Original Research

A Robust Green Multi-Channel Sustainable Supply Chain based on RFID technology with considering pricing strategy and subsidizing policies

Elham Kouchaki Tajani[1]. Armin Ghane Kanafi[2*]. Maryam Daneshman-Mehr[1]. Asgar Hosseinzadeh[2]
Received: 25 Aug 2022/ Accepted: 2 Jan 2023/ Published online: 10 Jan 2023

[*]Corresponding Author, arminghane@gmail.com

1- Department of Industrial Engineering, Lahijan Branch, Islamic Azad University, Lahijan, Iran
2 - Department of Industrial Mathematics, Lahijan Branch, Islamic Azad University, Lahijan, Iran

Abstract

In recent years, increasing carbon emissions and relatively unfavorable climate change have led to paying attention to the concepts of sustainability as well as the imposition of strict government regulations on manufacturers and service providers. This has caused all parts of society, containing consumers, governments, and companies, to pay greater attention to low-carbon manufacturing in the supply chain (SC). To this end, this paper has designed a sustainable, multi-echelon, multi-product, multi-period, and multi-objective closed-loop supply chain (CLSC) network, with different distribution and collection channels and Radio Frequency Identification (RFID) technology, in addition, in order to produce low-carbon products, low-carbon products and subsidizing policies, and also deals with pricing strategy. This model, at the same time, maximizes profits and the social responsibility of the SC network, while it minimizes the overall delay in delivery time and environmental pollution. To cope with the parameters' uncertainty, a Robust scenario-based Stochastic programming (RSSP) approach has been used, and to solve and validate, the small-size model the Augmented Epsilon Constraint (AEC) method, and to solve large-sized ones, the third edition of the Non-dominated Sorting Genetic Algorithm (NSGA-III) and Multi-Objective Grey Wolf Optimizer Algorithm (MOGWO) are used. According to the computational results, the suggested model can provide efficient decisions and the MOGWO algorithm yields 14.5% improvement in execution time compared to the NSGA-III algorithm. Also suggested model can be a great tool for managers and professionals with a wide range of strategic applications.

Keywords - Government Subsidy; Low-Carbon; Multi-Channel Closed-Loop Supply Chain; Pricing; Radio Frequency Identification technology

INTRODUCTION

Many businesses nowadays are attempting to compete effectively in extremely dynamic and competitive markets in order to expand and develop their businesses and fulfill the continually changing expectations and satisfaction of their consumers. One of the really crucial issues among scientific researchists and industrial managers in this area is supply chain management (SCM)

(Ramezani, Kimiagari, Karimi, & Hejazi, 2014; Sadeghi Rad & Nahavandi, 2018). The world's environmental problems have become increasingly serious. Lack of natural resources and increasing environmental pollution make various human societies concerned about the future. Historically, although industrial and development achievements have improved the economies, leading to higher employment rates, as well as benefits to individuals and organizations, they have also exacerbated environmental and social problems, which, has attracted more attention to sustainability in recent years (Ahmed & Sarkar, 2018). To this end, today, considering the concept of sustainability in designing supply chain (SC) networks, given the growing global impact, and consequently, the increase of human activities is an important issue for organizations, governments, and people, and in particular, for environmentalists. Furthermore, end-of-use/end-of-life product management is critical not only for economic, social, and environmental reasons, but it can also help to reduce the global trend of uncontrolled consumption, which improperly increases waste discharged (Demirel & Gökçen, 2008; Glassmeyer et al., 2009; Huang & Su, 2013; Persson, Sabelström, & Gunnarsson, 2009; Tong, Peake, & Braund, 2011). Many countries have taken a number of strategic steps to promote a low-carbon economy, such as enacting various carbon emission regulations (Zhou, Hu, & Xiao, 2020). In recent years, advances in information technology (IT) have also made the virtual world more efficient. IT has been and is an essential factor in effective SCM (Ben-Daya, Hassini, & Bahroun, 2017; Ross, Weston, & Stephen, 2010).

The Internet of Things (IoT) is a recent invention in IT and a new IT revolution thaat has changed various fields, including SCM, and is a network of physical objects that interact digitally with inter-company and intra-company sense, monitoring, and interaction; and allows for the agility, visibility, tracking, and sharing of data to help with timely scheduling, management, and coordination of SC activities (Ben-Daya et al., 2017). Object intelligence in the IoT is performed using devices such as Radio Frequency Identification (RFID), global positioning systems (GPS), and other sensor equipment in Internet-connected networks. Using information and communication technologies (ICTs), such as RFID, makes it possible to track goods in an SC. According to the findings of the majority of investigations, the data gathered via the usage of RFID technology in an SC is essential for optimizing SC operations (by increasing the monitoring capability and integration among participants) (Calatayud, Mangan, & Christopher, 2019). Therefore, this tool can play an essential role in agility and accelerate SC activity, and value creation in the organization.

In recent years, another important issue has been the consideration of several sales channels in the SC network. Customers are demanding for higher-quality products and services as a result of fast changes in living standards, and producers that can offer a choice of sales possibilities are preferred. Although some people still favor conventional buying methods, a rising number of people are shopping online. Therefore, many factories have different channels for selling their products to customers (Rahmani, Hasan Abadi, & Hosseininezhad, 2020). Also, it has been proven that the set of products used and reproduced can not only improve the use of resources and create a favorable social image, but also can be profitable and increase competitiveness. Because of this, the need to collect as many products as possible from the end user has led many companies to use more than one collection channel in the closed-loop supply chain (CLSC).

There are also several sorts of uncertainty that affect SC processes. Environmental and systemic uncertainty are the two basic forms of uncertainties. The first sort of uncertainty occurs prior to the production process, such as supply and demand uncertainty. The second type of uncertainty is relevant to quality, delivery time, production system failure, and product changes in the production process (Ho, 2007). In this study, we will consider both the main types of systemic and environmental uncertainties. In other words, according to the above, in this paper, a multi-objective, multi-echelon, multi-product, and multi-period model will be presented to design a sustainable CLSC with different sales and collection channels and RFID technology, and it will also address the policy of producing low-carbon products and the policy of subsidizing to produce these products and the pricing strategy, and it will use Robust scenario-based Stochastic programming (RSSP) to cope with uncertainty parameters. Thus, the remainder of the paper is laid out as follows: The literature relevant to the study will be reviewed in section 2. Section 3 defines the parameters and variables of the suggested model and describes certain and robust models based on them. Section 4 is devoted to expressing the solution approach and providing a numerical example and its computational results and analysis, and ultimately, section 5 provides conclusions, managerial insights, and suggestions for future studies.

LITERATURE REVIEW

The SC has become longer, larger, more fragmented, and complex and therefore requires transparency. Transparency provides a way to ensure SC risk reduction for SC members and end consumers. Transparency, in addition to reducing risk, allows SC members to track products to ensure tracking accuracy (Zelbst, Green, Sower, & Bond, 2019). Some of the performed researches on the use of RFID in the CLSC can be mentioned as follow:

In a CLSC, Kim and Glock (2014) used an RFID system to manage containers, transportation. They used the implementation of the RFID technology in the return path to support container position tracking in the SC (Kim & Glock, 2014). Hajipour et al. (2019) presented a CLSC problem using RFID technology to simultaneously minimize lead time, social, and environmental time-consuming objective functions. They used stochastic programming to deal with model uncertainty (Hajipour, Tavana, Di Caprio, Akhgar, & Jabbari, 2019). Nejad et al. (2021) discussed in an paper on optimizing profit and environmental objectives in a multi-product RFID-based closed-loop chain with a green entrepreneurial orientation in the food industry (Nezhad, Taghizadeh-Yazdi, Dahooie, Babgohari, & Sajadi, 2021).

- *Researches on Dual and Multi-channel CLSC design:*

In this regard, in addition to (Feng, Govindan, & Li, 2017; Honarvar & Ahmadi Yazdi, 2015; Hong, Wang, Wang, & Zhang, 2013; Wang, Wang, & Wang, 2016; Yan, Xiong, Xiong, & Guo, 2015); some other research related to recent years in this field can be mentioned as follows:

Chen et al. (2019) presented MINLP for modeling a reproducible network in a two-channel CLSC (Chen, Zhang, shi, & Xia, 2019). Niranjan et al. (2019) provided a model for an integrated multi-channel CLSC network problem, which includes the selection of an entity that meets the customer needs of the omnichannel at different time periods. The purpose of this model is to reduce the total costs incurred by the customer, the total costs incurred in the SC implementation, and the total pollution emissions caused by the transportation of products between different stages of the chain (Niranjan, Parthiban, Sundaram, & Jeyaganesan, 2019). Kaoud et al. (2020) suggested a mathematical model that integrates e-commerce with a multi-level CLSC, with a multi-period programming time horizon, taking into consideration dual-channels, in production and recovery centers (Kaoud, Abdel-Aal, Sakaguchi, & Uchiyama, 2020). Rahmani et al. (2020) presented a mathematical model based on a two-channel system to design a green SC. In this paper, Government subsidy policies have also been implemented to encourage managers to produce green products (Rahmani et al., 2020). Fathollahi-Fard et al. (2021), in a paper, under uncertainty, designed a dual-channel CLSC network for the tire industry. They used a fuzzy method, the Jimenez technique, to deal with the problem's uncertain parameters (such as pricing and demand)(Fathollahi-Fard et al., 2021).

Gharye Mirzaei et al. (2022) proposed a two-channel network of SCLSC for rice considering energy resources and consumption tax. They formulated a MILP model to optimize the total cost, the amount of pollutants and the number of job opportunities created in their SC network under cost, supply and demand uncertainty and used fuzzy logic to deal with the uncertainty. In addition, to solve the model in small sizes from the Lp-Metric method and to solve the model in large sizes from four multi-objective meta-heuristic algorithms called multi-objective crawler search optimization (MORSO), multi-objective simulated annealing optimization (MOSA), multi-objective paper swarm optimization (MOPSO) and MOGWO were used. Experimental results showed that MORSO worked very well and by building solar panel sites and producing energy from rice waste, up to 19% of electricity consumption was saved (Gharye Mirzaei, Goodarzian, Maddah, Abraham, & Abdelkareim Gabralla, 2022). Soleimani et al. (2022) in an paper designed a SCLSC including suppliers, manufacturers, distribution centers, customer areas and disposal centers considering energy consumption, in which distribution centers play the role of warehouse and collection centers they do. Their problem consists of three choices of refurbishing, recycling and discarding returned items. Objectives include total profit, energy consumption and number of job opportunities created. Their proposed model also addresses customer demand and real-world constraints for location, allocation, and inventory decisions in a CLSC framework.

Another novelty of this research was to develop a set of efficient and fast heuristic Lagrangian release reformulations to solve a real-world numerical example. The results showed that the obtained solution is achievable and the developed solution algorithm is very efficient for solving SC models (Soleimani, Chhetri, Fathollahi-Fard, Mirzapour Al-e-Hashem, & Shahparvari, 2022). Niranjan et al. (2022) considered the concept of multiple channels for a traditional offline SC of a battery manufacturer in the southern part of India. Their main goal is to develop a mathematical model for this multi-channel CLSC, considering economic and environmental objectives. To solve the model, PSO perturbed initial population generation with levy flight distribution is used. The results showed that modified PSO (MPSO) provides superior results (Niranjan, Thanigaivelan, & Singaravel, 2022).

- *Regarding the application of the RSSP approach in the CLSC, the following just can be mentioned:*

Saffari et al. (2015) provided a CLSC with the three objectives of minimizing SC costs and carbon emissions and maximizing job opportunities; and since customer demand is involved in high uncertainty, the RSSP approach has been used to control it and an efficient genetic algorithm to find the optimal Pareto solutions (Saffari, Makui, Mahmoodian, Pishvaee, & Engineering, 2015). Ma et al. (2016) designed a sustainable green CLSC problem to optimize the economic cost of the SC and the resulting environmental pollution, assuming uncertain costs and demand (Ma, Yao, Jin, Ren, & Lv, 2016). Safaei et al. (2017) employed mixed integer programming (MIP) to model suppliers and manufacturers and the RSSP method to cope with demand uncertainty in the cardboard recycling industry. Their model maximizes profits and determines the desired output of paper and cardboard (Safaei, Roozbeh, & Paydar, 2017). Paydar et al. (2017) applied an RSSP approach to cope with uncertainty in motor oil collection (Paydar, Babaveisi, & Safaei, 2017). Gholizadeh et al. (2018) suggested a multi-layered CLSC. The purpose of this model is to increase forward and reverse supply products (Gholizadeh, Tajdin, & Javadian, 2018).

Abdolazimi et al. (2020), to increase delivery time, minimize overall costs and environmental impacts, and considering the uncertainty of some parameters, designed a CLSC network under certain and uncertain situations. They studied their proposed approach in a Tier factory (Abdolazimi, Salehi Esfandarani, Salehi, & Shishebori, 2020). Atabaki et al. (2020) designed a MIP model for an SC of durable products based on the Circular Economy model. The suggested model contained multiple recovery centers to recover the returned products. In addition to the economic goal, they defined the two goals of CO2 emissions and energy consumption (Atabaki, Mohammadi, & Naderi, 2020). Gholizadeh et al. (2020) examined the scenario-based stochastic robust optimization in the CLSC for the smelting industry, taking into account consumer environmental awareness and demand uncertainty (Gholizadeh & Fazlollahtabar, 2020). Samuel et al. (2020), considering different carbon emission policies, designed a definitive CLSC model, and a robust mathematical model, to investigate the effects of returned product quality (Samuel, Venkatadri, Diallo, & Khatab, 2020). Fang and lin (2021), proposed a multi-objective mixed integer programming model for an integrated green CLSC network designed to maximize profit, amicable production level (environmentally friendly materials and clean technology usage), and quality level.

Also used a scenario-based robust optimization method to deal with uncertain parameters such as the demand of new products, the return rates of returned products and the sale prices of remanufactured products. The result showed a robust optimal resource allocation solution that considers multiple scenarios(Fang, Lin, & Management, 2021). Khorshidvand et.al (2021) proposed a new hybrid method, in which SCC decisions and CLSCND objectives are simultaneously involved. First, this approach makes price, greenness, and advertisement decisions, and then it aims at maximizing profit and minimizing CO2 emission. A new nonlinear programming (NLP) model is developed based on the sensitivity of the return rate to green quality and the customers' maximum tolerance, while the demands are uncertain. This model uses RSSP method to overcome uncertain demands. They also used a Lagrangian relaxation algorithm to solve large-scale instances in logical running time. The results showed the improvement of the performance of economic and environmental objectives under greening and advertising decisions (Khorshidvand, Soleimani, Sibdari, & Mehdi Seyyed Esfahani, 2021).

In a paper, Gholizadeh et al. (2021), supplements the augmented ε-constraint approach with linearization using robust optimization and heuristics with an improved algorithm to maximize the total profit and minimize the environmental effects of a SCLSC in the dairy industry. They considered pessimistic, optimistic, and worst-case scenarios are considered along with the sensitivity analysis on the profitability of the CLSC concerning the product lifetimes.The results showed that applying the heuristic on large-scale problems yields a 25% improvement in runtime. Furthermore, products with a longer lifetime under the worst-case scenario yield greater profit than those products with a shorter lifetime under an optimistic scenario(Gholizadeh, Jahani, Abareshi, & Goh, 2021). Abdolazimi et al. introduced a multi-objective CLSC network consisting of several levels, several periods, and several products and uncertainties in some parameters of the proposed model. Because of the multi-objective feature of the problem, four exact approaches including LP-metric, sequential linear goal programming (SLGP), TH approach, and simple additive weighting (SAW), were applied to unravel the objective functions(Abdolazimi, Bahrami, Shishebori, & Ardakani, 2021). In a paper, Mirzaei et al. (2022), for the first time, examined a green supplier selection problem by considering green and non-green evaluation criteria in a CLSC and used the cap-and-trade mechanism as a way. They proposed to control the air pollution caused by the manufacturers. To solve the described problem, a multi-objective scenario-oriented stochastic robust optimization model was proposed as an effective approach to deal with uncertainty. The results show that the developed model for green supplier selection can effectively promote the decision-making process of experts. Finally, they showed that the cap-and-trade mechanism compared to the penalty-based system provides a better solution in terms of the utility of the entire SC (Mirzaee, Samarghandi, & Willoughby, 2022).

Ebrahimi and Bagheri (2022) apply a CLSC network for the plastic bottle industry and then formulate a multi-objective mathematical model considering several hypotheses. This model seeks to optimize total costs, supply risk and customer satisfaction (distributor reliability). A revised multi-choice goal programming approach is also used to solve the model and verify it through a case study. In addition, the best-worst method is used as a robust multi-criteria decision-making tool to find supply risk parameter values(Ebrahimi & Bagheri, 2022). Ali Mohammadi Ardakani (2022) investigated the transfer of petroleum products from supply points to consumption areas through a SC. whose purpose is to reduce the cost of transportation and reduce the number of loads, and to deal with uncertainty, it used the rssp approach, and due to the high volume of calculations and data of the problem, as well as the inability to use accurate solution methods, especially on a large scale, from PSO and MOGA-II meta-heuristic algorithms were used to solve the proposed model. The results show that the model has the necessary efficiency in large dimensions and the proposed solution methods provide appropriate answers (Alimohammadi Ardekani, 2022).

By reviewing the literature on the design of two/multi-channel CLSCs, it is clear that there is no study that focuses on the concepts of sustainability and greenness at the same time. In other words, the type of technology in the production of green products has a significant effect on environmental issues, which has been given less attention in the mathematical models developed in the literature, and there is no study that simultaneously aims to maximize profit, social responsibility and minimization. Consider environmental pollution and delay in delivery time. It should be known that abandoning traditional methods and using new technologies in the industrial and economic fields is the basis for greater productivity. According to the studies conducted, it can be seen that the use of RFID technologies in the SCM literature is still limited. Also, due to the rapid change in living standards, customers prefer manufacturers who are able to provide different sales options, and due to the need to collect as many products as possible from the end user, many companies have more than one collection channel apply in CLSC, therefore, considering multiple channels and its mathematical modeling is one of the things that has recently received attention in the SC, but there are few studies in this field. Finally, therefore, these research gaps were used as research innovation.

The important innovations of the developed model are:

1. Considering the strategic decision about the type of production technology in the factory to create a green product.
2. Considering the government subsidy for the producers in order to reduce the prices due to the increase of the green area.
3. Considering RFID technology for transportation situations; that the use of rfid technology in the SC accelerates information transactions, reduces time delays in transportation, pays electronic tolls without stopping on highways, delivers orders on time, and transports faster and eliminates incorrect shipments, etc. and as a result, it can shorten the order chain and make the chain more agile and responsive.
4. Considering several sales channels and using combined facilities; the use of multiple sales channels allows industries and companies to reach customer segments that could not be reached through traditional (indirect) retail channels.
5. Considering environmental and systemic uncertainty in some model parameters to be more consistent with reality.
6. Using meta-heuristic algorithms of NSGA-III and MOGWO to solve the model in higher dimensions.

And to our knowledge, this is the first attempt to design a CLSC that simultaneously incorporates several complex features/concepts of robustness sustainability (economic, social and environmental dimensions), RFID technology, different sales and collection channels, pricing, role selection It considers environmental technologies as a source of improving the production process along with government subsidies to producers in a multi-objective, multi-period, multi-product manner, which creates a new and more comprehensive design of the CLSC.

PROBLEM STATEMENT AND MATHEMATICAL MODEL

This research will provide a nonlinear mixed-integer programming model of the multi-objective, multi-echelon, multi-product, and multi-period to design a sustainable CLSC, Considering RFID technology and systemic and environmental uncertainties. In the forward direction, raw materials are supplied from the supplier and sent to production-recovery centers to produce a new product. Newly produced products can be provided to customers both directly from production-recovery centers and indirectly from distribution/hybrid centers. Sales in distribution/hybrid centers are both online and offline. Customers' returned products are also sent to collection/testing centers for collection and testing after collection, and after testing and inspection, recoverable products are sent to production/recovery centers, repairable products to repair centers, and from there to secondary customers; and non-recoverable and non-repairable products are sent to disposal centers. In this chain, hybrid centers jointly both collect and distribute products. When opposed to individual distribution or collection centers, hybrid processing centers offer greater benefits such as cost savings and emission reduction owing to the sharing of production equipment and infrastructure. Figure 1 shows the structure of this SC.

