacement plan purchase new valves at a discount. Customers can also supply other companies' worn-out valves in the replacement plan. Only recycled brass is used to produce the products. Valves made of recycled brass are not different in quality from those made of brass purchased from suppliers. Scrap dealers also buy outdated valves based on their weights. Now, we can discuss the relevant model by presenting the problem and detailing the initial design of the supply chain of domestic valve manufacturing companies. It consists of nine main sections. The first part aims to sell the products manufactured by the company, which is to be directly delivered from the product line to consumers through retailers, the leading distribution channel for products in the market. The second part aims to generate revenue from selling the products to customers who buy from type 2 retailers, do not wish to replace them, and are trying to manage their product usage and return cycles. The third goal is to make money from selling to customers who buy from type 2 retailers, are willing to replace defective products, and work with the company to return faulty products to the production cycle. The fourth goal is to use worn-out valves as a source of revenue for the company to prevent the release of defective products into the environment.

The fifth goal is to reduce the cost of purchasing raw materials from suppliers, and the company is looking to use environment-friendly raw materials that somehow mitigate environmental damage. The sixth goal is the cost of producing products at the factory, and the company tries to reduce the cost of production and cost coverage by selling defective products. The seventh objective is the ongoing cost of signing contracts with the strategic suppliers the company wants to work with and meet their financial obligations under the agreements. The eighth objective is the cost of transporting raw materials and products between distribution centers and warehouses. The company has to choose optimized ways for distribution to minimize fuel consumption. Finally, the ninth goal is the cost of storing raw materials and products in warehouses. The company should focus on reducing warehousing costs and the volume of products and raw materials through inventory management. A mixed-integer linear programming (MILP) model can be developed to design the network in question according to the nine goals above. Our proposed model has the following features: multiperiod, multiproduct, and single-purpose. Before presenting the model, we first define the sets, parameters, and decision variables.

3.1. The Sets of the Proposed Model

s: The group of suppliers ($s \in S = \{1, \ldots, s\}$).

i: The set of plants ($i \in I = \{1, \ldots, I\}$).

k: The set of type 1 retailers ($k \in K = \{1, \ldots, k\}$).

l: The collection of type 2 retailers ($l \in L = \{1, \ldots, l\}$).

r: The set of wastes ($r \in R = \{1, \ldots, r\}$).

j: The set of manufactured goods/products ($j \in J = \{1, \ldots, j\}$).

e: The set of the raw materials which are needed to produce the products ($e \in E = \{1, \ldots, e\}$) ($e = 1$ denotes brass).

t: The set of periods ($t \in T = \{1, \ldots, t\}$).

Parameters and coefficients of the proposed model.

PF_{jt}: The sale price for the product j's each unit in the period t.

DIS_t: Off-price of the alternative plan in the period t.

PFF_t: The sale price for each kg of waste valves for waste in the period t.

PKH_{est}: The buying price of the raw material e in each unit in the period t from the supplier s.

$HT1_{\text{esit}}$: The expense of transferring the raw material e in the period t from the supplier s to the plant i.

$HT2_{jikt}$: Transferring expense for each unit of the product j in the period t from the plant i to the type I retailer k.

$HT3_{jilt}$: Transferring expense for each unit of the product j in the period t from the plant i to type II retailer l.

$HT4_{lit}$: Transferring expense for each unit of the worn-out valves in the period t from type II retailer l to the plant i.

$HT5_{lrt}$: Transferring expense for each unit of the worn-out valves in the period t from type II retailer l to waste r.

HNM_{jt}: Storage expense for each unit of the product j in the period t within the plant's warehouse.

HNA_{et}: Storage expense for each unit of the raw material e in the period t within the plant's warehouse.

HTO_{jt}: The manufacturing expense in period t for each unit of the product j.

$HSTA_s$: The constant expense for the contracting supplier s.

D_{jkt}: Demand for the product j in the period t from the type I retailer k.

DD_{jlt}: Demand for the product j in the period from type II retailer l.

BOM_{ej}: The quantity of the used raw material e for the product j.

CA_i: Raw materials storage capacity for the plant i.