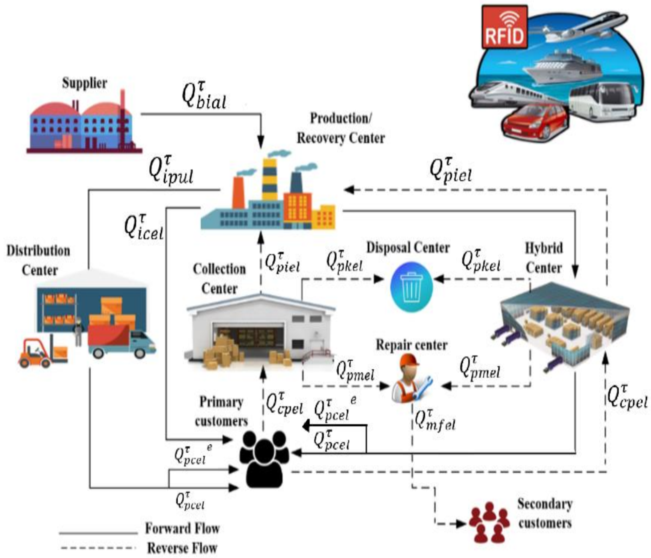


FIGURE 1
SCHEMATIC OF THE PROPOSED CLSC

There are, in this paper, several vehicles with limited time of use while delivering the product to the customer; therefore, it is necessary to transfer information quickly between the vehicles and the centers; in this chain, a transportation technology must be considered for each of the connections between the members of the chain. To this end, several predefined transportation technologies have been examined, each establishing connections between different members of the chain. These transportation technologies are different in terms of cost and delivery time, which SC management has to choose the most economical one, with a minimum total delay of delivery time. So, the use of various RFID Technologies is recommended. These Technologies, used in the shipping fleet, are responsible for monitoring customer orders online and try through integrating the information with their origin and destination, minimizing the time interval between ordering and receipt. Thus, in general, using an RFID technology can increase the availability time of the vehicle. Therefore, this research has used different types of RFID Technologies, which SC management must decide on selecting them. Selecting the RFID technology type affects two goals of minimizing the total delay of delivery time and economy. In terms of agility, the use of higher RFID technologies reduces delivery times (improves agility). On the other hand, the use of higher RFID technologies has a higher initial cost, and as a result, weakens the chain's economic performance.

In addition, carbon emissions and their control have been defined as one of the most significant challenges in SC networks. To that purpose, this study has tried, in addition to reducing the total amount of pollution, to address it strategically. One of the main objectives of designing an SC is to select factories with the least pollution for production. In fact, the right selection of production technology can reduce the pollutants from the production of the product. Therefore, in the model of this paper, "h" is defined as the product technology level, where a larger h means that the product is low-carbon or so-called greener. It should be noted that the cost of producing the product has a positive correlation with the h-level since producing a low-carbon/greener product necessitates the use of contemporary and advanced equipment and machinery, and as a result, the cost of production will also be higher.

The constant cost of openness/activity of the center i at technology level h in period τ can be defined as $FX_{ih}^{\tau} = CF_i^{\tau} + \theta_i^{\tau} \sum_h h^2 X_{ih}^{\tau} \forall i, h, \tau$, in which CF_i^{τ} is equal the initial regular production cost at the center i without considering technology h in period τ. θ_i^{τ} denotes the rate of price increase for each level of improvement in the level of low-carbon product production technology. The second term of this equation indicated that as the level of product technology increased, costs increased quadratically. It should be noted that the quadratic form is a common function to determine production costs for low-carbon/greener crop production (Deutch & Lester, 2004; Liu, Anderson, & Cruz, 2012; Rahmani et al., 2020). Moreover, there are two main points to compensate for the mentioned cost. The first point is that the number of pollutants from the production of low-carbon/greener products will be less. In addition, producers' decisions to produce low-carbon/greener products can be influenced by subsidies paid by the government. As a result, the higher the technology h level, the more subsidies the government pays to the factory, and as a result, part of the factory's costs are compensated (Rahmani et al., 2020; Yu, Han, & Hu, 2016). The assumptions of this research can be expressed in more detail as follows:

- In this chain, the locations of suppliers, primary and secondary customers, are known and fixed.
- There is a set of potential points that can be of the production-recovery centers, distribution and collection centers, hybrid centers, repair, and disposal centers.
- Each customer's demand can only be met through one distribution/sales channel.
- Distribution/hybrid centers have the ability to sell online and offline.
- There are two collection channels.
- The capacity of all centers is limited.
- A variety of different technologies can be used for low-carbon production.
- Transport capacity between different levels of the chain is limited.
- A variety of RFID Technologies can be used for different transportation options.
- The demand of customers must be satisfied.
- The overall quantity of greenhouse gas emissions must not exceed the determined limit.

I. CERTAIN MATHEMATICAL MODEL

Before presenting the mathematical model, the indices, parameters, and decision variables of the model are as follows:

Indexes of the proposed mathematical model:

$\boldsymbol{b}$: suppliers b=1,...,B
$\boldsymbol{i}$: production-recovery centers i=1,...,I
p: distribution,collection and hybrid centers p=1,...,P
c: primary customers c=1,...,C
k: product disposal centers k=1,...,K
m: repair centers m=1,...,M
f: secondary customers f=1,...,F
e: Products e=1,...,E
a: Raw Materials a=1,...,A
l: Transportation options l=1,...,L
τ: time periods τ=1,...,T
h: set of low-carbon product production technologies h=1,...,H
o: RFID technology type used in transportation options o=1,...,O
s: Scenario (high,medium,low)s=1,...,S
j, **j′**: set of all echelons $\mathbf{j}, \mathbf{j}' \in \{\mathbf{b}, \mathbf{i}, \mathbf{p}, \mathbf{c}, \mathbf{k}, \mathbf{m}, \mathbf{f}\}$
$\mathbf{w_j}$, $\mathbf{w_j}'$: set of facilitis in echelon $\mathbf{w_j}, \mathbf{w_j}' \in \{\mathbf{1}, \dots, \mathbf{W_j}\}$

Parameters

$\boldsymbol{D^{\tau}_{ce}/D^{\tau}_{ces}}$: In period τ,demand of primary customer c for product e/ under scenario s
$\boldsymbol{D^{\tau}_{fe}/D^{\tau}_{fes}}$: In period τ,demand of secondary customer f for product e/ under scenario s
$\boldsymbol{BC^{\tau}_{ba}}$: In period τ,cost of raw material purchasing unit a from supplier b
$\boldsymbol{MC^{\tau}_{ieh}}$: In period τ,cost of product producing unit e in center i
$\boldsymbol{RC^{\tau}_{ieh}}$: In period τ,cost of product recovery unit e in center i with technology h
$\boldsymbol{OF^{\tau}_{ew_j}}$: In period τ, operational cost at facility $\boldsymbol{w_j | j \in \{p, m, k\}}$
$\boldsymbol{CF^{\tau}_{i}}$: In period τ,the initial regular production cost at the center i without considering technology h
$\boldsymbol{FB^{\tau}_{b}}$:In period τ,fixed cost of supplier choosing b
$\boldsymbol{FF^{\tau}_{w_j}}$: In period τ,fixed cost of openness of facility $\boldsymbol{w_j | j \in \{p, k, m\}}$
$\boldsymbol{CB^{\tau}_{ba}}$: In period τ,Supplier capacity b for raw materials a
$\boldsymbol{CX^{\tau}_{ih}}$: In period τ,Production capacity in the center i with technology h
$\boldsymbol{CR^{\tau}_{ih}}$: In period τ,capacity of center i to recover returned products with technology h in period t
$\boldsymbol{CA^{\tau}_{w_j}}$: In period τ,capacity of facility $\boldsymbol{w_j | j \in \{p, k, m\}}$

$\boldsymbol{CBI^{\tau}_{bial}}$: In period τ,cost of raw material transfer unit a transported from supplier b to center i with transportation option l

$\boldsymbol{CTF^{\tau}_{elw_jw'_{j'}}}$: In period τ,cost of product transfer unit e transported from the facility $\boldsymbol{w_j | j \in \{i,p,c,m\}}$ to the facility $\mathbf{w_j}' | \boldsymbol{j' \in \{p,c,i,k,m,f\}}$ with the transportation option l,corresponding to $\boldsymbol{Q^{\tau}_{elw_jw'_{j'}}}$ illustrated in figure1

$\boldsymbol{EBI^{\tau}_{bial}}$: In period τ,environmental pollution resulting from transferring the raw materials a from supplier b to the center i with transportation option l

$\boldsymbol{ETF^{\tau}_{elw_jw'_{j'}}}$: In period τ,environmental pollution resulting from transferring the product e from the facility $\boldsymbol{w_j | j \in \{i,p,c,m\}}$ to the facility $\mathbf{w_j}' | \boldsymbol{j' \in \{p,c,i,k,m,f\}}$ with transportation option l,corresponding to $\boldsymbol{Q^{\tau}_{elw_jw'_{j'}}}$ illustrated in figure 1

$\boldsymbol{EP^{\tau}_{ieh}}$: In period τ,environmental pollution resulting from the production of product e in center i with technology h

$\boldsymbol{ER^{\tau}_{me}}$: In period τ,environmental pollution resulting from the production of product e in center m

$\boldsymbol{TBI^{\tau}_{bialo} / TBI^{\tau}_{bialos}}$: In period τ,delivery time of raw material a from supplier b to center i with transportation option l with RFID technology type o / under scenario s

$\boldsymbol{DTF^{\tau}_{elow_jw'_{j'}} / DTF^{\tau}_{elow_jw'_{j'}s}}$: In period τ,delivery time of product e from the facility $\boldsymbol{w_j | j \in \{i,p,c,m\}}$ to the facility $\mathbf{w_j}' | \boldsymbol{j' \in \{p,c,i,k,m,f\}}$ with transportation option l with RFID technology type o, corresponding to $\boldsymbol{Q^{\tau}_{elw_jw'_{j'}}}$ illustrated in figure 1/ under scenario s

$\boldsymbol{TBI^{\tau}_{ialo}{}' / TBI^{\tau}_{ialos}{}'}$: In period τ,expected delivery time of raw materials a from supplier b to center i with transportation option l with RFID technology type o/ under scenario s

$\boldsymbol{DTF^{\tau}_{elow_jw'_{j'}}{}' / DTF^{\tau}_{elow_jw'_{j'}s}{}'}$:In period τ,delivery time of product e from the facility $\boldsymbol{w_j | j \in \{i,p,c,m\}}$ to the facility $\mathbf{w_j}' | \boldsymbol{j' \in \{p,c,i,k,m,f\}}$ with transportation option l with RFID technology type o, corresponding to $\boldsymbol{Q^{\tau}_{elw_jw'_{j'}}}$ illustrated in figure 1/ under scenario s

$\boldsymbol{FRD^{\tau}_{low_jw'_{j'}}}$: In period τ,fixed cost of using RFID technology type o to send from the facility $\boldsymbol{w_j} | \boldsymbol{j} \in \{\boldsymbol{b,i,p,c,m}\}$ to the facility $\mathbf{w_j}' | \boldsymbol{j'} \in \{\boldsymbol{i,p,c,k,m,f}\}$ with transportation option l

$\boldsymbol{TCAPF^{\tau}_{lw_jw'_{j'}}}$: In period τ, transportation capacity to send from the facility $\boldsymbol{w_j} | \boldsymbol{j} \in \{\boldsymbol{b,i,p,c,m}\}$ to the facility $\mathbf{w_j}' | \boldsymbol{j'} \in \{\boldsymbol{i,p,c,k,m,f}\}$ with transportation option l

$\boldsymbol{WX^{\tau}_{ih}}$: In period τ,number of job opportunities per activity of the center i with technology h

$\boldsymbol{WF^{\tau}_{w_j}}$: In period τ,number of job opportunities per activity of facility $\boldsymbol{w_j} | \boldsymbol{j} \in \{\boldsymbol{p,k,m}\}$

$\boldsymbol{DX^{\tau}_{ih}}$: In period τ,the rate of economic development per activity of the center i with technology h

$\boldsymbol{DF^{\tau}_{w_j}}$: In period τ,the rate of economic development per activity of facility $\boldsymbol{w_j} | \boldsymbol{j} \in \{\boldsymbol{p,k,m}\}$

$\boldsymbol{LX^{\tau}_{ih}}$: In period τ,number of days lost,due to workers' injuries per activity of the center i with technology h

$\boldsymbol{LF^{\tau}_{w_j}}$: In period τ,number of days lost,due to workers' injuries,per activity of facility $\boldsymbol{w_j | j \in \{p,k,m\}}$

$\boldsymbol{n_{ae}}$: Coefficient of using raw material a in production of product e

$\boldsymbol{m_e}$: Coefficient of using of product e

$\boldsymbol{mcont_{\tau}}$: In period τ,probability of order contract,with collection/ hybrid center p to center i

$\boldsymbol{RR_e}$: Return rate of the used product e

$\boldsymbol{RXi_e, RXm_e, RXd_e}$: Recovery rate, repair rate, Disposal rate of the used product e, respectively; $(\boldsymbol{RXi_e + RXm_e + RXd_e = 1})$

$\boldsymbol{\psi_i}$: The allowable maximum emission of pollution for center i

$\boldsymbol{Sb^{\tau}_{ih}}$: In period τ,The subsidy that the government gives to the center i at the level of technology h

$\boldsymbol{\theta^{\tau}_i}$: In period τ,the increase rate of price,per level of improvement,at the product greenness level for the center i

$\boldsymbol{\lambda p_1}$: the coefficient of price elasticity of the demand for the primary customer demand channel

$\boldsymbol{\lambda p_2}$: the coefficient of price elasticity of the demand for the secondary customer demand channel

$\boldsymbol{\gamma_1}$ and $\boldsymbol{\gamma_2}$: the coefficients cross-price elasticity of demand for primary and secondary customer channels

$\boldsymbol{\beta}$: weighting factor for the forward responsiveness (or importance)

$\boldsymbol{1-\beta}$: weighting factor for the reverse responsiveness

$\boldsymbol{\varsigma_1, \varsigma_2, \varsigma_3}$: the weights given to the elements of social responsibility objective: (1) the number of created jobs (2) economic development (3) workers's lost days, respectively.

$\boldsymbol{BM}$: A very large number

$\boldsymbol{M1^{\tau}_{ialo}} = \{\boldsymbol{b} | \boldsymbol{TBI^{\tau}_{bialo}} \geq \boldsymbol{TBI^{\tau}_{ialo}}{}'\}$: Supply centers f that have a delay in the delivery of raw materials to production-recovery centers i in period τ

$\boldsymbol{MF^{\tau}_{w'_{j'}elo}} = \left\{\boldsymbol{m} \middle| \boldsymbol{DTF^{\tau}_{elo,w_jw'_{j'}}} \geq \boldsymbol{DTF^{\tau}_{elow'_{j'}}}{}'\right\}$: the facility $\boldsymbol{w_j} | \boldsymbol{j} \in \{\boldsymbol{i,p,c,m}\}$ that have a delay in product delivery to facility $\boldsymbol{w'_{j'}} | \boldsymbol{j'} \in \{\boldsymbol{p,c,i,k,m,f}\}$ in period τ

$\boldsymbol{P_s}$: Probability of scenario s

$\boldsymbol{\omega}$: Weight for violated Constraints

$\boldsymbol{\lambda 1, \lambda 2, \lambda 3}$: fixed values

Decision variables

$\boldsymbol{Q^{\tau}_{bial} / Q^{\tau}_{bials}}$: In period τ,quantity of transported raw material a from supplier b to the center i with transportation option l/ under scenario s

$Q^{\tau}_{elw_j w'_{j'}}/Q^{\tau}_{elw_j w'_{j'} s}$: In period τ,quantity of transported repairable products e from the facility $w_j|j \in \{i,p,c,m\}$ to the facility $w_j'|j' \in \{p,c,i,k,m,f\}$ with transportation option l/ under scenario s
$INV^{\tau}_{pe}/INV^{\tau}_{pes}$: In period τ,inventory of Product e at the distribution/hybrid center p/ under scenario s
$FX^{\tau}_{ih}/FX^{\tau}_{ihs}$: In period τ,production cost of the center i, with technology h/ under scenario s
$d^{\tau}_{ce}/d^{\tau}_{ces}$: In period τ,proposed demand of primary customer c for product e/ under scenario s
$d^{\tau}_{fe}/d^{\tau}_{fes}$: In period τ,proposed demand of secondary customer f for product e/ under scenario s
PR^{τ}_{ce}: In period τ,selling price of each product unit e to the primary customer c
PR^{τ}_{fe}: In period τ,selling price of each product unit e to the secondary customer f
OS^{τ}_{cpe}: In period τ,1 if the demand of customer c for product e is met through online sales by distribution center p; otherwise,0
B^{τ}_{b}: In period τ,1 if supplier b is selected; otherwise,0
X^{τ}_{ih}: In period τ,1 if the production-recovery center i is opened,with technology h; otherwise,0
$OF^{\tau}_{w_j}$: In period τ,1 if the facility $w_j|j \in \{p,k,m\}$ is opened; otherwise,0
$ORF^{\tau}_{low_j w'_{j'}}$: In period τ,1 if the transport option l with RFID technology type o,links the facility $w_j|j \in \{b,i,p,c,m\}$ to the facility $w_j'|j' \in \{i,p,c,k,m,f\}$; otherwise,0
$\theta 1_s, \theta 2_s, \theta 3_s$: Linearization coefficient based on scenario s for the first objective function, the third objective function and the second objective function, respectively.
$\eta 1^{\tau}_{ces}$: In period τ,unfulfilled demand for product e for the primary customer c in scenario s
$\eta 2^{\tau}_{fes}$: In period τ,unfulfilled demand for product e for the secondary customer f in scenario s

Objective functions:

$$\mathbf{MaxObjective1} = \sum_{\tau}(Income_{\tau} - cost_{\tau}) \quad (1)$$

$$\mathbf{Income_{\tau}} = \sum_{e,l,w_{j\in\{p,i\}},w'_{j'\in\{c\}}} PR^{\tau}_{ce} Q^{\tau}_{elw_{j\in\{p,i\}},w'_{j'\in\{c\}}} + \sum_{elw_{j\in\{m\}},w'_{j'\in\{f\}}} PR^{\tau}_{fe} Q^{\tau}_{elw_{j\in\{m\}},w'_{j'\in\{f\}}} \sum_{e,l,h,w_{j\in\{p,i\}},w'_{j'\in\{c\}}} Sb^{\tau}_{ih} X^{\tau}_{ih} PR^{\tau}_{ce} Q^{\tau}_{elw_{j\in\{p,i\}},w'_{j'\in\{c\}}} \quad (2)$$

$$\mathbf{Cost_{\tau}} = \left(\sum_{i,h} FX^{\tau}_{ih}(X^{\tau}_{ih} - X^{\tau-1}_{ih}) + \sum_{w_{j\in\{p,k,m,\}}} FF^{\tau}_{w_j}\left(OF^{\tau}_{w_j} - OF^{\tau-1}_{w_j}\right) + \sum_{b} F\, B^{\tau}_{b} B^{\tau}_{b}\right) + \left(\sum_{b,i,a,l} Q^{\tau}_{bial}\, BC^{\tau}_{br} + \sum_{e,l,w_{j\in\{i\}},w'_{j'\in\{p,c\}}} Q^{\tau}_{elw_{j\in\{i\}}w'_{j'\in\{p,c\}}} MC^{\tau}_{ieh} + \sum_{elw_{j\in\{p,c\}},w'_{j'\in\{c,m,p,k\}}} Q^{\tau}_{elw_{j\in\{p,c\}},w'_{j'\in\{c,m,p,k\}}} OF^{\tau}_{ew_j} + \sum_{e,h,l,w_{j\in\{p\}},w'_{j'\in\{i\}}} Q^{\tau}_{elw_{j\in\{p\}}w'_{j'\in\{i\}}} RC^{\tau}_{ieh} + \sum_{p,e} INV^{\tau}_{pe} HC^{\tau}_{pe}\right) + \sum_{b,i,a,l} Q^{\tau}_{bial}\, CBI^{\tau}_{bial} + \sum_{e,l,w_{j\in\{i,p,c,m\}},w'_{j'\in\{i,c,p,k,m,f\}}} Q^{\tau}_{elw_{j\in\{i,p,c,m\}}w'_{j'\in\{p,c,i,k,m,f\}}} CTF^{\tau}_{elw_{j\in\{i,p,c,m\}}w'_{j'\in\{p,c,i,k,m,f\}}} + \sum_{e,l,w_{j\in\{b,i,p,c,m\}},w'_{j'\in\{i,p,c,k,m,f\}}} ORF^{\tau}_{lo,w_{j\in\{b,i,p,c,m\}}w'_{j'\in\{i,p,c,k,m,f\}}} FRD^{\tau}_{lo,w_{j\in\{b,i,p,c,m\}}w'_{j'\in\{i,p,c,k,m,f\}}} \quad (3)$$

$$\mathbf{MinObjective2} = \beta\left(\sum_{b\in M1^{\tau}_{ialo},i,a,l,o,\tau} OBI^{\tau}_{bilo}\left(TBI^{\tau}_{bialo} - TBI^{\tau}_{ialo}{}'\right) + \sum_{b\in MF^{\tau}_{e,l,o,w_{j\in\{i,p\}}w'_{j'\in\{p,c\}}}\, l,o,lo,w_{j\in\{i,p\}}w'_{j'\in\{p,c\}},\tau} ORF^{\tau}_{lo,w_{j\in\{i,p\}}w'_{j'\in\{p,c\}}}\left(DTF^{\tau}_{elo,w_{j\in\{i,p\}}w'_{j'\in\{p,c\}}} - DTF^{\tau}_{elo,w_{j\in\{i,p\}}w'_{j'\in\{p,c\}}}{}'\right)\right) + (1-\beta)\left(\sum_{b\in MF^{\tau}_{e,l,o,w_{j\in\{c,p,m\}}w'_{j'\in\{p,i,k,m\}}}} ORF^{\tau}_{lo,w_{j\in\{c,p,m\}}w'_{j'\in\{p,i,k,m\}}}\left(DTF^{\tau}_{elo,w_{j\in\{c,p,m\}}w'_{j'\in\{p,i,k,m\}}} - DTF^{\tau}_{elo,w_{j\in\{c,p,m\}}w'_{j'\in\{p,i,k,m\}}}{}'\right)\right) \quad (4)$$

$$\mathbf{MaxObjective3} = \varsigma_1\left(\sum_{i,h,\tau} WX^{\tau}_{ih} X^{\tau}_{ih} + \sum_{w_{j\in\{p,k,m\}},\tau} WF^{\tau}_{w_j} OF^{\tau}_{w_j}\right) + \varsigma_2\left(\sum_{i,h,\tau} DX^{\tau}_{ih} X^{\tau}_{ih} + \sum_{w_{j\in\{p,k,m\}},\tau} DF^{\tau}_{w_j} OF^{\tau}_{w_j}\right) - \varsigma_3\left(\sum_{i,h,\tau} LX^{\tau}_{ih} X^{\tau}_{ih} + \sum_{w_{j\in\{p,k,m\}},\tau} LF^{\tau}_{w_j} OF^{\tau}_{w_j}\right) \quad (5)$$

$$\mathbf{MinObjective4} = \sum_{b,i,a,l,\tau} Q^{\tau}_{bial} \times EBI^{\tau}_{bial} + \sum_{e,l,w_{j\in\{i,p,c,m\}}w'_{j'\in\{p,c,i,k,m,f\}},\tau} Q^{\tau}_{elw_{j\in\{i,p,c,m\}}w'_{j'\in\{p,c,i,k,m,f\}}} + ETF^{\tau}_{elw_{j\in\{i,p,c,m\}}w'_{j'\in\{p,c,i,k,m,f\}}} \sum_{e,h,l,w_{j\in\{i\}},w'_{j'\in\{p,c\}},\tau} Q^{\tau}_{elw_{j\in\{i\}}w'_{j'\in\{p,c\}}} EP^{\tau}_{ieh} + \sum_{e,l,w_{j\in\{p\}},w'_{j'\in\{m\}},\tau} Q^{\tau}_{elw_{j\in\{p\}}w'_{j'\in\{m\}}} ER^{\tau}_{me} \quad (6)$$

Equation (1) is the first objective function, which maximizes the chain's overall profit, which is derived from the difference among incomes and costs. Equation (2) determines the income from product sales in each period. The sale of products in each period includes conventional or online sales to primary customers, direct sales from production-recovery centers to primary customers, and the sale of conventionally repaired products to secondary customers, as well as subsidies received from the government. Equation (3) shows the overall costs of each chain period. These costs include the fixed costs of opening/activity each center, the fixed costs of a supplier choice, the purchasing costs of raw materials from suppliers, the producing costs of products in production-recovery centers, the operating costs of distribution/hybrid centers, the operating costs of repairing in the repair centers, the cost of product inspection and collection in collection/hybrid centers, the cost of product recovery in production and recovery centers, disposal costs, inventory maintenance costs in collection/hybrid centers, transfer costs by different transportation options in the SC, and finally, there is the fixed cost of using a variety of RFID Technologies for SC transportation options. Equation (4) refers to the second objective function, i.e., minimizing the overall delay of delivery time in the forward and reverse SCs. Equation (5) indicates the third objective function, which is maximizing the social responsibility of the SC. This objective consists of three parts. In the first part, the total created jobs are calculated.

In the second part, the total economic development resulting from the SC is calculated. The construction of facilities in deprived and less developed areas leads to the promotion of economic development in those areas. In the third part, the total number of lost working days due to worker injuries in the SC is calculated. Regarding the health and safety of employees, usually the index of "the number of injured and injured" and "the number of working days lost due to injuries" are used. In this paper, the index of the number of working days lost. The cause of injury is used. Equation (6), the fourth objective function, represents the minimizing pollution of the SC. This contamination is due to transferring products between different centers, as well as taking into account the contaminants of production-recovery and repairing the product.

Constraints:

$$\sum_{p,e,l} n_{ae} Q_{ipel}^{\tau} + \sum_{c,e,l} n_{ae} Q_{icel}^{\tau} = \sum_{b,l} Q_{bial}^{\tau} + \sum_{p,e,l} n_{ae} Q_{piel}^{\tau}, \forall i, a, \tau \quad (7)$$

$$INV_{pe}^{\tau-1} + \sum_{i,l} Q_{ipel}^{\tau} = INV_{pe}^{\tau} + \sum_{c,l} Q_{pcel}^{\tau} + \sum_{c,l} {Q_{pcel}^{\tau}}^{e}, \forall p, e, \tau \quad (8)$$

$$Q_{pcel}^{\tau} \leq BM.OS_{cpe}^{\tau}, \forall p, c, e, l, \tau \quad (9)$$

$${Q_{pcel}^{\tau}}^{e} \leq BM.\left(1 - OS_{cpe}^{\tau}\right), \forall p, c, e, l, \tau \quad (10)$$

$$\sum_{c,l} Q_{pcel}^{\tau} + \sum_{c,l} {Q_{pcel}^{\tau}}^{e} + \sum_{i,l} Q_{icel}^{\tau} = d_{ce}^{\tau}, \forall c, e, \tau \quad (11)$$

$$\sum_{p,l} Q_{cpel}^{\tau} = d_{ce}^{\tau} RR_{e}, \forall c, e, \tau \quad (12)$$

$$\sum_{i,l} Q_{piel}^{\tau} = \sum_{c,l} Q_{cpel}^{\tau} RXi_{e}, \forall p, e, \tau \quad (13)$$

$$\sum_{K,l} Q_{pkel}^{\tau} = \sum_{c,l} Q_{cpel}^{\tau} RXd_{e}, \forall p, e, \tau \quad (14)$$

$$\sum_{m,l} Q_{pmel}^{\tau} = \sum_{c,l} Q_{cpel}^{\tau} RXm_{e}, \forall p, e, \tau \quad (15)$$

$$\sum_{k,l} Q_{pkel}^{\tau} + \sum_{i,l} Q_{piel}^{\tau} + \sum_{m,l} Q_{pmel}^{\tau} = \sum_{c,l} Q_{cpel}^{\tau}, \forall p, e, \tau \quad (16)$$

$$\sum_{p,l} Q_{pmel}^{\tau} = \sum_{f,l} Q_{mfel}^{\tau}, \forall m, e, \tau \quad (17)$$

$$\sum_{m,l} Q_{mfel}^{\tau} = d_{fe}^{\tau}, \forall f, e, \tau \quad (18)$$

$$\sum_{i,l} Q_{bial}^{\tau} \leq B_{b}^{\tau} CB_{ba}^{\tau}, \forall b, a, \tau \quad (19)$$

$$\sum_{p,e,l} m_{e} Q_{ipel}^{\tau} + \sum_{c,e,l} m_{e} Q_{icel}^{\tau} \leq CX_{ih}^{\tau} X_{ih}^{\tau} \; \forall i, h, \tau \quad (20)$$

$$\sum_{p,e,l} m_{e} Q_{ipel}^{\tau} \leq mcont_{\tau} CX_{ih}^{\tau} X_{ih}^{\tau}, \forall i, h, \tau \quad (21)$$

$$\sum_{c,e,l} m_{e} Q_{icel}^{\tau} \leq (1 - mcont_{\tau}) CX_{ih}^{\tau} X_{ih}^{\tau}, \forall i, h, \tau \quad (22)$$

$$\sum_{e} m_{e} INV_{pe}^{\tau} + \sum_{c,e,l} m_{e} \left(Q_{pcel}^{\tau} + {Q_{pcel}^{\tau}}^{e}\right) \leq CY_{p}^{\tau} Y_{p}^{\tau} + CU_{p}^{\tau} U_{p}^{\tau}, \forall p, \tau \quad (23)$$

$$\sum_{c,e,l} m_{e} Q_{cpel}^{\tau} \leq CZ_{p}^{\tau} Z_{p}^{\tau} + CU_{p}^{\tau} U_{p}^{\tau}, p, \tau \quad (24)$$

$$\sum_{p,e,l} m_{e} Q_{piel}^{\tau} \leq CR_{ih}^{\tau} X_{ih}^{\tau}, \forall i, h, \tau \quad (25)$$

$$\sum_{p,e,l} m_{e} Q_{pkel}^{\tau} \leq CV_{k}^{\tau} V_{k}^{\tau}, \forall k, \tau \quad (26)$$

$$\sum_{p,e,l} m_{e} Q_{pmel}^{\tau} \leq CM_{m}^{\tau} VM_{m}^{\tau}, \forall m, \tau \quad (27)$$

$$OF_{w_{j \in \{p\}}}^{\tau} \leq 1, \forall j, \tau \quad (28)$$

$$\sum_{l,o,w_{j \in \{b,i,p,c,m\}}, w'_{j \in \{i,p,c,k,m,f\}'}} ORF_{low_{j \in \{b,i,p,c,m\}}, w'_{j \in \{i,p,c,k,m,f\}'}}^{\tau} \leq 1, \forall j \in \{b, i, p, c, m\}, j' \in \{i, p, c, k, m, f\}, \tau \quad (29)$$

$$\sum_{a} Q_{bial}^{\tau} \leq BM \cdot \sum_{o,w_{j \in \{b\}}, w'_{j' \in \{i\}}} ORF_{low_{j \in \{b\}} w'_{j' \in \{i\}}}^{\tau}, \forall j \in \{b\}, j' \in \{i\}, l, \tau \quad (30)$$

$$\sum_{e} Q_{elw_{j \in \{i,p,c,k,m,f\}} w'_{j \in \{p,c,i,k,m,f\}'}}^{\tau} \leq BM \cdot \sum_{l,o,w_{j \in \{i,p,c,k,m,f\}} w'_{j \in \{p,c,i,k,m,f\}'}} ORF_{low_{j \in \{i,p,c,k,m,f\}} w'_{j \in \{p,c,i,k,m,f\}'}}^{\tau},$$

$$\forall j \in \{i,p,c,k,m,f\}, j' \in \{p,c,i,k,m,f\}, l, \tau \quad (31)$$

$$\sum_a Q_{bial}^{\tau} \leq \sum_{w_{j\in\{b\}}, w'_{j'\in\{i\}}} TCAPF_{lw_{j\in\{b\}}, w'_{j'\in\{i\}}}^{\tau} . \sum_o OBI_{bilo}^{\tau}, \forall j \in \{b\}, j' \in \{i\}, l, \tau \quad (32)$$

$$\sum_e Q_{elw_{j\in\{i,p,c,k,m,f\}} w'_{j\in\{p,c,i,k,m,f\}'}}^{\tau} \leq TCAPF_{lw_{j\in\{i,p,c,k,m,f\}} w'_{j\in\{p,c,i,k,m,f\}'}}^{\tau} . \sum_o ORF_{low_{j\in\{i,p,c,k,m,f\}} w'_{j\in\{p,c,i,k,m,f\}'}}^{\tau}$$

$$, \forall j \in \{i,p,c,k,m,f\}, j' \in \{p,c,i,k,m,f\}, l, \tau \quad (33)$$

$$FX_{ih}^{\tau} = CF_i^{\tau} + \theta_i^{\tau} \sum_h h^2 X_{ih}^{\tau}, \forall i, h, \tau \quad (34)$$

$$ep_{ieh}^{\tau} X_{ih}^{\tau} \left(\sum_{c,l} Q_{i,c,e,l}^{\tau} + \sum_{p,l} Q_{i,p,e,l}^{\tau} \right) \leq \psi_i \ \forall i, e, h, \tau \quad (35)$$

$$d_{ce}^{\tau} = D_{ce}^{\tau} - \lambda p1. PR_{ce}^{\tau} + \gamma . PR_{fe}^{\tau}, \forall c, e, f, \tau \quad (36)$$

$$d_{fe}^{\tau} = D_{fe}^{\tau} - \lambda p2. PR_{fe}^{\tau} + \gamma . PR_{ce}^{\tau}, \forall c, e, f, \tau \quad (37)$$

$$Q_{bial}^{\tau}, Q_{elw_{j\in\{i,p,c,k,m,f\}} w'_{j\in\{p,c,i,k,m,f\}'}}^{\tau}, INV_{pe}^{\tau}, PX_{ih}^{\tau}, d_{ce}^{\tau}, d_{fe}^{\tau} \geq 0, \forall b, i, j \in \{i,p,c,k,m,f\}, j' \in \{p,c,i,k,m,f\}, l, \tau, h, e, a \quad (38)$$

$$B_b^{\tau}, X_{ih}^{\tau}, OF_{w_{j\in\{p,k,m\}}}^{\tau}, ORF_{low_{j\in\{i,p,c,k,m,f\}} w'_{j\in\{p,c,i,k,m,f\}'}}^{\tau}, OS_{cpe}^{\tau} \in \{0,1\}, \forall\ j \in \{i,p,c,k,m,f\}, j' \in$$

$$\{p,c,i,k,m,f\}, c, p, e, b, i, h, c, l, o, \tau \quad (39)$$

Constraint 7 indicates that total inflows from all suppliers and collection/hybrid centers to each production-recovery center equal outflows in each period. Constraint 8 guarantees that for each product, in each period, the total in flows to each of the distribution/hybrid centers, from the production-recovery centers, as well as the remaining inventory from previous periods, is equal to the total inflows from distribution/hybrid centers online and offline, to primary customers, as well as the rest of the inventory in the current period. Constraints 9 and 10 indicate the online and offline purchasing relationships of primary customers. Constraint 11 indicates that in each period, for each product, the outflow of distribution/hybrid centers, online and offline, and production-recovery centers to each primary customer must be met by the primary customer demand. Constraint 12 refers to the relationship between the demand allocated to primary customers, as well as the rate of return from the primary customer to collection/hybrid centers. Constraint 13 indicate that for each product, in each period, the total income from the primary customers, in the collection/hybrid centers, to the production-recovery centers, which can be recovered, is equal to the total sent values from these centers to the production-recovery centers multiply by the recovery rate. Constraint 14 indicates that for each product, in each period, the total income from the primary customers in the collection/hybrid centers is sent to the disposal centers is equal to the total sent value from these centers to the disposal centers multiplied by the disposal rate.

Constraint 15 indicates that for each product in each period, total income from the primary customers in the collection/hybrid centers to the repair centers that can be repaired is equal to the total sent value from these centers, multiplied by the repair rate. Constraint 16 guarantees that total income from the primary customers in the collection/hybrid centers is equal to the total sent value to each production-recovery center for recovery, to open repair centers to repair and reuse, and to each disposal center, for removing it. Constraint 17 indicates the return flow from collection/hybrid centers to each repair and reuse center. In other words, the sent product for repair to repair centers should be equal to the sent products from repair centers to secondary customers. Constraint 18 shows the relationship between the demand allocated to secondary customers and the repair and reuse centers. Constraint 19 guarantees that in each period, the total output flow from each supplier to all production-recovery centers for each raw material does not exceed that supplier's capacity. Constraint 20 indicates that the total output flow from each production-recovery center in each period does not exceed the capacity of these production-recovery centers. According to constraint 21 in each period, the total output flow from each production-recovery center to all distribution/hybrid centers is at most equal to the capacity considered for that production-recovery center, and based on the contract, the distributors have a larger share of it .

Constraint 22 shows that in each period, the total output flow from each production-recovery center to the total of the primary customers is equal to the maximum remaining capacity of the production-recovery centers, which in each period is not considered in the concluded contracts with distributors. According to constraint 23, the residual inventory in each distribution/hybrid center shall not exceed the distribution/hybrid center's capacity in each period. Constraint 24 shows that in each period, the returned goods by the primary customers to the collection/hybrid centers should not exceed their capacity. Constraint 25 shows that in each period, the total returned products to each production-recovery center shall not exceed the recovery capacity in that production-recovery center. Constraint 26 indicates that in each period, the total sent value from the collection/hybrid center to the disposal centers shall not exceed the capacity of these disposal centers. According to constraint 27, the total sent value from the collection/hybrid center to the repair center in each period must not surpass the repair center's capacity. The maximum number of centers that can be opened in any period is limited by constraint 28. According to this relation, in each period, for each p , we can have one of the distributions, collection, and hybrid centers.

According to constraints 29 in each member of the chain, only one transportation option can be used to transport products. Constraints 30 and 31 indicate that the transportation option is applied between members of the chain who send products to each other. Constraints 32 and 33 indicate the capacity of the transportation options between members of the chain that send products to each other. Constraint 34 indicates the cost of production at the low-carbon technology h . Constraint 35 guarantees that the total pollution resulting from each center is less than a certain virtual limit. Constraint 36 is related to the product demand function for the primary customer, and Constraint 37 is also related to the product demand function for the secondary customer. In these Constraints, $\lambda p1$ and $\lambda p2$ are respectively the price elasticity of demand for the primary customer demand channels and the price elasticity of demand for the secondary customer demand channel, and they indicate that with the increase of each unit of price, the amount of demand decreases by several units (both positive are). Furthermore, γ_1 and γ_2 are the cross-price elasticity of demand for primary customer channels and the cross-price elasticity of demand for secondary customer channels, respectively. In other words, γ_1 states that the changes of each unit of the price of secondary customers (f), how many units affect the demand of the primary customers (c) and γ_2 states that the changes of each unit of the price of primary customers (c), how many units affect the demand Jupiter influences the secondary (f). γ_1 and γ_2 indicate the degree of displacement or substitution between the two channels of primary and secondary customers. Relationships 38 and 39 show that the decision variables are non-negative and integers, respectively.

II. UNCERTAINTY IN THE MODEL

Considering the uncertain nature of real-world data, effective methods for developing mathematical programming models based on uncertain data is essential since, in real-world problem, a rapid change in data leads to high costs for the system and make the answer impossible and incorrect. There are several ways to deal with these uncertainties regarding the nature of data uncertainty. The most popular methods of dealing with uncertainty are stochastic optimization, fuzzy optimization, and robust optimization (Gholami, Paydar, Hajiaghaei-Keshteli, & Cheraghalipour, 2019), which this paper uses an RSSP (Mulvey, Vanderbei, & Zenios, 1995), which is less sensitive to changes in data. Although this approach has some restrictions, it has more practical benefits than stochastic linear programming. For the first time, they presented the two concepts of *solution robustness* and *model robustness* in optimization; if the solution obtained from the optimization model can remain almost optimal for all considered scenarios of the input data, this robustness is called the solution, and when it is feasible for almost all the considered scenarios, the robustness is called the model. Therefore, assuming that the primary and secondary demand parameters, and delivery time, are uncertain thus, the robust stochastic scenario-based optimization approach of Mulvey *et al*. will be used for the robustness of the proposed model.