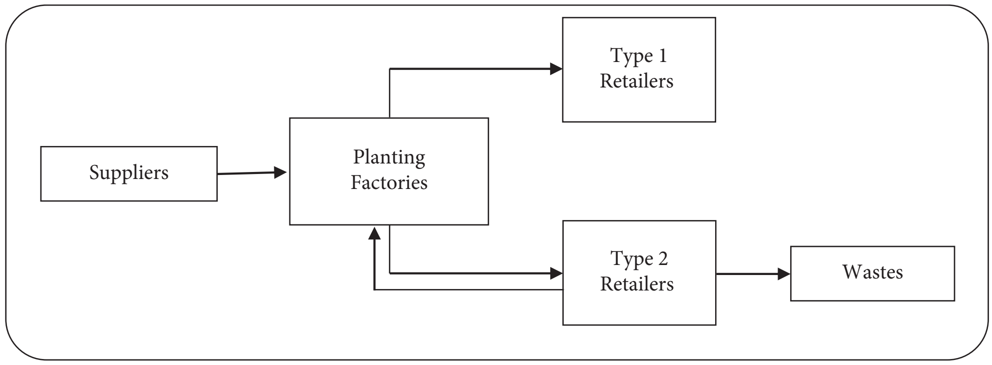

Figure 1: The closed-loop supply chain of domestic valves.

CM_i: Products storage capacity for the plant i.

CF_i: Recycled/worn-out valve storage capacity for the plant i.

CTA_{set}: Raw material supplying capacity of the supplier s in the period t.

CTO_{it}: The required time to manufacture in the period t at the plant i.

ZT_j: The temporal cycle of producing the product j.

VB_j: Packaging volume for the product j.

VA_e: The volume per each unit of the raw material e.

W_E: The mean weight per worn-out/reclaimed valve.

VF: The mean volume per worn-out/reclaimed valve.

B: The mean weight for the used brass metal per returned valve.

A: The rate of type II retail customers (%) who would like to apply for alternative plan.

M: A huge positive quantity.

RD_{lt}: The quantity of worn-out valves which have been returned to type II retailer l in the period t.

Introducing the decision-making variables.

P_{esit}: The weight or quantity of the raw material e shipped by the supplier s to the plant i in the period t.

Q_{jikt}: The quantity of produced components of the product j shipped by the plant i to type I retailer k in the period t.

O_{jilt}: The quantity of produced components of the product j shipped by the plant i to type II retailer k in the period t.

U_{lit}: The quantity of worn-out valves sent by type II retailer l to the plant i in the period t.

V_{lrt}: The quantity of worn-out valves sent by type II retailer l to waste r in the period t.

IM_{jit}: The storage list of the product j in plant i during the period t.

IMA_{eit}: The storage list of the raw material e in the plant i during the period t.

TM_{jit}: The quantity of manufactured product j in the plant i during the period t.

IFT_s: =1 in case of raw materials supplier selection, =0 otherwise.

3.2. The Proposed Mathematical Model. Based on the concepts and terms we used in the preceding sections to introduce the mathematical model's sets, parameters, and decision variables, we are now ready to formulate it as follows:

$$
\begin{aligned}
\mathbf{MAXZ} = & \sum_{j=1} J \sum_{i=1} I \sum_{k=1} K \sum_{t=1} T\left(PF_{jt} \times Q_{Jikt}\right) \\
& + (1+\alpha) \times \sum_{j=1} J \sum_{i=1} I \sum_{l=1} L \sum_{t=1} T\left(PF_{jt} \times O_{jilt}\right) \\
& + \alpha \times \sum_{J=1} J \sum_{i=1} I \\
& \sum_{l=1} L \sum_{t=1} T\left(PF_{jt} - DI\ S_t\right) \times O_{jilt} \\
& + \sum_{l=1} L \sum_{r=1} R \sum_{t=1} TV_{lrt} \times PFF_t \times W_E \\
& - \sum_{e=1} E \sum_{s=1} S \sum_{i=1} I \sum_{t=1} T\left(PKH_{est} \times P_{esit}\right) - \sum_{j=1} J \\
& \sum_{i=1} I \sum_{t=1} T\left(HT_{ojt} \times TM_{jit}\right) - \sum_{s=1} S\left(HSTA_s \times IFT_s\right) \\
& - \sum_{e=1} E \sum_{s=1} S \sum_{i=1} I \sum_{t=1} T\left(HT1_{esit} \times P_{esit}\right) \\
& - \sum_{j=1} J \sum_{i=1} I \sum_{k=1} K \sum_{t=1} T\left(HT2_{jikt} \times Q_{jikt}\right) \\
& - \sum_{j=1} J \sum_{i=1} I \sum_{l=1} L \sum_{t=1} T\left(HT3_{jit} \times O_{jilt}\right) \\
& - \sum_{l=1} L \sum_{i=1} I \sum_{t=1} T\left(HT4_{lit} \times U_{lit}\right) \\
& - \sum_{l=1} L \sum_{r=1} R \sum_{t=1} T\left(HT5_{lrt} \times V_{lrt}\right) \\
& - \sum_{j=1} J \sum_{i=1} I \sum_{t=1} T\left(HNM_{jt} \times IM_{jit}\right) \\
& - \sum_{e=1} E \sum_{i=1} I \sum_{t=1} T\left(HNA_{et} \times PIMA_{eit}\right),
\end{aligned} \tag{1}
$$