Objective functions:

The first, second, and fourth objective functions are re-formulated as Robust Mulvey optimization due to the effect of the uncertain parameters on them, and because they consist of these parameters (demand and delivery time); however, *the* third objective function, on the other hand, remains unchanged due to the ineffectiveness of the uncertain parameters on it:

$$\boldsymbol{MaxObjective1} = \sum_s (P_s \xi 1_s) - \Bigg(\Bigg(\sum_{i,h,\tau} FX_{ih}^{\tau} (X_{ih}^{\tau} - X_{ih}^{\tau-1}) + \sum_{w_{j\in\{p,k,m,\}},\tau} FF_{w_j}^{\tau} \left(OF_{w_j}^{\tau} - OF_{w_j}^{\tau-1} \right) + \sum_{b,\tau} F\, B_b^{\tau} B_b^{\tau} \Bigg) + \left(\sum_{e,l,w_{j\in\{b,i,p,c,m\}}, w'_{j'\in\{i,p,c,k,m,f\}},\tau} ORF_{lo,w_{j\in\{b,i,p,c,m\}} w'_{j'\in\{i,p,c,k,m,f\}}}^{\tau} \,.\, FRD_{lo,w_{j\in\{b,i,p,c,m\}} w'_{j'\in\{i,p,c,k,m,f\}}}^{\tau} \right) \Bigg)$$
$$-\lambda 1 \sum_s P_s \left(\left(\xi 1_s - \sum_{s'} P_{s'} \xi 1_{s'} \right) + 2\theta 1_s \right) - \omega \left(\sum_{c,f,e,\tau,s} P_s \left(\eta 1_{ces}^{\tau} + \eta 2_{fes}^{\tau} \right) \right) \quad (40)$$

$$\xi 1_s = \sum_{e,l,w_{j\in\{p,i\}}, w'_{j'\in\{c\}},\tau,s} PR_{ce}^{\tau} Q_{elw_{j\in\{p,i\}}, w'_{j'\in\{c\}},s}^{\tau} +$$
$$\sum_{elw_{j\in\{m\}}, w'_{j'\in\{f\}},\tau,s} PR_{fe}^{\tau} Q_{elw_{j\in\{m\}}, w'_{j'\in\{f\}},s}^{\tau} \sum_{e,l,h,w_{j\in\{p,i\}}, w'_{j'\in\{c\}},\tau,s} Sb_{ih}^{\tau} X_{ih}^{\tau} PR_{ce}^{\tau} Q_{elw_{j\in\{p,i\}}, w'_{j'\in\{c\}},s}^{\tau}$$

$$-\left(\left(\sum_{b,i,a,l,\tau,s} Q^{\tau}_{bials}\, BC^{\tau}_{br} + \sum_{e,l,w_{j\in\{i\}},w'_{j'\in\{p,c\}}} Q^{\tau}_{elw_{j\in\{i\}}w'_{j'\in\{p,c\}}s} MC^{\tau}_{ieh} + \sum_{elw_{j\in\{p,c\}},w'_{j'\in\{c,m,p,k\}},\tau,s} Q^{\tau}_{elw_{j\in\{p,c\}},w'_{j'\in\{c,m,p,k\}}s} OF^{\tau}_{ew_j} + \sum_{e,h,l,w_{j\in\{p\}},w'_{j'\in\{i\}},\tau,s} Q^{\tau}_{elw_{j\in\{p\}}w'_{j'\in\{i\}},s} RC^{\tau}_{ieh} + \sum_{p,e,\tau,s} INV^{\tau}_{pes} HC^{\tau}_{pe}\right) + \left(\sum_{b,i,a,l,\tau,s} Q^{\tau}_{bial}\, CBI^{\tau}_{bial} + \sum_{e,l,w_{j\in\{i,p,c,m\}},w'_{j'\in\{i,c,p,k,m,f\}},\tau,s} Q^{\tau}_{elw_{j\in\{i,p,c,m\}}w'_{j'\in\{p,c,i,k,m,f\}},s} . CTF^{\tau}_{elw_{j\in\{i,p,c,m\}}w'_{j'\in\{p,c,i,k,m,f\}}}\right)\right) \quad (40\text{-}1)$$

$$\boldsymbol{MinObjective2} = \sum_s P_s\, \xi 3_s + \lambda 3 \sum_s p_s \left(\left(\xi 3_s - \sum_{s'} P_{s'}\, \xi 3_{s'}\right) + 2\theta 3_s\right) \quad (41)$$

$$\xi 3_s = \beta \left(\sum_{b\in M1^{\tau}_{ialo},i,a,l,o,\tau} OBI^{\tau}_{bilo}\left(TBI^{\tau}_{bialos} - TBI^{\tau}_{ialos}{}'\right) + \sum_{b\in MF^{\tau}_{e,l,o,w_{j\in\{i,p\}}w'_{j'\in\{p,c\}}}\, l,o,lo,w_{j\in\{i,p\}}w'_{j'\in\{p,c\}},\tau} ORF^{\tau}_{lo,w_{j\in\{i,p\}}w'_{j'\in\{p,c\}}} \left(DTF^{\tau}_{elo,w_{j\in\{i,p\}}w'_{j'\in\{p,c\}}s} - DTF^{\tau}_{elo,w_{j\in\{i,p\}}w'_{j'\in\{p,c\}}s}{}'\right)\right) + (1-\beta)\left(\sum_{b\in MF^{\tau}_{e,l,o,w_{j\in\{c,p,m\}}w'_{j'\in\{p,i,k,m\}}}} ORF^{\tau}_{lo,w_{j\in\{c,p,m\}}w'_{j'\in\{p,i,k,m\}}} \left(DTF^{\tau}_{elo,w_{j\in\{c,p,m\}}w'_{j'\in\{p,i,k,m\}}s} - DTF^{\tau}_{elo,w_{j\in\{c,p,m\}}w'_{j'\in\{p,i,k,m\}}s}{}'\right)\right) \quad (41\text{-}1)$$

$$\boldsymbol{MaxObjective3} = \varsigma_1\left(\sum_{i,h,\tau} WX^{\tau}_{ih}X^{\tau}_{ih} + \sum_{w_{j\in\{p,k,m\}},\tau} WF^{\tau}_{w_j}OF^{\tau}_{w_j}\right) + \varsigma_2\left(\sum_{i,h,\tau} DX^{\tau}_{ih}X^{\tau}_{ih} + \sum_{w_{j\in\{p,k,m\}},\tau} DF^{\tau}_{w_j}OF^{\tau}_{w_j}\right) - \varsigma_3\left(\sum_{i,h,\tau} LX^{\tau}_{ih}X^{\tau}_{ih} + \sum_{w_{j\in\{p,k,m\}},\tau} LF^{\tau}_{w_j}OF^{\tau}_{w_j}\right) \quad (42)$$

$$\boldsymbol{MinObjective4} = \sum_s P_s\, \xi 2_s + \lambda 2 \sum_s p_s \left(\left(\xi 2_s - \sum_{s'} P_{s'}\, \xi 2_{s'}\right) + 2\theta 2_s\right) \quad (43)$$

$$\xi 2_s = \sum_{b,i,a,l,\tau,s} Q^{\tau}_{bials} \times EBI^{\tau}_{bial} + \sum_{e,l,w_{j\in\{i,p,c,m\}}w'_{j'\in\{p,c,i,k,m,f\}},\tau,s} Q^{\tau}_{elw_{j\in\{i,p,c,m\}}w'_{j'\in\{p,c,i,k,m,f\}}s} .ETF^{\tau}_{elw_{j\in\{i,p,c,m\}}w'_{j'\in\{p,c,i,k,m,f\}}} + \sum_{e,h,l,w_{j\in\{i\}},w'_{j'\in\{p,c\}},\tau,s} Q^{\tau}_{elw_{j\in\{i\}}w'_{j'\in\{p,c\}}s} EP^{\tau}_{ieh} + \sum_{e,l,w_{j\in\{p\}},w'_{j'\in\{m\}},\tau,s} Q^{\tau}_{elw_{j\in\{p\}}w'_{j'\in\{m\}}s} ER^{\tau}_{me} \quad (43\text{-}1)$$

Constraints:

$$\sum_{p,e,l} n_{ae} Q^{\tau}_{ipels} + \sum_{c,e,l} n_{ae} Q^{\tau}_{icels} = \sum_{b,l} Q^{\tau}_{bials} + \sum_{p,e,l} n_{ae} Q^{\tau}_{piels}, \forall i,a,\tau,s \quad (44)$$
$$INV^{\tau-1}_{pes} + \sum_{i,l} Q^{\tau}_{ipels} = INV^{\tau}_{pes} + \sum_{c,l} Q^{\tau}_{pcels} + \sum_{c,l} Q^{\tau}_{pcels}{}^{e}, \forall p,e,\tau,s \quad (45)$$
$$Q^{\tau}_{pcels} \le BM.OS^{\tau}_{cpe}, \forall p,c,e,l,\tau,s \quad (46)$$
$$Q^{\tau}_{pcels}{}^{e} \le BM.\left(1 - OS^{\tau}_{cpe}\right), \forall p,c,e,l,\tau,s \quad (47)$$
$$\sum_{c,l} Q^{\tau}_{pcels} + \sum_{c,l} Q^{\tau}_{pcels}{}^{e} + \sum_{i,l} Q^{\tau}_{icels} = d^{\tau}_{ces} - \eta 1^{\tau}_{ces}, \forall c,e,\tau,s \quad (48)$$
$$\sum_{p,l} Q^{\tau}_{cpels} = d^{\tau}_{ces} RR_e, \forall c,e,\tau \quad (49)$$
$$\sum_{i,l} Q^{\tau}_{piels} = \sum_{c,l} Q^{\tau}_{cpels} RXi_e, \forall p,e,\tau,s \quad (50)$$
$$\sum_{K,l} Q^{\tau}_{pkels} = \sum_{c,l} Q^{\tau}_{cpels} RXd_e, \forall p,e,\tau,s \quad (51)$$
$$\sum_{m,l} Q^{\tau}_{pmels} = \sum_{c,l} Q^{\tau}_{cpels} RXm_e, \forall p,e,\tau,s \quad (52)$$
$$\sum_{k,l} Q^{\tau}_{pkels} + \sum_{i,l} Q^{\tau}_{piels} + \sum_{m,l} Q^{\tau}_{pmels} = \sum_{c,l} Q^{\tau}_{cpels}, \forall p,e,\tau,s \quad (53)$$
$$\sum_{p,l} Q^{\tau}_{pmels} = \sum_{f,l} Q^{\tau}_{mfels}, \forall m,e,\tau,s \quad (54)$$
$$\sum_{m,l} Q^{\tau}_{mfels} = d^{\tau}_{fes} - \eta 2^{\tau}_{fes}, \forall f,e,\tau,s \quad (55)$$

$$\sum_{i,l} Q^{\tau}_{bials} \le B^{\tau}_{b} CB^{\tau}_{ba}, \forall b,a,\tau,s \quad (56)$$
$$\sum_{p,e,l} m_e Q^{\tau}_{ipels} + \sum_{c,e,l} m_e Q^{\tau}_{icels} \le CX^{\tau}_{ih} X^{\tau}_{ih}\ \forall i,h,\tau,s \quad (57)$$
$$\sum_{p,e,l} m_e Q^{\tau}_{ipels} \le mcont_{\tau} CX^{\tau}_{ih} X^{\tau}_{ih}, \forall i,h,\tau,s \quad (58)$$
$$\sum_{c,e,l} m_e Q^{\tau}_{icels} \le (1 - mcont_{\tau}) CX^{\tau}_{ih} X^{\tau}_{ih}, \forall i,h,\tau,s \quad (59)$$

$$\sum_e m_e\, INV_{pes}^{\tau} + \sum_{c,e,l} m_e \left(Q_{pcels}^{\tau} + {Q_{pcels}^{\tau}}^{e}\right) \le CY_p^{\tau} Y_p^{\tau} + CU_p^{\tau} U_p^{\tau}, \forall p,\tau,s \quad (60)$$
$$\sum_{c,e,l} m_e Q_{cpels}^{\tau} \le CZ_p^{\tau} Z_p^{\tau} + CU_p^{\tau} U_p^{\tau}, p,\tau,s \quad (61)$$
$$\sum_{p,e,l} m_e Q_{piels}^{\tau} \le CR_{ih}^{\tau} X_{ih}^{\tau}, \forall i,h,\tau,s \quad (62)$$
$$\sum_{p,e,l} m_e Q_{pkels}^{\tau} \le CV_k^{\tau} V_k^{\tau}, \forall k,\tau,s \quad (63)$$
$$\sum_{p,e,l} m_e Q_{pmels}^{\tau} \le CM_m^{\tau} VM_m^{\tau}, \forall m,\tau,s \quad (64)$$

$$OF_{w_{j\in\{p\}}}^{\tau} \le 1, \forall j,\tau \quad (65)$$

$$\sum_{l,o,w_{j\in\{b,i,p,c,m\}},w'_{j\in\{i,p,c,k,m,f\}'}} ORF_{low_{j\in\{b,i,p,c,m\}},w'_{j\in\{i,p,c,k,m,f\}'}}^{\tau} \le 1, \forall\, j \in \{b,i,p,c,m\}, j' \in \{i,p,c,k,m,f\},\tau \quad (66)$$

$$\sum_a Q_{bial}^{\tau} \le BM \cdot \sum_{o,w_{j\in\{b\}},w'_{j'\in\{i\}}} ORF_{low_{j\in\{b\}}w'_{j'\in\{i\}}}^{\tau}, \forall j \in \{b\}, j' \in \{i\}, l,\tau \quad (67)$$
$$\sum_e Q_{elw_{j\in\{i,p,c,k,m,f\}}w'_{j\in\{p,c,i,k,m,f\}'}}^{\tau} \le BM \cdot \sum_{l,o,w_{j\in\{i,p,c,k,m,f\}}w'_{j\in\{p,c,i,k,m,f\}'}} ORF_{low_{j\in\{i,p,c,k,m,f\}}w'_{j\in\{p,c,i,k,m,f\}'}}^{\tau}, \forall\, j \in \{i,p,c,k,m,f\}, j' \in \{p,c,i,k,m,f\}, l,\tau \quad (68)$$

$$\sum_a Q_{bial}^{\tau} \le \sum_{w_{j\in\{b\}},w'_{j'\in\{i\}}} TCAPF_{lw_{j\in\{b\}},w'_{j'\in\{i\}}}^{\tau} . \sum_o OBI_{bilo}^{\tau}, \forall j \in \{b\}, j' \in \{i\}, l,\tau \quad (69)$$
$$\sum_e Q_{elw_{j\in\{i,p,c,k,m,f\}}w'_{j\in\{p,c,i,k,m,f\}'}}^{\tau} \le TCAPF_{lw_{j\in\{i,p,c,k,m,f\}}w'_{j\in\{p,c,i,k,m,f\}'}}^{\tau} . \sum_o ORF_{low_{j\in\{i,p,c,k,m,f\}}w'_{j\in\{p,c,i,k,m,f\}'}}^{\tau}$$
$$\forall j \in \{i,p,c,k,m,f\}, j' \in \{p,c,i,k,m,f\}, l,\tau \quad (70)$$

$$FX_{ihs}^{\tau} = CF_i^{\tau} + \theta_i^{\tau} \sum_h h^2 X_{ih}^{\tau}, \forall i,h,\tau,s \quad (71)$$

$$ep_{ieh}^{\tau} X_{ih}^{\tau} \left(\sum_{c,l} Q_{icelds}^{\tau} + \sum_{p,l} Q_{ipels}^{\tau}\right) \le \psi_i \ \forall i,e,h,\tau,s \quad (72)$$

$$d_{ces}^{\tau} = D_{ces}^{\tau} - \lambda p1. PR_{ce}^{\tau} + \gamma. PR_{fe}^{\tau}, \forall c,e,\tau,f,s \quad (73)$$
$$d_{fes}^{\tau} = D_{fes}^{\tau} - \lambda p2. PR_{fe}^{\tau} + \gamma. PR_{ce}^{\tau}, \forall c,e,\tau,f,s \quad (74)$$

$$\xi 1_s - \sum_{s'} \left(P_{s'} \xi 1_{s'}\right) + \theta 1_s \ge 0 \quad (75)$$
$$\xi 2_s - \sum_{s'} \left(P_{s'} \xi 2_{s'}\right) + \theta 2_s \ge 0 \quad (76)$$
$$\xi 3_s - \sum_{s'} \left(P_{s'} \xi 3_{s'}\right) + \theta 3_s \ge 0 \quad (77)$$

$$Q_{bials}^{\tau}, Q_{elw_{j\in\{i,p,c,k,m,f\}}w'_{j\in\{p,c,i,k,m,f\}'}s}^{\tau}, INV_{pes}^{\tau}, FX_{ihS}^{\tau}, d_{ceS}^{\tau}, d_{feS}^{\tau} \ge 0, \forall b,i,j \in \{i,p,c,k,m,f\}, j' \in \{p,c,i,k,m,f\}, l,\tau,h,e,a,s \quad (78)$$

$$B_b^{\tau}, X_{ih}^{\tau}, OF_{w_{j\in\{p,k,m\}}}^{\tau}, ORF_{low_{j\in\{i,p,c,k,m,f\}}w'_{j\in\{p,c,i,k,m,f\}'}}^{\tau}, OS_{cpe}^{\tau} \in \{0,1\}, \forall\, j \in \{i,p,c,k,m,f\}, j' \in \{p,c,i,k,m,f\}, c,p,e,b,i,h,c,l,o,\tau \quad (79)$$

Constraints 44 to 74 are like constraints in certain model based on different scenarios. Constraints 75 to 77 are used in the model to convert a nonlinear objective function to a linear function, and constraints 78 and 79 show the type of variables and ensure that they are non-negative.

III. THE SUGGESTED MODEL'S LINEARIZATION

Since solving a linear model is easier than a nonlinear one, we convert the nonlinear model to a linear model. In this certain suggested model, in the first objective function, both in the income and cost parts, as well as in the Constraints 35 (and the Constraints 72 in the robust state), a binary variable is multiplied by a continuous variable, which converts the model to a nonlinear one. To linearize it, we will use the following process:

$$Z \leq y_2$$
$$Z \leq M \times y_1$$
$$Z \geq y_2 - M \times (1 - y_1) \qquad (80)$$

Suppose $Z = y_1 \times y_2$, where y_1 is a binary variable, and y_2, a continuous variable. Therefore, if $y_1 = 1$, then Z will be equal to the continuous variable, and otherwise, 0. To linearize this statement, three auxiliary Constraints apply as follows (Chang & Chang, 2000). In addition, in the income section of the first objective function of the proposed deterministic model, i.e. relation (2) and section (40-1) of the income objective function of the robust model, there are several relations in which the continuous variable is multiplied by a continuous variable, which turns the model into a non-linear model. To linearize it, according to the method proposed by (Vidal & Goetschalckx, 2001), it is done in three steps.

For example, for $\sum_{p,c,e,l} PR_{ce}^{\tau} Q_{pcel}^{\tau}$:

Step 1: For each of the continuous variables of the above equation, upper and lower bounds are determined.

$$LPR_{ce}^{\tau} \leq PR_{ce}^{\tau} \leq UPR_{ce}^{\tau} \forall c, e, \tau \qquad (81)$$
$$0 \leq Q_{pcel}^{\tau} \leq D_{ce}^{\tau} \forall p, c, e, l, \tau \qquad (82)$$

Step 2: The multiplication of two continuous variables is equal to a new continuous variable, which is inserted in the model instead of the multiplication of two continuous variables.

$$PRQ_{pcel}^{\tau} = PR_{ce}^{\tau}.Q_{pcel}^{\tau} \forall p, c, e, l, \tau \qquad (83)$$

Step 3: The following constraints are added to the main model.

$$0 \leq PRQ_{pcel}^{\tau} \leq D_{ce}^{\tau}.PR_{ce}^{\tau}, \forall p, c, e, l, \tau \qquad (84)$$
$$LPR_{ce}^{\tau}.Q_{pcel}^{\tau} \leq PRQ_{pcel}^{\tau} \leq UPR_{ce}^{\tau}.Q_{pcel}^{\tau}, \forall p, c, e, l, \tau \qquad (85)$$

For other expressions of multiplication of two continuous variables, we will have the same three steps.

THE APPROACH OF SOLVING AND EVALUATING MODEL

Various methods have been proposed to solve the multi-objective models. In this paper, we use the Augmented Epsilon constraint (AUGMECON) method (G. Mavrotas, 2009) and the third edition of the Non-dominated Sorting Genetic Algorithm (NSGA-III) (Deb & Jain, 2014) and Multi-Objective Grey Wolf Optimizer (MOGWO) algorithm (Mirjalili, Saremi, Mirjalili, & Coelho, 2016).

AUGMECON method: The constraint Epsilon (CE) method optimizes one objective function and considers other objective functions as constraints and is widely used to solve multi-objective linear programming problems (G. Mavrotas, Figueira, & Antoniadis, 2011; Şakar & Köksalan, 2013). One of the biggest advantages of this method is that it can be controlled by properly adjusting the number of network points, the range of each objective function and the number of efficient responses. However, this range must be calculated. On the other hand, this method has weaknesses. First, solving any problem with more than two objective functions with it is generally time consuming, and not every effort will necessarily lead to finding a new Pareto point on the Pareto surface. These weaknesses have been the motivation for the introduction of the Epsilon method of generalized constraint by (G. J. A. m. Mavrotas & computation, 2009) which is introduced in the form of (86) (Nikas, Fountoulakis, Forouli, & Doukas, 2020).

$$max\{f_1(x) + eps \times (s_2 + s_3 + \cdots + s_p)\}, eps \in (10^{-6}, 10^{-3})$$

subjectto: $\quad f_2(x) - s_2 = e_2 \qquad (86)$

$$f_3(x) - s_3 = e_3$$
$$\ldots$$
$$f_p(x) - s_P = e_p$$
$$x \in X$$

NSGA-III algorithm: This investigation uses the finite NSGA-III algorithm to solve the multi-objective optimization problem. Analogized to the prior generation algorithm (NSGA-II), the NSGA-III has been revised with the intro of a reference point-based selection mechanism while inheriting most of the NSGA-II functions. In NSGAIII, there are five stages: population initialization, tournament selection, offspring generation, non-dominant sorting, and reference point-based selection. All stages are cycled until the population is initialized until the end conditions are reached.

Reference point-based selection mechanism: After non-dominant sorting, blended populations are arranged on a string of fronts. In order to select a new population of size N in the next generation, a reference point-based selection mechanism has been presented in the NSGA-III algorithm, which ensures uniformity of distribution and increases the optimization movement in targeted optimization problems. Whether a reference point-based selection mechanism should be regarded depends on the number of possible solutions. As in the case of non-dominant sorting, feasible solutions are organized according to the dominance connection, while impossible solutions are organized according to the constraint violation. Thereby, if the number of possible solutions is less than N, all possible solutions are present in the new parent population and the remains of the infeasible solutions are with the least constraint violation. In this case, the choice mechanism is not applicable. However, if the number of possible solutions is greater than N, there will be a crucial front (CF), where the sum of the solutions on the fronts below CF is smaller than N, but the sum is greater on the fronts including CF. Therefore, only some of the solutions in CF are designated for the new parent population. A reference point-based selection mechanism is assumed here to determine which solution to choose in CF, including generating reference points, Association with solutions, and the addition of solution points to the new parent population.

MOGW algorithm: Mirjalili and Saremi (Mirjalili et al., 2016) presented a multi-objective gray wolf optimization algorithm to decipher multi-objective problems. In this algorithm, the wolf hunting method is used to optimize the problems. Wolves live in packs, and the group leader, Alpha, is responsible for determinations such as invasion and timing. It consists of the ensuing three phases: 1. Tracing, chasing, and approaching prey 2. Chase, besiege, and harass the prey until it stops moving 3. Attack on prey. In order to model the social conduct of wolves, an accidental population of solutions is developed and the most proper solution called alpha (α), the second and third superior solutions, are also beta (β) and delta (δ), respectively called. Other candidate solutions are considered omega (ω) wolves. The gray wolf algorithm uses the α, β, δ responses for hunting (optimization) and follows the ω responses. As noted above, gray wolves wrap prey during hunting. In order to mathematically model the siege behavior, the following equations are offered:

$$\vec{D}(t) = \left|\vec{C}.\vec{X}_p(t) - \vec{X}(t)\right|, t = 1,2,\dots,t_{max} \qquad (87)$$

$$\vec{X}(t+1) = \vec{X}_p(t) - \vec{A}.\vec{D}(t), t = 1,2,\dots,t_{max} \qquad (88)$$

$$\vec{A} = \vec{a}.(2\vec{r}_1 - 1) \qquad (89)$$

$$\vec{C} = 2.\vec{r}_2 \qquad (90)$$

Where t represent the current iteration, $\vec{A}$ and $\vec{C}$ are vector coefficient, $\vec{X}_p$ is the position vector of the prey, and the position vector of a grey wolf, respectively. Also, $\vec{a}$ the elements are decreased linearly from 2 to 0 under the iteration route. Here, $\vec{r}_1$ and $\vec{r}_2$ are random vectors in the range [0, 1]. To design the MOGWO algorithm, two new mixtures have been counted to the Gray Wolf Optimizer (GWO) algorithm. The first element is the library (responsible for storing Pareto optimal solutions without mastery) and the second element is the leader selection procedure (helping to select alpha, beta, and delta from the archive). A library is a repository unit that stores or protects a non-dominant solution. Management input solutions and library fullness. Leader Selection uses the roulette wheel method to select a masterless solution from the least packed library to present alpha, beta, and delta wolves. In this paper, MOGWO and NSGA-III algorithms are used to deal with the complexity of the problem, and the main reasons for choosing MOGWO and NSGA-III algorithms can be stated as follows:

The MOGWO algorithm was chosen among the existing algorithms due to its strong structure in terms of escalation and diversity. NSGA-III has a relatively better ability to handle multi-objective problems (having four or more objectives) and is a powerful technique to eliminate the disadvantages of NSGA-II such as the lack of uniform diversity and the lack of lateral diversity preservation operator among the best current solutions.

I. NUMERICAL EXAMPLE AND MODEL EVALUATION

In this part, first, a numerical example is provided to evaluate the validity and performance of the suggested model and the AUGMECON approach, and examine the problem variables, and to analyze its sensitivity, the results of which will be presented below in deterministic/certain and robust scenario-based state. In the robust state, three scenarios of the low, medium, and high were considered for uncertain parameters and both cases were coded in GAMS. Table 1 shows the size of the designed experiment, and Table 2 provides the stochastic data generated based on the uniform distribution for the model parameters.

TABLE 1
THE SIZE OF THE DESIGNED PROBLEM

$\|B\|$	$\|I\|$	$\|P\|$	$\|C\|$	$\|K\|$	$\|M\|$	$\|F\|$	$\|E\|$	$\|A\|$	$\|L\|$	$\|T\|$	$\|H\|$	$\|O\|$
2	2	3	5	2	2	3	2	3	2	2	2	**2**

TABLE 2
VALUES OF MODEL PARAMETERS

$D^{\tau}_{ce} \sim u(50,90)$	$ECP^{\tau}_{cpel} \sim u(1,3)$	$FIC^{\tau}_{iclo} \sim u(80,150)$	$CB^{\tau}_{ba} \sim u(780200,8903000)$
$D^{\tau}_{fe} \sim u(40,70)$	$EPI^{\tau}_{piel} \sim u(1,4)$	$FPC^{\tau}_{pclo} \sim u(100,300)$	$CX^{\tau}_{ih} \sim u(780400,8905500)$
$BC^{\tau}_{ba} \sim u(3,5)$	$EPK^{\tau}_{pkel} \sim u(1,6)$	$FCP^{\tau}_{cplo} \sim u(300,440)$	$CY^{\tau}_{p} \sim u(780500,8901500)$
$CF^{\tau}_{i} \sim u(0.5,1)$	$EPM^{\tau}_{pmel} \sim u(1,6)$	$FPI^{\tau}_{pilo} \sim u(300,480)$	$CZ^{\tau}_{p} \sim u(780100,8900250)$
$MC^{\tau}_{ieh} \sim u(50,100)$	$EMF^{\tau}_{mfel} \sim u(1,3)$	$FPK^{\tau}_{pkl} \sim u(200,430)$	$CU^{\tau}_{p} \sim u(780100,8900250)$
$OC^{\tau}_{pe} \sim u(2,3)$	$EP^{\tau}_{ieh} \sim u(1,1.5)$	$FPM^{\tau}_{pmlo} \sim u(230,300)$	$CR^{\tau}_{ih} \sim u(780100,8900250)$
$OC^{\tau}_{me} \sim u(3,12)$	$ER^{\tau}_{me} \sim u(1,3)$	$FMF^{\tau}_{mflo} \sim u(180,230)$	$CV^{\tau}_{k} \sim u(780000,8900100)$
$IC^{\tau}_{pe} \sim u(1,3)$	$TBI^{\tau}_{bialo} \sim u(3,5)$	$WX^{\tau}_{ih} \sim u(2,20)$	$CM^{\tau}_{m} \sim u(780100,8900200)$
$RC^{\tau}_{ieh} \sim u(1,2)$	$TIP^{\tau}_{ipelo} \sim u(3,18)$	$WY^{\tau}_{p} \sim u(20,40)$	$TCAPBI^{\tau}_{bil} \sim u(80000,1500000)$
$DC^{\tau}_{ke} \sim u(1,3)$	$TIC^{\tau}_{icelo} \sim u(2,5)$	$WZ^{\tau}_{p} \sim u(40,60)$	$TCAPIP^{\tau}_{ipl} \sim u(80,1000000)$
$HC^{\tau}_{pe} \sim u(50,100)$	$TPC^{\tau}_{pcelo} \sim u(3,20)$	$WU^{\tau}_{p} \sim u(20,40)$	$TCAPIC^{\tau}_{icl} \sim u(30,80)$
$FB^{\tau}_{b} \sim u(200,300)$	${TPC^{\tau}_{pcelo}}^{e} \sim u(2,18)$	$WV^{\tau}_{k} \sim u(2,60)$	$TCAPPC^{\tau}_{pcl} \sim u(14000,18000)$
$FY^{\tau}_{p} \sim u(300,600)$	$TCP^{\tau}_{cpelo} \sim u(3,7)$	$WM^{\tau}_{m} \sim u(10,40)$	$TCAPCP^{\tau}_{cpl} \sim u(12000,13000)$
$FZ^{\tau}_{p} \sim u(200,400)$	$TPI^{\tau}_{pielo} \sim u(3,15)$	$DX^{\tau}_{ih} \sim u(200,400)$	$TCAPPI^{\tau}_{pil} \sim u(10000,19000)$
$FU^{\tau}_{p} \sim u(200,300)$	$TPK^{\tau}_{pkel} \sim u(7,15)$	$DY^{\tau}_{p} \sim u(256,456)$	$TCAPPK^{\tau}_{pkl} \sim u(14500,20000)$
$FV^{\tau}_{k} \sim u(300,400)$	$TPM^{\tau}_{pmelo} \sim u(3,10)$	$DZ^{\tau}_{p} \sim u(223,454)$	$TCAPPM^{\tau}_{pml} \sim u(17000,18000)$
$FM^{\tau}_{m} \sim u(350,450)$	$TMF^{\tau}_{mfelo} \sim u(6,20)$	$DU^{\tau}_{p} \sim u(234,490)$	$TCAPMF^{\tau}_{mfl} \sim u(19000,20000)$
$CBI^{\tau}_{bial} \sim u(2,5)$	${TBI^{\tau}_{irlo}}' \sim u(2,8)$	$DV^{\tau}_{k} \sim u(202,404)$	$n_{ae}, m_{e} = 1$
$CIP^{\tau}_{ipel} \sim u(2,3)$	${TIP^{\tau}_{pelo}}' \sim u(2,8)$	$DM^{\tau}_{m} \sim u(442,504)$	$mcont_{\tau} = 0.70$
$CIC^{\tau}_{icel} \sim u(1,3)$	${TIC^{\tau}_{icelo}}' \sim u(1,4)$	$LX^{\tau}_{ih} \sim u(5,7)$	$PR_{e} = 0.25$
$CPC^{\tau}_{pcel} \sim u(2,3)$	${TPC^{\tau}_{celo}}' \sim u(2,8)$	$LY^{\tau}_{p} \sim u(2,4)$	$PXi_{e} = 0.40$
${CPC^{\tau}_{pcel}}^{e} \sim u(3,4)$	${TPC^{\tau}_{celo}}'^{e} \sim u(2,8)$	$LZ^{\tau}_{p} \sim u(2,4)$	$PXm_{e} = 0.25$
$CCP^{\tau}_{cpel} \sim u(2,8)$	${TCP^{\tau}_{pelo}}' \sim u(2,8)$	$LU^{\tau}_{p} \sim u(2,4)$	$PXd_{e} = 0.35$
$CPI^{\tau}_{piel} \sim u(3,7)$	${TPI^{\tau}_{ielo}}' \sim u(1,8)$	$LV^{\tau}_{k} \sim u(2,3)$	$\beta = 0.5$
$CPK^{\tau}_{pkel} \sim u(4,7)$	${TPK^{\tau}_{kel}}' \sim u(3,8)$	$LM^{\tau}_{m} \sim u(2,5)$	$\xi_1 = 0.5$
$CPM^{\tau}_{pmel} \sim u(2,3)$	${TPM^{\tau}_{melo}}' \sim u(5,8)$	$ep^{t}_{ieh} \sim u(1,1.5).\frac{1}{h}$	$\xi_2 = 0.25$
$CMF^{\tau}_{mfel} \sim u(1,3)$	${TMF^{\tau}_{felo}}' \sim u(2,8)$	$Sb^{\tau}_{ih} \sim u(100,150).\frac{h}{3}$	$\xi_3 = 0.25$
$EBI^{\tau}_{bial} \sim u(2,5)$	$FBI^{\tau}_{bilo} \sim u(100,200)$	$\psi_i \sim u(700,800)$	$\lambda p1 = 0.3$
$EIP^{\tau}_{ipel} \sim u(2,4)$	$FIP^{\tau}_{iplo} \sim u(100,300)$	$\theta^{\tau}_{i} \sim u(0.3,0.5)$	$\lambda p2 = 0.1$
$EIC^{\tau}_{icel} \sim u(2,2)$			$BM = 10^{8}$
$EPC^{\tau}_{pcel} \sim u(2,4)$			$\gamma_1 = 20$
			$\gamma_2 = 20$

Therefore, after solving the model, the optimum values of each of the objectives be shown in Table 3.

To examine the proposed model, the optimum product flow path and the output variables for the certain and robust states of the last iteration are shown in figures 2, 3, 4, and 5 for the first, second, and third scenarios respectively.

TABLE 3
OPTIMUM VALUES OF OBJECTIVE FUNCTIONS, IN A CERTAIN AND ROBUST STATE

	Iteration	Z1	Z2	Z3	Z4	Eps2	Eps3	Eps4
Certain	1	9.98E+08	353.717	2241.697	38746.464	432.77	2085.098	4.32E+07
	2	8.74E+08	107.815	2227.746	42452.69	107.925	1614.957	5.91E+07
	3	9.98E+08	353.717	2241.697	38762.323	416.531	2172.138	5.74E+07
	4	7.97E+08	48.499	2241.697	43398.749	48.781	1565.797	5455206.48
	5	9.98E+08	353.717	2241.697	38763.294	716.63	2221.517	2.23E+07
Robust	Iteration	Z1	Z2	Z3	Z4	Eps2	Eps3	Eps4
	1	1.950361E+9	1068.867	6904.835	434698.347	1085.399	5641.671	434698.347
	2	2.978574E+9	3073.262	6904.835	558600.988	3073.776	6370.272	558600.988
	3	2.978574E+9	3073.262	6904.835	558600.988	1013.189	6546.020	697445.465
	4	2.454037E+9	4197.780	6904.835	423707.145	6307.782	6236.520	423707.145
	5	2.454037E+9	4197.780	6904.835	423707.145	991.803	6694.557	494185.257

For the model in a certain state, we have:

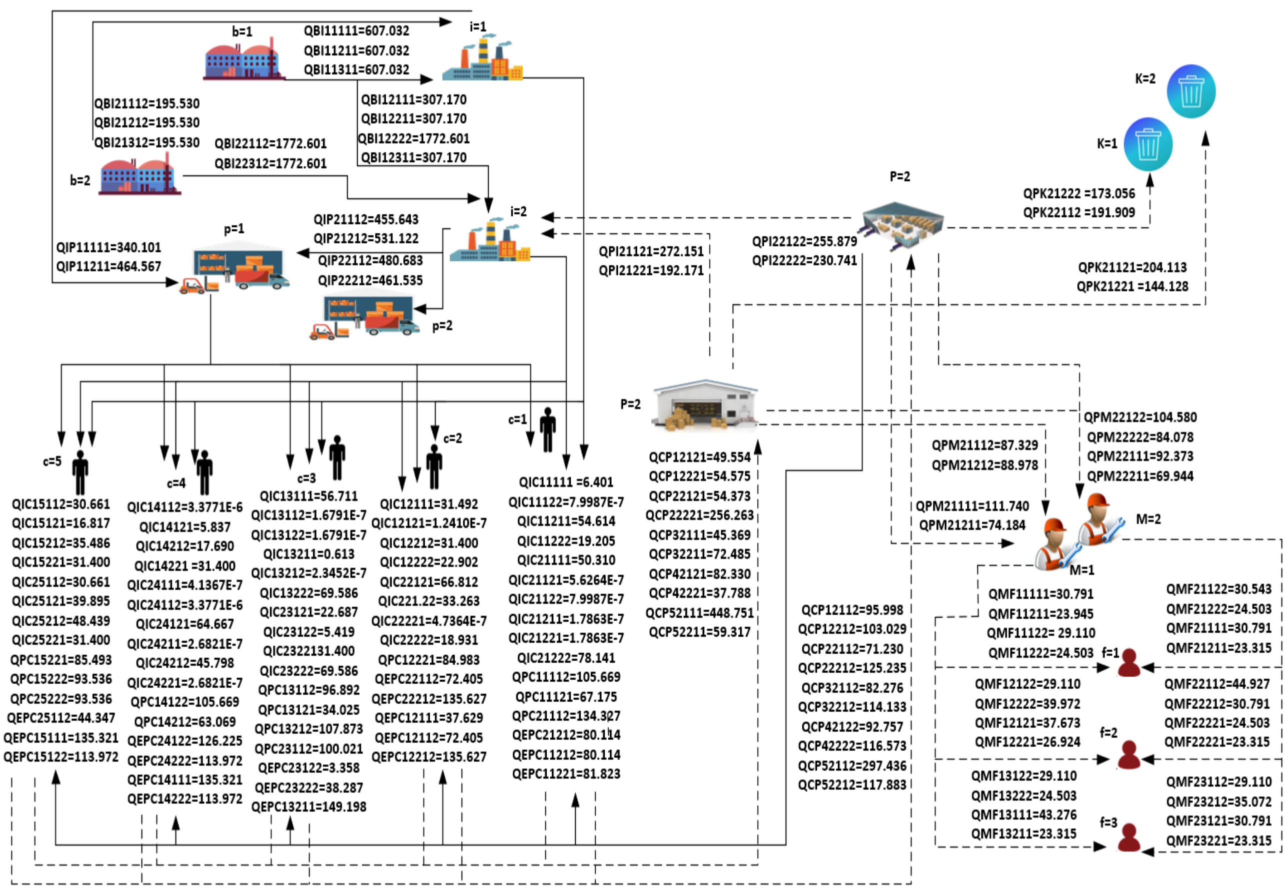


FIGURE 2
OPTIMUM PRODUCT FLOW FOR THE CERTAIN STATE

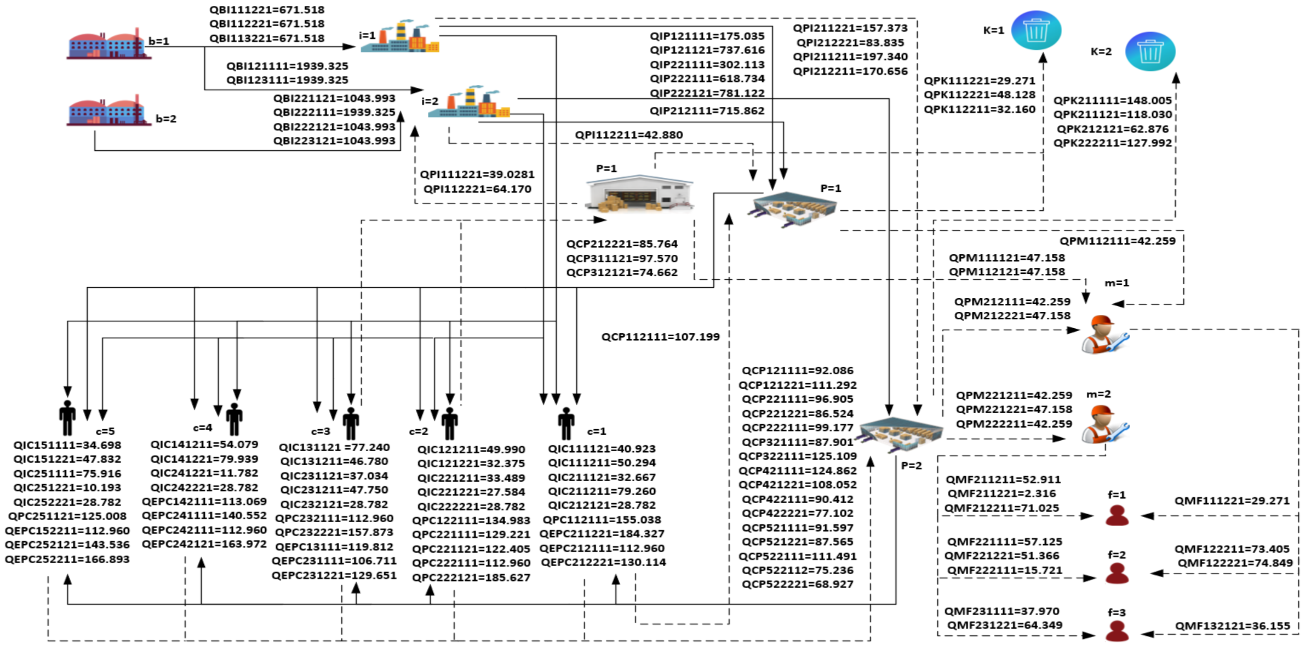


FIGURE 3

OPTIMUM PRODUCT FLOW FOR THE ROBUST STATE, IN THE FIRST SCENARIO

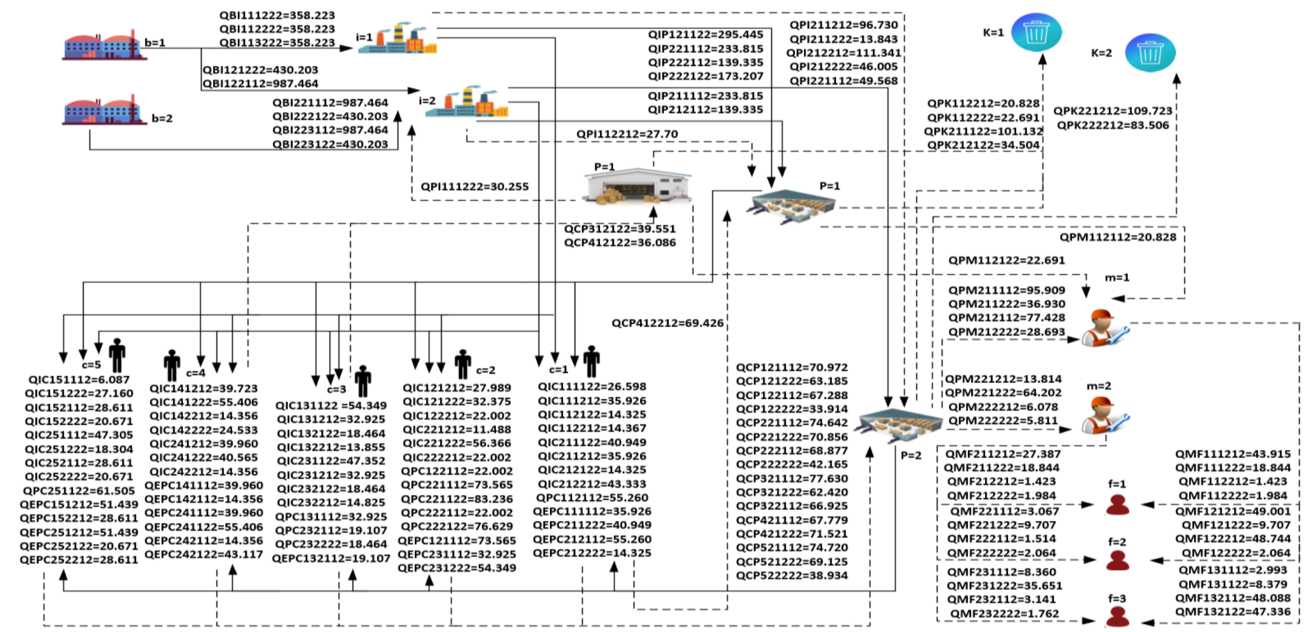


FIGURE 4

OPTIMUM PRODUCT FLOW FOR THE ROBUST STATE, IN THE SECOND SCENARIO

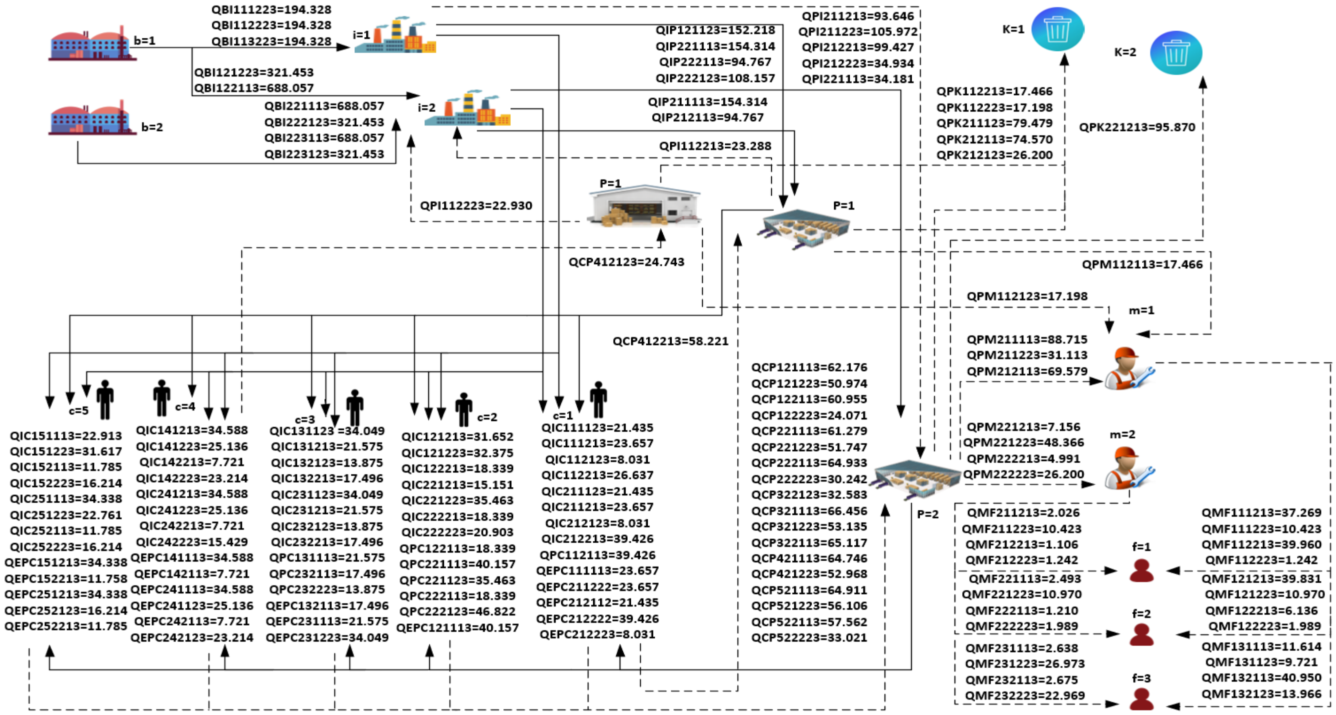


FIGURE 5
OPTIMUM PRODUCT FLOW FOR THE ROBUST STATE, IN THE THIRD SCENARIO

And the values of the other variables are as follows:

TABLE 4
THE CONSTANT COST OF ACTIVITY OF PRODUCTION-RECOVERY CENTER IN THE CERTAIN STATE, AND IN EACH SCENARIO

$FX(i.h.\tau)$	Value	$FX(i,h,\tau,s)$	Value	$FX(i,h,\tau,s)$	Value	$FX(i,h,\tau,s)$	Value
1.1.1	1.384	1.1.1.1	1.210	1.2.1.3	2.685	2.1.2.2	1.010
1.1.2	1.098	1.1.1.2	1.210	1.2.2.1	2.035	2.1.2.3	1.010
1.2.1	2.626	1.1.1.3	1.210	1.2.2.2	2.035	2.2.1.1	2.300
1.2.2	2.270	1.1.2.1	1.113	1.2.2.3	2.035	2.2.1.2	2.300
2.1.1	1.242	1.1.2.2	1.113	2.1.1.1	1.259	2.2.1.3	2.300
2.1.2	1.112	1.1.2.3	1.113	2.1.1.2	1.259	2.2.2.1	2.338
2.2.1	2.449	1.2.1.1	2.685	2.1.1.3	1.259	2.2.2.2	2.338
2.2.2	2.546	1.2.1.2	2.685	2.1.2.1	1.010	2.2.2.3	2.338

TABLE 5
THE PROPOSED DEMAND OF PRIMARY CUSTOMERS IN A CERTAIN STATE, AND IN EACH SCENARIO

d(c.e.τ)	*Value*	*d(c.e.τ.s)*	*Value*	*d(c.e.τ.s)*	*Value*	*d(c.e.τ.s)*	*Value*
1.1.1	123.886	1.1.1.1	230.216	2.2.1.3	162.332	4.1.2.2	178.803
1.1.2	239.995	1.1.1.2	177.429	2.2.2.1	214.409	4.1.2.3	132.420
1.2.1	136.438	1.1.1.3	155.440	2.2.2.2	105.411	4.2.1.1	226.030
1.2.2	257.574	1.1.2.1	278.231	2.2.2.3	75.604	4.2.1.2	173.565
2.1.1	135.933	1.1.2.2	157.962	3.1.1.1	219.752	4.2.1.3	145.553
2.1.2	178.074	1.1.2.3	127.435	3.1.1.2	194.075	4.2.2.1	192.754
2.2.1	116.383	1.2.1.1	267.998	3.1.1.3	166.140	4.2.2.2	90.215
2.2.2	313.087	1.2.1.2	168.220	3.1.2.1	243.926	4.2.2.3	61.858
3.1.1	113.423	1.2.1.3	152.387	3.1.2.2	156.051	5.1.1.1	228.993
3.1.2	205.690	1.2.2.1	158.896	3.1.2.3	132.839	5.1.1.2	186.799
3.2.1	181.212	1.2.2.2	84.786	3.2.1.1	312.772	5.1.1.3	162.279
3.2.2	285.333	1.2.2.3	60.179	3.2.1.2	167.380	5.1.2.1	218.913
4.1.1	205.825	2.1.1.1	242.262	3.2.1.3	162.793	5.1.2.2	172.813
4.1.2	231.894	2.1.1.2	186.606	3.2.2.1	186.655	5.1.2.3	140.264
4.2.1	94.469	2.1.1.3	153.198	3.2.2.2	98.877	5.2.1.1	279.853
4.2.2	291.432	2.1.2.1	216.310	3.2.2.3	81.457	5.2.1.2	188.090
5.1.1	122.663	2.1.2.2	177.140	4.1.1.1	312.154	5.2.1.3	143.906
5.1.2	180.677	2.1.2.3	129.367	4.1.1.2	169.448	5.2.2.1	172.318
5.2.1	148.293	2.2.1.1	247.943	4.1.1.3	161.864	5.2.2.2	97.334
5.2.2	270.995	2.2.1.2	172.193	4.1.2.1	270.130	5.2.2.3	82.553

TABLE 6
THE PROPOSED DEMAND OF SECONDARY CUSTOMERS IN A CERTAIN STATE, AND IN EACH SCENARIO

d(f.e.τ)	*Value*	*d(f.e.τ.s)*	*Value*	*d(f.e.τ.s)*	*Value*	*d(f.e.τ.s)*	*Value*
1.1.1	61.582	1.1.1.1	78853.941	2.1.1.1	78858.155	3.1.1.1	78866.605
1.1.2	59.653	1.1.1.2	78844.945	2.1.1.2	78850.031	3.1.1.2	78847.091
1.2.1	47.260	1.1.1.3	78838.300	2.1.1.3	78840.862	3.1.1.3	78841.624
1.2.2	49.006	1.1.2.1	1.1379E+5	2.1.2.1	1.1378E+5	3.1.2.1	1.1380E+5
2.1.1	68.464	1.1.2.2	1.1380E+5	2.1.2.2	1.1378E+5	3.1.2.2	1.1377E+5
2.1.2	74.037	1.1.2.3	1.1377E+5	2.1.2.3	1.1378E+5	3.1.2.3	1.1378E+5
2.2.1	50.239	1.2.1.1	43676.388	2.2.1.1	43678.768	3.2.1.1	43665.084
2.2.2	64.475	1.2.1.2	43656.761	2.2.1.2	43667.829	3.2.1.2	43653.451
3.1.1	74.067	1.2.1.3	43645.322	2.2.1.3	43655.266	3.2.1.3	43646.313
3.1.2	58.220	1.2.2.1	48077.557	2.2.2.1	48072.398	3.2.2.1	48057.405
3.2.1	46.630	1.2.2.2	48061.051	2.2.2.2	48039.626	3.2.2.2	48052.544
3.2.2	59.575	1.2.2.3	48037.302	2.2.2.3	48038.097	3.2.2.3	48046.245

Sensitivity analysis: In the following, in order to study the real-world conditions and the behavior of the objective function in dealing with the changes, we analyze the sensitivity on the robustness parameters of the problem (solution and model robustness). Now, by analyzing the sensitivity on the described problem, as a sample problem, we analyze the effectiveness of these parameters on the objective functions, the outcomes of which are shown in Diagram 1.

According to diagram 1, with the increase of $\lambda_1$to 0.18, the average profit and absolute deviation from profit increase, and with the increase of $\lambda_1$from 0.18 to 0.38, the average profit and absolute deviation from profit decrease. For the second objective function, i.e. delay in delivery time, with an increase in λ_1, the average delay in delivery time and its absolute deviation decrease, and for the fourth objective function, with an increase in λ_1 to 0.18, the average environmental pollution and its absolute deviation increase, but From 0.18 to 0.38, both decrease. Therefore, according to the value of the objective functions in this problem, we can say that $\lambda_1 = 0.18$, $\lambda_1 = 0.3$, $\lambda_1 = 0.25$ and $\omega = 20$ are suitable values for these parameters.

TABLE 7

SELLING PRICE OF EACH PRODUCT UNIT E TO THE PRIMARY AND SECONDARY CUSTOMERS C IN A CERTAIN STATE, AND IN EACH SCENARIO

PR(c.e.τ)	*Value*	*PR(c.e.τ,s)*	*Value*	*PR(f.e.τ)*	*Value*	*PR(f.e.τ,s)*	*Value*
1.1.1	16.423	1.1.1	39600.401	1.1.1	20.546	1.1.1	3997.720
1.1.2	16.398	1.1.2	57154.065	1.1.2	36.863	1.1.2	5746.708
1.2.1	12.242	1.2.1	21914.135	1.2.1	11.691	1.2.1	2229.067
1.2.2	15.286	1.2.2	24119.853	1.2.2	60.682	1.2.2	2421.579
2.1.1	16.423	2.1.1	39600.401	2.1.1	20.546	2.1.1	3997.720
2.1.2	16.398	2.1.2	57154.065	2.1.2	36.863	2.1.2	5746.708
2.2.1	12.242	2.2.1	21914.135	2.2.1	11.691	2.2.1	2229.067
2.2.2	15.286	2.2.2	24119.853	2.2.2	60.682	2.2.2	2421.579
3.1.1	16.423	3.1.1	39600.401	3.1.1	20.546	3.1.1	3997.720
3.1.2	16.398	3.1.2	57154.065	3.1.2	36.863	3.1.2	5746.708
3.2.1	12.242	3.2.1	21914.135	3.2.1	11.691	3.2.1	2229.067
3.2.2	15.286	3.2.2	24119.853	3.2.2	60.682	3.2.2	2421.579
4.1.1	16.423	4.1.1	39600.401				
4.1.2	16.398	4.1.2	57154.065				
4.2.1	12.242	4.2.1	21914.135				
4.2.2	15.286	4.2.2	24119.853				
5.1.1	16.423	5.1.1	39600.401				
5.1.2	16.398	5.1.2	57154.065				
5.2.1	12.242	5.2.1	21914.135				
5.2.2	15.286	5.2.2	24119.853				

TABLE 8
UNFULFILLED DEMAND FOR PRODUCT E, FOR PRIMARY AND SECONDARY IN EACH SCENARIO

$\eta 1(c.e.\tau.s)$	Value	$\eta 1(c.e.\tau.s)$	Value	$\eta 2(c.e.\tau.s)$	Value	$\eta 2(c.e.\tau.s)$	Value
1.1.1.2	33.723	3.2.1.3	92.808	1.1.1.1	78801.030	2.2.2.2	48035.497
1.1.1.3	60.811	3.2.2.2	43.485	1.1.1.2	78798.643	2.2.2.3	48034.118
1.1.2.1	20.614	3.2.2.3	39.831	1.1.1.3	78799.005	3.1.1.1	78828.635
1.1.2.2	49.466	4.1.1.1	51.322	1.1.2.1	1.1376E+5	3.1.1.2	78835.738
1.1.2.3	63.132	4.1.1.2	9.844	1.1.2.2	1.1376E+5	3.1.1.3	78827.372
1.2.1.3	7.471	4.1.1.3	23.512	1.1.2.3	1.1375E+5	3.1.2.1	1.1373E+5
1.2.2.2	41.812	4.1.2.1	2.183	1.2.1.1	43605.362	3.1.2.2	1.1373E+5
1.2.2.3	36.087	4.1.2.2	27.427	1.2.1.2	43653.915	3.1.2.3	1.1374E+5
2.1.1.1	29.561	4.1.2.3	57.013	1.2.1.3	43604.256	3.2.1.1	43665.084
2.1.1.3	26.083	4.2.1.2	116.141	1.2.2.1	48077.557	3.2.1.2	43602.221
2.1.2.1	33.946	4.2.1.3	114.671	1.2.2.2	48057.082	3.2.1.3	43602.687
2.1.2.2	5.164	4.2.2.2	22.565	1.2.2.3	48034.818	3.2.2.1	48021.251
2.1.2.3	26.067	5.1.1.1	118.379	2.1.1.1	78801.030	3.2.2.2	48003.446
2.2.1.2	84.186	5.1.1.2	30.531	2.1.1.2	78797.964	3.2.2.3	48009.310
2.2.1.3	88.976	5.1.1.3	36.352	2.1.1.3	78798.538		
2.2.2.2	28.782	5.1.2.1	35.879	2.1.2.1	1.1373E+5		
2.2.2.3	7.879	5.1.2.2	65.844	2.1.2.2	1.1376E+5		
3.1.1.1	18.510	5.1.2.3	49.750	2.1.2.3	1.1376E+5		
3.1.1.2	62.375	5.2.1.2	73.646	2.2.1.1	43589.641		
3.1.1.3	79.841	5.2.1.3	96.767	2.2.1.2	43617.570		
3.1.2.3	30.690	5.2.2.2	35.320	2.2.1.3	43647.921		
3.2.1.2	100.486	5.2.2.3	33.910	2.2.2.1	47997.549		

In order to further validate the proposed model for higher dimensions based on Table X, 20 numerical examples were designed. To solve these problems, the AUGMECON approaches will be used in small sizes and NSGA-III and MOGWO algorithms will be used for large sizes.