subject to

$$\sum_{i=1}^{I} Q_{jikt} \leq D_{jkt} \quad \forall j \in J, k \in K, t \in T, \tag{2}$$

$$\sum_{i=1}^{I} O_{jitl} \leq D_{jlt} \quad \forall j \in J, l \in L, t \in T, \tag{3}$$

$$\alpha \sum_{t=1}^{T} \sum_{i=1}^{I} O_{jilt} = RD_{lt} \quad \forall i \in I, t \in T, \tag{4}$$

$$\sum_{l=1}^{L} U_{lit} - \sum_{t=1}^{T} V_{lrt} = RD_{lt} \quad \forall l \in L, t \in T, \tag{5}$$

$$\begin{aligned} IM_{jit} &= IM_{ji,t-1} + TM_{jit} - \sum_{j=1}^{J} Q_{jikt} - \sum_{j=1}^{J} O_{jilt} \\ &\forall j \in J, l \in L, t \in T, \end{aligned} \tag{6}$$

$$\begin{aligned} IMA_{eit} &= IMA_{ei,t-1} + \sum_{i=1}^{I} P_{esit} - \sum_{j=1}^{J} \left(TM_{jit} \times BOM_{ej} \right) \\ &\forall e \in E, e \neq 1, i \in I, t \in T, \end{aligned} \tag{7}$$

$$\begin{aligned} IMA_{eit} = IMA_{ei,t-1} + \sum_{i=1}^{I} P_{esit} - \sum_{t=1}^{T} \left(B \times \sum_{l=1}^{L} U_{lit} \right) \\ - \sum_{i=1}^{I} \left(TM_{jit} \times BOM_{ej} \right) \quad \forall e \in E, e = 1, i \in I, t \in T, \end{aligned} \tag{8}$$

$$\sum_{i=1}^{I} P_{esit} \leq CTA_{set} \quad \forall s \in S, e \in E, t \in T, \tag{9}$$

$$\sum_{i=1}^{I} \left(VA_e \times \sum_{t=1}^{T} \sum_{i=1}^{I} P_{esit} \right) \leq CA_i \quad \forall i \in I, t \in T, \tag{10}$$

$$\sum_{i=1}^{I} \left(TM_{jit} \times ZT_j \right) \leq CTO_{it} \quad \forall i \in I, t \in T, \tag{11}$$

$$\sum_{i=1}^{I} \left(VB_j \times TM_{jit} \right) \leq CM_i \quad \forall i \in I, t \in T, \tag{12}$$

$$VF \times \sum_{l=1}^{L} U_{lit} \leq CF_i \quad \forall i \in I, t \in T, \tag{13}$$

$$\begin{aligned} &P_{esit} \leq M \times IFT_s \quad \forall e \in E, s \in S, i \in I, t \in T, \\ &P_{esit}, Q_{jikt}, O_{jilt}, U_{lit}, V_{lrt}, IM_{jit}, IMA_{eit}, TM_{jit} \geq 0, \\ &IFT_s \in \{0, 1\}. \end{aligned} \tag{14}$$

As mentioned in the proposed model, the objective function maximizes the total profit of the closed-loop supply chain network and consists of nine parts. The first part is the proceeds received from the sale of products by type 1 retailers. The second part describes the proceeds from selling products to customers who do not wish to use a replacement plan proposed by type 2 retailers. The third part is the proceeds received from the sale of products to customers who are willing to switch to type 2 retailers. The fourth section discusses the proceeds from the sale of waste valves to scrap dealers. The fifth part concerns the cost of purchasing raw materials from suppliers. The sixth part is the cost of producing the products in the factories. The seventh section refers to the fixed cost of contracting suppliers. Section eight deals with the cost of transporting raw materials and products between facilities. Finally, section nine shows the cost of storing raw materials and products in warehouses.

Now, let us explain the conditions and constraints of the model. Constraints (2) and (3) represent the response to customers' demand by type 1 and type 2 retailers, respectively. Constraint (4) indicates the collection of worn-out valves in style two retailers. Constraint (5) means the transmission of collected, worn-out valves to factories and scrap dealers. Constraint (6) shows the equilibrium flow of products manufactured in the factory warehouse. Constraint (7) shows the equilibrium flow of raw materials, except for the brass metal, in raw material storage. Constraint (8) shows the flow equilibrium of brass in the raw material warehouse. Constraint (9) states the capacity limitation of suppliers in supplying raw materials. Constraint (10) shows the capacity limitation for storing raw materials at manufacturing plants. Constraint (11) is related to product manufacturing in the factories. Constraint (12) describes the storage capacity limitation of finished products in manufacturing plants. Constraint (13) indicates the storage capacity limitation of reclaimed outlet valves in the manufacturing plants. Finally, constraint (14) states the choice or nonselection of suppliers to supply parts.

3.3. Solution Approach. Since in today's competitive market, some essential parameters, including customer demand, the quantity and quality of returned products, shipping costs, and capacity, are not specific, uncertainty arises naturally in studying such issues. In our aforementioned mathematical model, a fuzzy approach has been used to deal with the fate of the parameters. The proposed solution method combines Torabi and Hassini [30] and Jiménez [31]. This method has good computational efficiency in solving fuzzy linear problems because it maintains the linearity of the model and does not increase the number of objective functions and problem constraints (of unequal material). The approach relies on a general ranking way which Jiménez suggested in 1996.

Additionally, it can be applied to some uncertain parameters having several fuzzy-type membership functions, including trapezoidal, triangular, and nonlinear ones, either in symmetric or asymmetric mode. Powerful mathematical concepts of fuzzy numbers, including "mathematical expectation" and "expected distance" (represented initially by Ya Garder in 1981), are

Table 1: Numerical information on the number of supply chain sets under study.

The name of the supply chain set	Producers (|I|)	Suppliers (|S|)	Type 1 retailers (|K|)	Type 2 retailers (|L|)	Wastes (|R|)	Productions (|J|)
Number	2	9	10	5	9	12

considered the basics of this approach. As a result, this approach enjoys powerful mathematical support. Therefore, the necessary changes occur in the equations of the proposed fuzzy model and make the model nonfuzzy or deterministic, which is used to solve the model in the first phase as follows:

Step 1. Determine the possible probabilistic, triangular distribution functions based on the historical data, and determine the single-objective mathematical model.

$$\mu_c(x) = \begin{cases} f_c(x) = \dfrac{x - c^p}{c^m - c^p}, & c^p \leq x \leq c^m, \\ 1, & x = c^m, \\ g_c(x) = \dfrac{c^0 - x}{c^0 - c^m}, & c^m \leq x \leq c^0, \\ 0, & x \leq c^p \ or \ x \geq c^0. \end{cases} \quad (15)$$

Step 2. Defuzzify the objective function using mathematical hope parameters with uncertainty.

$$EV(\tilde{c}) = \frac{E_1^c + E_2^c}{2} = \frac{C^p + 2C^m + C^0}{4}. \quad (16)$$

Step 3. Determine the minimum degree of acceptance of the answer vectors and nonfuzzy constraints, and determine the auxiliary model.

$$\frac{\alpha}{2} \leq \mu_M(\tilde{a}, \tilde{b}) \leq 1 - \frac{\alpha}{2}. \quad (17)$$

Step 4. Determine the ideal answer with an alpha degree and the negative ideal with an alpha degree for the objective function.

$$\begin{aligned} EI(\tilde{c}) &= \left[E_1^c, E_2^c\right] \\ &= \left[\int_0^1 f_c^{-1}(x)dx, \int_0^1 g_c^{-1}(x)dx\right] \\ &= \left[\frac{1}{2}\left(c^p + c^m\right), \frac{1}{2}\left(c^m + c^0\right)\right]. \end{aligned} \quad (18)$$

Step 5. Define a linear fuzzy membership function for the objective function.