Due to the fact that the problem of this research is one of the problems with high complexity and Gomez software in high dimensions cannot be solved, MATLAB software and NSGAII and MOGWO metaheuristic algorithms are used.

Algorithm parameter adjustment using Taguchi method for NSGA-III algorithm: The Taguchi method is one of the FFE methods for parameterization (optimal level control of agents) that was introduced in 1978. In Taguchi method, the factors affecting the test result are divided into two categories: uncontrollable (so-called disturbance (N)) and controllable (so-called signal (S)). An S / N variable is then defined, which is the signal-to-perturbation ratio. Taguchi's parameter setting method adjusts the factors to levels that maximize the S / N ratio. In minimization problems the less-better formula is used and in optimization problems the more-better Taguchi formula is used to calculate the S / N ratio.

Where the response variable (target value / response variable) is in test i and n indicates the number of tests. In the NSGAIII method, the four parameters MaxIt, NPOP, PC, PM must be set at optimal levels. For this purpose, first, for each parameter, three levels of low (1), medium (2) and high (3) are defined separately to solve the problems, which are given in Table Xi. Then, the proposed set of experiments of Taguchi method is calculated for four factors in three levels, and 9 different modes are designed by Taguchi method. (It should be noted that each experiment is performed 10 times and their average is recorded, which is done to reduce the error of the algorithms and the answer will be more reliable).

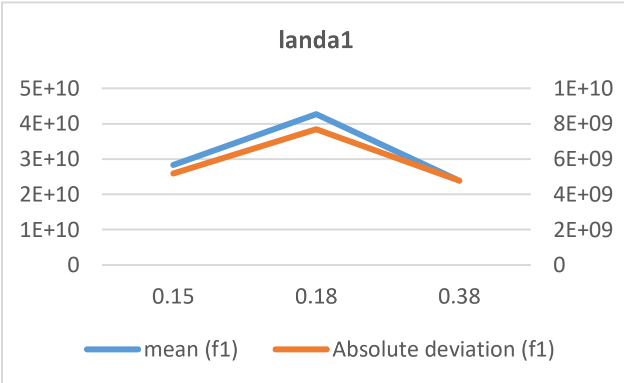
TABLE 9

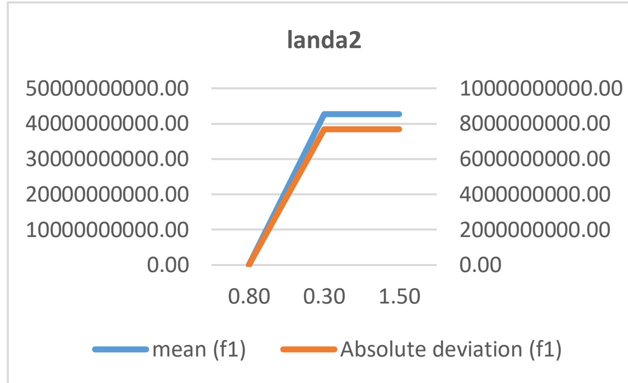
THE TYPE OF RFID TECHNOLOGY USED IN EACH FLOW OF THE CERTAIN STATE

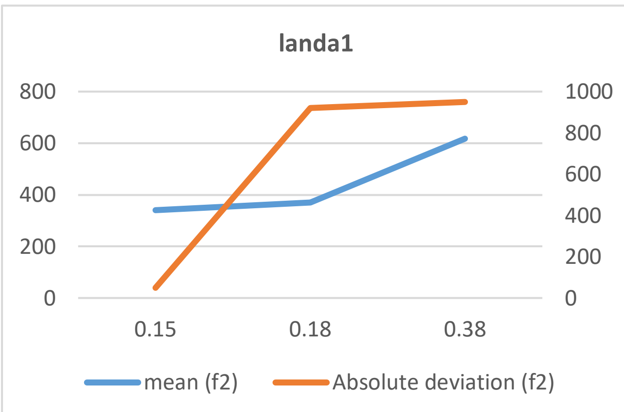
$OBI(b,i,l,o,\tau)$	*Value*	$OCP(c,p,l,o,\tau)$	*Value*	$OMF(m,f,l,o,\tau)$	*Value*	$OEPC(p,c,l,o,\tau)$	*Value*
1.1.1.2.1	1	4.2.2.1.2	1	1.1.1.1.1	1	2.4.2.1.2	1
1.2.1.2.1	1	5.2.1.1.1	1	1.1.2.1.2	1	2.5.1.2.2	1
Value	1	5.2.1.2.2	1	1.2.2.1.1	1	$OPC(p,c,l,o,\tau)$	*Value*
2.1.1.2.2	1	$OIC(i,c,l,o,\tau)$	*Value*	1.2.2.2.2	1	1.1.1.1.2	1
2.2.1.1.2	1	1.1.1.2.1	1	1.3.1.1.1	1	1.1.2.1.1	1
$OIP(i,p,l,o,\tau)$	*Value*	1.1.2.1.2	1	1.3.2.1.2	1	1.2.2.1.1	1
1.1.1.1.1	1	1.2.1.1.1	1	2.1.1.1.1	1	1.3.1.2.2	1
1.1.1.1.2	1	1.2.2.1.2	1	2.1.2.1.2	1	1.3.2.2.1	1
2.1.1.1.2	1	1.3.1.2.1	1	2.2.1.1.2	1	1.4.1.1.1	1
2.2.1.2.2	1	1.3.2.2.2	1	2.2.2.1.1	1	1.4.2.1.2	1
$OPI(p,i,l,o,\tau)$	*Value*	1.4.1.1.2	1	2.3.1.2.2	1	1.5.2.1.2	1
2.1.2.1.1	1	1.4.2.1.1	1	2.3.2.1.1	1	1.5.2.2.1	1
2.2.2.2.2	1	1.5.1.1.2	1	$OEPC(p,c,l,o,\tau)$	*Value*	2.1.1.2.2	1
$OPM(p,m,l,o,\tau)$	*Value*	1.5.2.2.1	1	1.1.1.1.2	1	2.2.2.2.2	1
2.1.1.1.1	1	2.1.1.1.1	1	1.1.2.1.1	1	2.3.1.1.2	1
2.1.1.2.2	1	2.1.2.1.1	1	1.2.1.1.1	1	2.4.1.2.2	1
2.2.1.1.1	1	2.1.2.1.2	1	1.2.1.1.2	1	2.5.1.2.1	1
2.2.2.2.2	1	2.2.2.2.1	1	1.3.1.2.1	1	2.5.2.2.2	1
$OCP(c,p,l,o,\tau)$	*Value*	2.2.2.2.2	1	1.4.1.1.1	1	$OPK(p,k,l,o,\tau)$	*Value*
1.2.1.2.2	1	2.3.2.1.1	1	1.4.2.2.2	1	2.1.2.1.2	1
1.2.2.1.1	1	2.3.2.2.2	1	1.5.1.2.1	1	2.1.2.2.1	1
2.2.1.1.2	1	2.4.1.1.1	1	1.5.2.2.2	1	2.2.1.1.2	1
2.2.2.1.1	1	2.4.1.1.2	1	2.1.1.2.2	1	2.2.2.1.1	1
3.2.1.1.1	1	2.4.2.2.1	1	2.2.1.2.2	1		
3.2.1.1.2	1	2.5.1.2.2	1	2.3.2.2.2	1		
4.2.2.1.1	1	2.5.2.1.1	1	2.4.2.1.1	1		

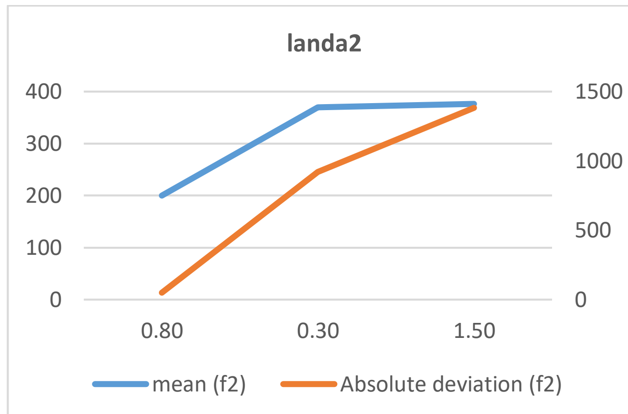
TABLE 10
The type of rfid technology used in each scenario

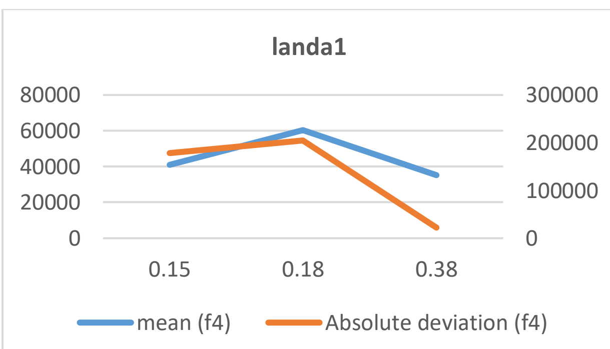
$OBI(b,i,l,o,\tau-s)$	Value	$OIC(i,c,l,o,\tau-s)$	Value	$OEPC(p,c,l,o,\tau-s)$	Value	$OCP(c,p,l,o,\tau-s)$	Value
1.1.2.1.2	1	1.1.1.2.2	1	1.3.1.2.1	1	2.1.2.1.2	1
1.2.1.2.1	1	1.1.2.2.1	1	1.4.1.2.1	1	2.2.1.1.1	1
1.2.2.2.2	1	1.2.2.1.2	1	1.5.2.1.1	1	2.2.2.1.2	1
2.2.1.1.1	1	1.2.2.2.1	1	2.1.1.1.1	1	3.1.1.1.2	1
2.2.1.2.2	1	1.3.1.2.2	1	2.1.2.2.2	1	3.2.1.1.1	1
$OIP(i,p,l,o,\tau-s)$	Value	1.3.2.2.1	1	2.2.1.1.1	1	3.2.2.2.2	1
1.2.1.1.2	1	1.4.2.1.2	1	2.3.1.2.1	1	4.1.1.1.2	1
1.2.1.2.1	1	1.4.2.2.1	1	2.3.2.1.2	1	4.1.2.2.1	1
2.1.1.2.1	1	1.5.1.2.1	1	2.4.1.1.1	1	4.2.1.1.1	1
2.2.1.2.1	1	1.5.2.1.2	1	2.4.1.2.2	1	4.2.2.2.2	1
2.2.1.2.2	1	2.1.1.2.2	1	2.5.1.1.2	1	5.1.2.1.2	1
$OPI(p,i,l,o,\tau-S)$	Value	2.1.2.2.1	1	2.5.2.2.1	1	5.2.1.2.1	1
1.1.2.1.1	1	2.2.2.1.1	1	$OMF(m,f,l,o,\tau-s)$	Value	5.2.2.2.2	1
1.1.2.2.2	1	2.2.2.2.2	1	1.1.2.1.2	1	$OPM(p,m,l,o,\tau-s)$	Value
1.2.1.2.1	1	2.3.1.1.2	1	1.1.2.2.1	1	1.1.2.1.2	1
2.1.2.1.1	1	2.3.2.2.1	1	1.2.2.2.1	1	1.1.2.2.1	1
2.1.2.1.2	1	2.4.2.2.1	1	1.2.2.2.2	1	2.1.1.1.2	1
2.2.1.1.1	1	2.4.2.2.2	1	1.3.1.1.1	1	2.1.1.2.1	1
2.2.2.2.2	1	2.5.1.1.1	1	1.3.1.1.2	1	2.2.2.1.1	1
$OPC(p,c,l,o,\tau-s)$	Value	2.5.2.2.2	1	2.1.2.1.1	1	2.2.2.2.2	1
1.1.1.2.1	1	$OPK(p,k,l,o,\tau-s)$	Value	2.1.2.2.2	1	$OPM(p,m,l,o,\tau-s)$	Value
1.2.1.2.1	1	1.1.2.1.2	1	2.2.1.2.1	1	1.1.1.1.2	1
1.3.1.2.1	1	1.1.2.2.1	1	2.2.2.1.2	1	1.1.1.2.1	1
1.4.1.2.1	1	2.1.1.1.2	1	2.3.1.1.1	1	2.1.1.2.1	1
1.5.1.1.1	1	2.1.1.2.1	1	2.3.2.2.2	1	2.1.2.1.2	1
2.2.1.1.1	1	2.2.2.1.1	1	$OCP(c,p,l,o,\tau-s)$	Value	2.2.2.2.1	1
2.2.1.1.2	1	2.2.2.2.2	1	1.1.1.2.1	1	2.2.2.2.2	1
2.3.1.2.1	1	$OEPC(p,c,l,o,\tau-s)$	Value	1.1.2.2.2	1		
2.3.2.1.2	1	1.1.1.1.1	1	1.2.1.1.1	1		
2.5.1.2.2	1	1.2.1.1.1	1	1.2.2.2.2	1		

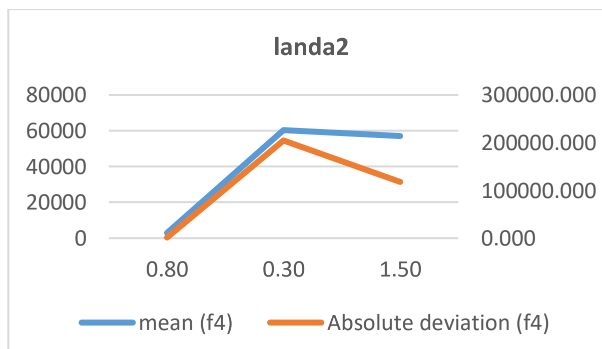

landa1
5E+10
4E+10
3E+10
2E+10
1E+10
0
1E+10
8E+09
6E+09
4E+09
2E+09
0
0.15
0.18
0.38
mean (f1)
Absolute deviation (f1)


landa2
50000000000.00
40000000000.00
30000000000.00
20000000000.00
10000000000.00
0.00
10000000000.00
8000000000.00
6000000000.00
4000000000.00
2000000000.00
0.00
0.80
0.30
1.50
mean (f1)
Absolute deviation (f1)


landa1
800
600
400
200
0
1000
800
600
400
200
0
0.15
0.18
0.38
mean (f2)
Absolute deviation (f2)


landa2
400
300
200
100
0
1500
1000
500
0
0.80
0.30
1.50
mean (f2)
Absolute deviation (f2)


landa1
80000
60000
40000
20000
0
300000
200000
100000
0
0.15
0.18
0.38
mean (f4)
Absolute deviation (f4)


landa2
80000
60000
40000
20000
0
300000.000
200000.000
100000.000
0.000
0.80
0.30
1.50
mean (f4)
Absolute deviation (f4)

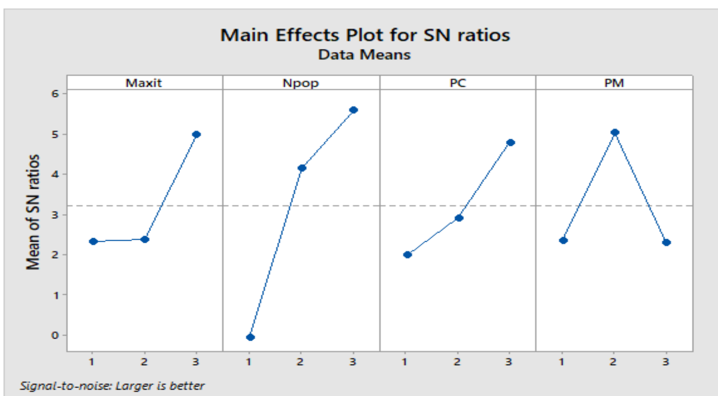
DIAGGRAM 1
RESULTS OF THE SENSITIVITY ANALYSIS

TABLE 11
SIZE OF DESIGNED PROBLEMS

TesT Problem	$\|B\|$	$\|I\|$	$\|P\|$	$\|C\|$	$\|K\|$	$\|M\|$	$\|F\|$	$\|E\|$	$\|A\|$	$\|L\|$	$\|T\|$	$\|H\|$	$\|O\|$
1	2	2	3	5	2	2	3	2	3	2	2	2	2
2	2	2	3	6	2	3	3	2	3	2	3	3	2
3	2	2	4	6	2	3	4	2	3	3	3	3	2
4	3	2	4	7	2	3	4	3	3	3	3	3	2
5	3	3	4	8	3	3	4	3	3	3	4	3	3
6	5	4	7	10	3	5	6	3	3	4	4	3	4
7	5	4	7	10	4	5	6	3	3	4	4	3	4
8	5	5	8	12	4	5	8	4	4	4	4	4	4
9	5	6	8	13	4	6	8	4	4	4	4	4	4
10	5	6	8	14	4	6	9	4	4	4	5	4	4
11	5	6	8	16	4	6	10	4	4	4	5	4	4
12	5	6	8	20	4	6	15	4	4	4	5	4	4
13	5	6	8	30	5	7	25	4	5	4	5	4	4
14	5	7	8	40	5	7	35	4	5	5	5	4	4
15	6	7	8	50	5	8	45	4	5	5	5	4	4
16	6	7	9	60	5	8	50	4	5	5	5	4	4
17	6	7	9	70	5	8	55	5	5	5	6	5	5
18	6	7	9	80	6	8	60	5	5	5	6	5	5
19	6	8	9	90	6	9	65	5	5	5	6	5	5
20	7	8	10	100	6	9	70	5	5	5	6	5	5

TABLE 12
SMALL, MEDIUM AND LARGE DIMENSION PARAMETER LEVELS FOR NSGA-III ALGORITHM

NSGA-III parameter	low	medium	high
MaxIt	150	250	300
Npop	120	150	200
pc	0.6	0.7	0.8



Max It	N Pop	pc	pm
300	200	0.8	0.25

FIGURE 6
MINITAB SOFTWARE OUTPUT FOR SMALL SIZE NSGA-III

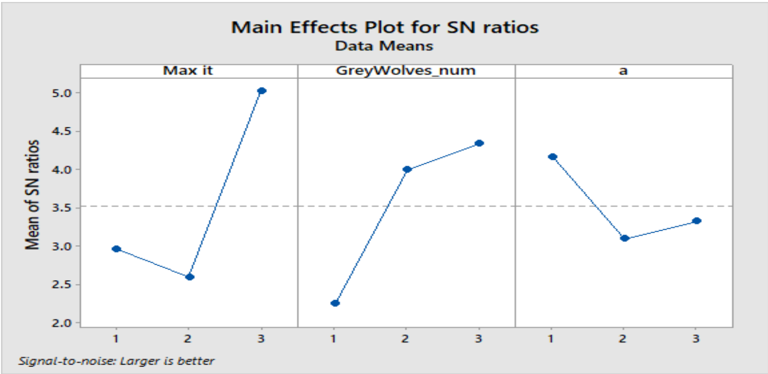
Other parameters such as the division of reference points (D) and mutation scale (MS) are considered, 10 and 0.1, respectively. After determining the level for the parameters of the algorithm using the Taguchi method, finally the output of the minitab software will be in the Figure 6 and the levels of the parameters will be presented.

Parameter setting of MOGWO algorithm: In MOGWO solution method, which is one of the methods used in this research, maximum repetition (MaxIt), GeryWolves_num, a, are three factors affecting the quality of the solution method. In this section, three levels are considered for each parameter, which is shown in Table XII.

TABLE 13
LEVELS REQUIRED FOR MOGWO ALGORITHM PARAMETERS

MOGWO parameter	low	medium	high
MaxIt	150	250	300
GeryWolves_num	120	150	200
a	1	1.5	2

Then, the necessary experiments are designed by the miniature software and Taguchi method, which is finally applied to this algorithm according to what was presented in the NSGAII parameter setting, which is presented in the final parameter setting in Figure 6.