$$\mu_1(x) = \begin{cases} 1, & z_1^{\alpha-PIS} \leq z_1, \\ \dfrac{z_1 - z_1^{\alpha-NIS}}{Z_1^{\alpha-PIS} - Z_1^{\alpha-NIS}}, & z_1^{\alpha-NIS} \leq Z_1 \leq Z_1^{\alpha-PIS}, \\ 0, & z_1 \leq z_1^{\alpha-NIS}. \end{cases} \quad (19)$$

Step 6. Convert the linear fuzzy model to a deterministic model using the integration function.

$$\min \lambda(x) - \gamma\lambda_h + (1-\gamma)\sum_h \theta_h \mu_h(x), \quad (20)$$

subject to

$$\begin{aligned} &\lambda_0 \leq \mu_h(x), h = 1, 2, \\ &x \in F(x), \\ &\lambda_0, \lambda \in [0, 1]. \end{aligned} \quad (21)$$

Here, $\mu_h(x)$ indicates the degree of satisfaction of the objective function, and $F(x)$ represents the impenetrable region formed based on the deterministic constraints of the model. Also, $\theta(h)$ and λ indicate the degree of importance of the objective function and the correction factor, respectively.

Step 7. Determine the correction factor and the relative importance of the fuzzy goals, and solve the deterministic, single-objective model. If the answer is satisfactory for the decision-maker, stop solving. Otherwise, to get a new solution, return to the third step.

4. Results: A Numerical Example

In this section, an example is presented to validate the proposed model. Also, the computational results are shown. As mentioned before, this model is a mixed operation research model with a linear integer programming form. The model's numerical solution will be acquired upon gathering the related data via GAMS software. The desired data were collected from the organization under study to solve the proposed problem. Table 1 shows the numerical data regarding the number of related supply chain sets. Select the suppliers of raw materials.

The values of some of the parameters are given in Table 2.

After solving, the proposed model based on the information and data collected in Tables 1 and 2–4, and 5 can be obtained. As the results of this example show, all suppliers were used to supply raw materials. Also, 10014 kg brass has been purchased, and all twelve varieties have been produced. Total type 1 retailer demand was 1816, which responded to 1748 (96%), and complete type 2 retailer demand was 6011,

Table 2: The values of some of the parameters.

Parameter	B	$PFFt$	WE	DIS_t	VF	CM_i	CF_i	CA_i	$Djkt$	PF_{jt}	DD_{jlt}	BOM_{ej}	PKH_{est}	CTA_{set}	VB_j	CTO_{it}	VA_e	HNM_{jt}	HNA_{et}	HTO_{jt}	A	ZTj	$HT1_{esit}$	$HT2_{jikt}$	$HT3jilt$	$HT4_{lit}$	$HT5_{lrt}$	M
		5.000				700.00	300.000	800.000	24.00	245000.00		5.00	78.00	0.8900		0.3200	0.200	0.3400	0.4500	12.00		0.100	10.00	0.310	0.280	0.170	0.190	
		7.000							34.00	342000.00		4.00	76.00	0.8700			0.5600			16.00								
		4.000							15.00	256000.00		4.00	75.00	0.7300						12.00								
									20.00	278000.00		3.50	76.00	0.9300														
Value(s)	1		5.1	25.000	3.500	9000.000	4000.000	900.000	17.00	34000.000	35.00	2.00	77.00	0.6500	0.400	0.4300		0.3700	0.5000		0.24	0.189	12.00	0.398	0.277	0.189	0.178	$+\infty$
		6.000							25.00	452000.00		3.00	84.00	0.7800			0.6600			15.00								
									26.00	263000.00		4.00	79.00	0.7900														
									34.00	367000.00		3.00	78.00	0.600														
									22.00	321000.00		4.00	75.00	0.8900														

Table 3: The number of purchases from each supplier.

Supplier	S1	S2	S3	S4	S5	S6	S7	S8	S9
Number	39685	29754	26554	43875	33487	23985	54093	49834	47344

Table 4: The number of products sent to each type 1 retailer.

Type 1 retailers	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12
Number	48654	54655	65434	37556	59845	65766	78544	38724	55476	28714	45634	47655

Table 5: The number of recycled wastes (worn-out valves) of each sold product.

RD_{lt}	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}	L_{12}
Number	3654	2544	2984	1874	4766	2187	1092	2764	3872	3255	2654	1287

responding to 5605 (93%). A total of 4484 customers used the replacement plan and returned their worn-out valves to type 2 retailers. Moreover, 4472 of these valves were sent to valve factories, and their brass was used to produce new products. Other collected valves have been sold to scrap dealers. The total profit of the chain was equal to 313275200 tomans. The number of purchases from each supplier and the number of products shipped to each customer can be seen in Tables 3 and 4, respectively. Table 3 shows that the optimal number of purchases was from supplier S7. Also, Table 4 reveals that the optimal number of products was sent to retailer K7. The number of recyclable wastes recycled by each retailer is shown in Table 5, which can profit the company and reduce environmental damage.

5. Discussion

The results of the present study are similar to those of Romin [20], which mentions the belief that, by recycling products and consideration of multisectorial collection centers, in addition to the achievement of the environmental goals of governments, the customers also benefit from more affordable and less expensive products. Shi et al. [26] and Pishvaee et al. [25] showed that their models were consistent with real-world conditions and reduced environmental factors. Dawei et al. [32] presented their second model for removing damaging environmental effects through pollutants. Gang and Cheng [24] argued that hierarchical closed-loop green supply chain structures were similar to real-world operations. Yang et al. [21] presented a model with two objective functions to reduce the total cost and environmental pollution factors. The present study results confirm the suitability of our proposed model compared to the effects of all similar research.

6. Conclusion and Outlook

The present study aims to provide a multiproduct and multiperiodic model for closed-loop green supply chain under uncertainty based on a fuzzy approach for solving problem of business market. The consumer desires to receive the best possible product as quickly as possible. There is a likelihood that such a chain of consumption, and in most cases, this approach, will impact the environment and lead to the production of unsustainable products and processes. Following the development of the competitive environment in the current business environment, supply chain management (SCM) is known as one of the most critical issues facing businesses today. It comprises all steps involved in manufacturing, cost reduction, quality improvement, and service delivery.

On the other hand, with the increase in greenhouse gases and the volume of pollutants, organization managers and researchers have sought to design and operate networks that focus on environmental factors, reduce contaminants in all sectors, and optimize economic optimization. A supply chain greening initiative involves the consideration of environmental metrics or factors throughout the supply chain. A closed-loop supply chain can increase environmental considerations in network design by utilizing environment-friendly raw materials and increasing the reuse of products via the design of recycling, dismantling, and modernizing suitable products. There must be a tradeoff between being green and the objective functions that maximize the benefits in this design process. Designing a closed-loop supply chain to minimize the costs of the supply chain and the number of pollutants to the environment and, in parallel, maximize the level of meeting customer demands is inevitable. Therefore, providing a practical model seems to be necessary. This paper proposed the replacement of worn-out valves with new ones. The forward supply chain of the valves became a closed-loop supply chain, which reduced both the costs of purchasing raw materials and environmental pollution. In this study, a mixed-integer linear programming model for the design of this supply chain was developed, and a numerical example was presented for validation.

After solving the proposed model based on the information, data can be obtained. As the results of this example show, all suppliers were used to supply raw materials. Also, 10014 kg brass has been purchased, and all twelve varieties have been produced. Total type 1 retailer demand was 1816, which responded to 1748 (96%), and complete type 2 retailer demand was 6011, responding to 5605 (93%). A total of 4484 customers used the replacement plan and returned their worn-out valves to type 2 retailers. Based on the results, it can be said that businesses should pay more attention to environmental issues, such as recycling defective products (focusing on repairing and recycling units) and evaluating suppliers using green indicators. A green supply chain is essentially a series of green suppliers that profoundly impact the performance of the supply chain as a whole. Finally, based on the proposed model results, we predict that companies will be willing to implement it. It is common for researchers to encounter limitations in their research, some of which are evident from the outset. The results of this study may be specific to companies engaged in valve manufacturing and therefore may not be generalizable to other companies.

Furthermore, the data and databases of the organization may be distorted or altered. Further, for future research, it is important to consider Iran's geographical location and risk factors such as floods and earthquakes, which may adversely affect performance and the supply chain. Ideally, future models will incorporate these factors, consider the sustainability and elasticity of supply chains, and suggest environmental factors, such as job opportunities, as part of an integrated approach [33–35].

Data Availability

The data used to support the findings of the study can be obtained from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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