MaxIt	GeryWolves_num	a	alpha	nGrid	beta	gama
300	200	1	0.1	10	4	1

FIGURE 7
MINITAB SOFTWARE OUTPUT FOR SMALL SIZE MOGWO

Comparison of the output of meta-heuristic algorithms with AUGMECON method: After adjusting the parameters of the proposed algorithm by the Taguchi method described in the previous section, in this section, small-scale random problems are evaluated based on the defined three criteria in Section II, which is shown in Table 14.

TABLE 14
OUTPUT FROM NSGAIII ALGORITHMS OF RESEARCH WITH GAMS SOFTWARE

problem	Time			MID			NOS		
	AUGMECON	MOGWO	NSGA-III	AUGMECON	MOGWO	NSGA-III	AUGMECON	MOGWO	NSGA-III
1	420	319/522	426/349	6.25E+06	6.26E+06	6.85E+06	10	12	12
2	2100	322/567	478/87	1.15E+07	1.16E+07	1.63E+07	8	15	16
3	2940	368/669	497/567	3.19E+07	3.19E+07	3.11E+07	6	6	10
4	6300	396/018	562/814	2.62E+07	2.62E+07	2.64E+07	9	8	9
5	14000	417/599	577/444	1.13E+07	1.15E+07	2.17E+07	10	12	15

II. EVALUATION INDICATORS

The question now is how to evaluate and compare these algorithms according to the output of the algorithms. If a single-objective optimization problem (the problem of minimization) is considered, it is very clear that any solution that offers a solvable solution that is less costly is better. But in the case of MODM, the evaluation method is different and cannot be evaluated as a single objective. Accordingly, we define the following indexes for evaluating and comparing the two MODM methods. The execution time criterion of the algorithm: The speed of running the algorithms to find near optimum solutions is one of the most important indices to evaluate the performance of an algorithm. The distance from the ideal response (MID): this metric is used to compute the distances between the Pareto fronts and the ideal point.

$$MID = \frac{\sum_{i=1}^{n} c_i}{n} \qquad (91)$$

where n is the number of Pareto optimizations and the value of c_i is obtained by the following equation. It should be noted that the lower the MID, the higher the performance of the algorithm is.

$$c_i = \sqrt{f_{1i}^2 + f_{2i}^2} \qquad (92)$$

The spread of non-dominance solutions (SNS): The higher the SNS value the better the algorithm is, which is defined by the following equation.

$$SNS = \sqrt{\frac{\sum_{i=1}^{n} (MID - C_I)^2}{n-1}} \qquad (93)$$

Diversification Metric (DM):This metric can be computed by (135). In this metric, the algorithm with a higher value has a better capability.

$$Diversity = \sqrt{(max f_{1i} - min\, f_{1i})^2 + (max f_{2i} - min\, f_{2i})^2} \qquad (94)$$

The rate of achievement to two objectives simultaneously (RAS): RAS index is obtained by the below equation.

$$RAS = \frac{\sum_{i=1}^{n} \left(\frac{f_{1i} - F_i}{F_i}\right) + \left(\frac{f_{2i} - F_i}{F_i}\right)}{n} \qquad (95)$$

Number of non-dominated solutions in final parato (NOS): It counts the number of Pareto solutions.

Now, according to the expressed indicators and problems designed in Table X to compare algorithms, each problem is executed 10 times for each algorithm and the average is reported as the final answer for each solution method the values of all the indicators are shown in Table 15.

According to Table 15, which shows the presented indicators related to each algorithm, we evaluation the outputs and analyze them.

Evaluation the solution time: Figure 8 shows the solution time of each algorithm for each problem. The comparison diagram of the algorithms shows that the solution time of the MOGWO algorithm is less than the NSGAII algorithm. Given that any algorithm that has less solving time has better performance, we can say that the MOGWO algorithm is better.

TABLE 15
NSGAIII_MOGWO ALGORITHM OUTPUTS

problem	Time		SNS		DM		MID		RAS	
	MOGWO	NSGA-III	MOGWO	NSGA-III	MOGWO	NSGA-III	MOGWO	NSGA-III	MOGWO	NSGA-III
1	319/522	426/349	9.55E+07	2.59E+07	4.45E+07	9.88E+07	6.26E+06	6.85E+06	0.099	0.054
2	322/567	478/87	8.43E+07	9.06E+07	1.01E+08	1.14E+08	1.16E+07	1.63E+07	0.07	0.025
3	368/669	497/567	7.00E+07	5.18E+07	3.57E+08	3.02E+08	3.19E+07	3.11E+07	0.099	0.1068
4	396/018	562/814	3.13E+08	2.84E+08	4.58E+08	3.16E+08	2.62E+07	2.64E+07	0.078	0.0349
5	417/599	577/444	3.90E+08	3.53E+08	2.28E+08	2.30E+08	1.15E+07	2.17E+07	0.06	0.0175
6	447/832	589/848	3.16E+08	3.23E+08	2.08E+08	4.01E+08	2.50E+07	2.79E+07	0.031	0.0148
7	477/736	618/758	5.28E+08	5.27E+08	2.91E+08	3.94E+08	1.97E+07	3.68E+07	0.054	0.0147
8	548/709	671/741	7.68E+08	7.28E+08	4.49E+08	3.87E+08	1.72E+07	3.13E+07	0.238	0.1814
9	627/655	709/8	1.15E+09	1.18E+09	3.15E+08	4.33E+08	1.32E+07	6.62E+07	0.472	0.0522
10	748/72	875/77	1.64E+09	1.60E+09	3.23E+08	5.16E+08	1.39E+07	5.86E+07	0.126	0.0417
11	896/14	1020/81	1.61E+09	1.52E+09	4.44E+08	4.65E+08	1.47E+07	5.47E+07	0.041	0.0158
12	940/8	1095/22	1.96E+09	1.93E+09	3.60E+08	4.49E+08	2.16E+07	2.91E+07	0.034	0.0086
13	1023/82	1158/5	2.49E+09	2.23E+09	2.89E+08	3.39E+08	2.47E+07	3.16E+07	0.024	0.0043
14	1057/07	1216/53	2.98E+09	2.80E+09	2.83E+08	5.74E+08	2.50E+07	8.39E+07	0.024	0.0046
15	1103/27	1254/54	3.33E+09	3.11E+09	4.36E+08	6.00E+08	3.71E+07	6.03E+07	0.023	0.0064
16	1129/94	1308/79	3.52E+09	2.44E+09	5.43E+08	5.90E+08	3.06E+07	4.40E+07	0.024	0.0089
17	1250/27	1385/79	3.56E+09	2.03E+09	5.97E+08	5.89E+08	3.30E+07	7.48E+07	0.022	0.0052
18	1324/61	1412/46	4.79E+09	4.18E+09	5.83E+08	3.52E+08	3.44E+07	1.01E+08	0.027	0.0029
19	1354/99	1481/06	6.02E+09	6.33E+09	9.18E+08	8.68E+08	6.82E+07	1.19E+08	0.016	0.0052
20	1435/35	1601/04	7.23E+09	6.97E+09	5.43E+08	7.40E+08	4.95E+07	5.61E+07	0.017	0.0127
AV	809/56435	947/18505	2.143E+09	1.935E+09	388539906	437861485	25766820	48864524	0.07895	0.03088

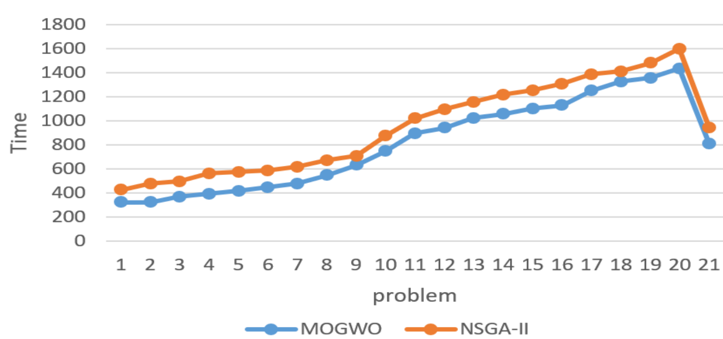


FIGURE 8
DISPLAY OF TIME INDEX FOR RESEARCH ALGORITHMS

Evaluation the DM index: Due to the shape and nature of this index, the more the better. It appears that the NSGA_III algorithm performed better than the MOGWO algorithm.

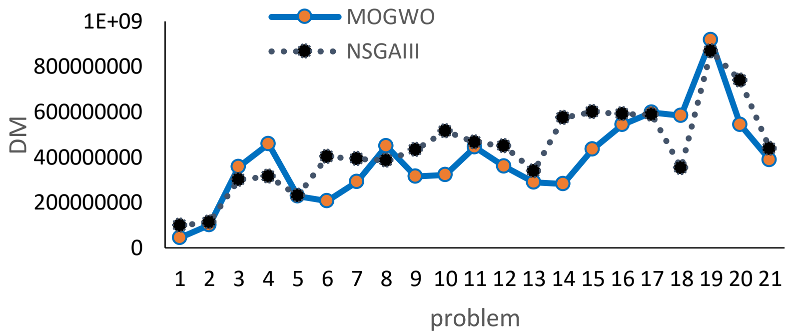


FIGURE 9
DISPLAY INDEX DM FOR RESEARCH ALGORITHMS

Evaluation the MID index: For MID index (each algorithm has a smaller value and has better performance) according to figure 10 it can be concluded that The MOGWO algorithm performed better.

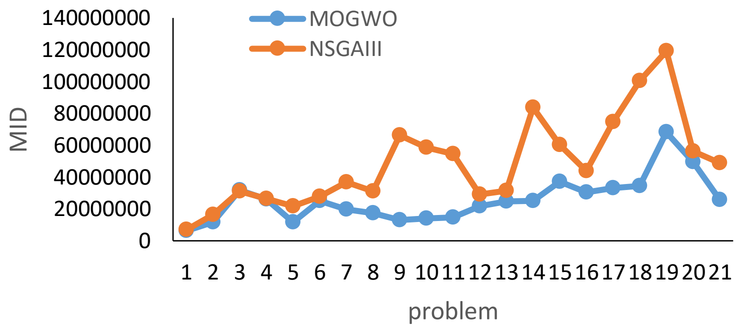


FIGURE 10
DISPLAY INDEX MID FOR RESEARCH ALGORITHMS

Evaluation the SNS index: Given that the SNS index is positive in nature, that is, the higher the better, Figure 11, it can be said that there is not much difference between the two algorithms. However, the MOGWO algorithm has performed better in some large dimension issues.

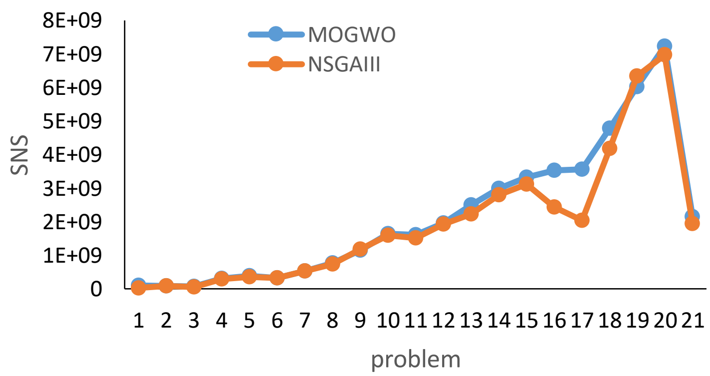


FIGURE 11
DISPLAY INDEX SNS FOR RESEARCH ALGORITHMS

Evaluation the RAS index: The last indicator studied in this research is RAS, which, as mentioned earlier, has a negative nature (the less - the better), ie any algorithm with a lower RAS value is better. According to Figure 12, it is clear that the NSGAII algorithm performed better.

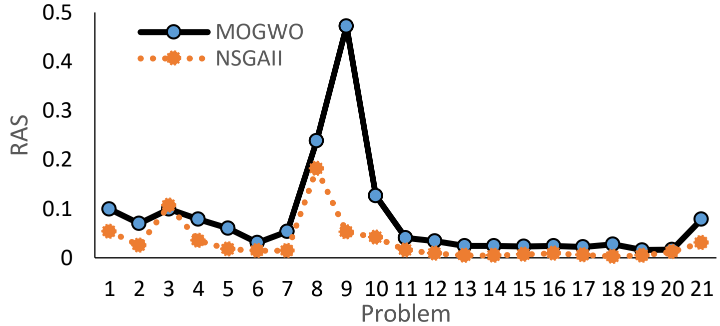


FIGURE 12
DISPLAY INDEX SNS FOR RESEARCH ALGORITHMS

According to the obtained diagrams, it can be concluded that there is no significant difference in small dimensions between the two algorithms, but as the dimensions of the problem increase, this difference increases and is significant. According to Table 14, the study of the mean in different dimensions shows that the MOGWO algorithm performed better in terms of Time, MID, SNS indices and the NSGAII algorithm performed better in terms of RAS and Diversity indices.

CONCLUSIONS, MANAGERIAL INSIGHTS, AND FUTURE RESEARCH

Results: optimal design of the SC network has many effects on the performance, efficiency, and effectiveness of SCs to achieve the expected goals and to meet the customers' needs. In this regard, this paper has tried to design a CLSC network with different sales channels by taking into account the RFID system and pricing strategy. Moreover, this paper, in addition to reducing the total pollutants, as a separate goal, has dealt with the strategy of reducing carbon and paying government subsidies; in other words, because considering low-carbon product manufacturing technology increases constant costs, and consequently, production costs, the government subsidizes managers to encourage them to produce low-carbon products. In addition, the model simultaneously looks for maximizing the profit and social responsibility of the SC network while minimizing total delay at delivery times and environmental pollution; moreover, RSSP was used to deal with fluctuations in demand of the primary and secondary customers and delivery time. Due to the four objective functions of the model, the AUGMECON approach and the NSGA-III and MOGWO algorithms were applied to solve the model.

To validate the model, a small-scale problem was designed to further analyze and compare solving approaches of 20 numerical small, large, and medium examples, and finally, certain and robust models, in three scenarios were coded and solved for each problem with the mentioned solution approaches in GAMS and MATLAB, and its computational results were presented. In addition, to observe the behavior of the objective function due to changes in parameters, sensitivity analysis was done on the parameters of problem robustness (solution and model robustness), and the results were also expressed. In general, the computational results show the superiority of this model, which can be considered by taking into account the uncertainty of some parameters and providing an optimal model in terms of achieving profit and social responsibility, and reducing delays in delivery time and environmental pollution, as well as determine which suppliers, which potential centers of production-recovery, distribution/hybrid, collection/hybrid, repair and disposal, and which means of transportation, with what technology RFID, what production technology to be used, and what will be the amount of transported products and the inventory between the desired facilities.

Also it can be seen that e-commerce has increased income and since sales intermediaries are eliminated in online shopping, this results in quick response to customer demand, high accessibility and low distribution cost, and due to the reduction of pollution, it has significant environmental effects on health. In this robust model, by applying the scenario-based stochastic robust approach, the problems of uncertain models, in which the solutions were impossible or non-optimal, are solved, and can also be implemented for real problems. This designed the SC, in terms of application, has the ability to use in a variety of different industries, and manufacturing companies that their produced raw materials and products have had the ability to recover or renew, as well as, is repairable and also, is a tool for researchers to investigate interesting challenges. It should be noted that no research is free from limitations. Therefore, this paper is not an exception. One of the limitations we faced in this paper was the lack of access to a case study on which the proposed model could be implemented.

Managerial Insight: The proposed model also offers good managerial insight. Factory managers can determine the low-carbon content of factory-produced products by considering government subsidy policies, on the one hand, and assessing the extent of pollution from low-carbon product technology, on the other. The suggested model also assists them in suggesting the optimum price for each customer in order to increase the market influence to absorb more customers. Due to the limited use of vehicles, the use of RFID in the SC allows partners to easily know how long is the product life, where it currently stands, and where it will go, as well as lead to reduce time interruptions of transporting, timely delivery of orders, faster transporting, and elimination of incorrect transportations and shortening of order chains, and in general, enable managers to make timely and more confident decisions.

In addition, considering that this paper has analyzed the optimal policies in certain and uncertain conditions and considering the difference between certain and uncertain solutions, it was found that the analysis of uncertain conditions plays a very important role in designing the network for managers. In fact, considering the uncertainty of demand parameters and delivery time are among the inseparable components of the problem, and considering the number of available resources to find a valid solution in the system is one of the necessities. On the other hand, the sensitivity analysis of the parameters $\lambda_1,\lambda_2,\lambda_3$ and ω was performed in order to study the effectiveness of the robustness parameters, as well as analyze the solution and the model robustness. The behavior of the objective functions has been different from each of the robust parameters, so management should take into account that the appropriate level of required and backup resources in the event of uncertainty is essential to be prepared to deal with a lot of changes due to uncertainty.

Suggestions: In future studies, other variables and Constraints can be applied to the model for greater adaptation to real-world situations. Also, the uncertainty of the suggested model can be examined with other robust uncertainty approaches, and the results and their comparison can be presented. Other available or developed meta-heuristic methods can also be applied in order to solve the problem. In addition, other support policies of governments, various discount policies for the procurement of materials and products, and the reliability of existing components can also be examined. Another research shortcoming of the current paper is the neglect of disruptions, and in this regard, future studies can add resilience strategies such as backup suppliers to the current issue.

REFERENCES

[1] Abdolazimi, O., Bahrami, F., Shishebori, D., & Ardakani, M. A. (2021). A multi-objective closed-loop supply chain network design problem under parameter uncertainty: comparison of exact methods. *Environment, Development and Sustainability, 24*(9), 10768-10802. doi:10.1007/s10668-021-01883-2

[2] Abdolazimi, O., Salehi Esfandarani, M., Salehi, M., & Shishebori, D. (2020). Robust design of a multi-objective closed-loop supply chain by integrating on-time delivery, cost, and environmental aspects, case study of a Tire Factory. *Journal of Cleaner Production, 264*, 121566. doi:10.1016/j.jclepro.2020.121566

[3] Ahmed, W., & Sarkar, B. (2018). Impact of carbon emissions in a sustainable supply chain management for a second generation biofuel. *Journal of Cleaner Production, 186*, 807-820. doi:10.1016/j.jclepro.2018.02.289

[4] Alimohammadi Ardekani, M. J. A. i. I. E. (2022). A Multi-Objective Supply Chain Configuration for the Oil Industry under Uncertainty. *56*(1), 15-41. doi:10.22059/aie.2022.335295.1816

[5] Atabaki, M. S., Mohammadi, M., & Naderi, B. (2020). New robust optimization models for closed-loop supply chain of durable products: Towards a circular economy. *Computers & Industrial Engineering, 146*, 106520. doi:10.1016/j.cie.2020.106520

[6] Babaeinesami, A., Tohidi, H. & Seyedaliakbar, S.M. (2020): Designing a data-driven leagile sustainable closed-loop supply chain network, International Journal of Management Science and Engineering Management, DOI: 10.1080/17509653.2020.1811794

[7] Ben-Daya, M., Hassini, E., & Bahroun, Z. (2017). Internet of things and supply chain management: a literature review. *International Journal of Production Research, 57*(15-16), 4719-4742. doi:10.1080/00207543.2017.1402140

[8] Calatayud, A., Mangan, J., & Christopher, M. (2019). The self-thinking supply chain. *Supply Chain Management: An International Journal, 24*(1), 22-38. doi:10.1108/scm-03-2018-0136

[9] Chang, C.-T., & Chang, C.-C. (2000). A linearization method for mixed 0–1 polynomial programs. *Computers & Operations Research, 27*(10), 1005-1016. doi:10.1016/s0305-0548(99)00071-4

[10] Chen, C., Zhang, G., shi, J., & Xia, Y. (2019). Remanufacturing Network Design for Dual-Channel Closed-Loop Supply Chain. *Procedia CIRP, 83*, 479-484. doi:10.1016/j.procir.2019.04.132

[11] Deb, K., & Jain, H. (2014). An Evolutionary Many-Objective Optimization Algorithm Using Reference-Point-Based Nondominated Sorting Approach, Part I: Solving Problems With Box Constraints. *IEEE Transactions on Evolutionary Computation, 18*(4), 577-601. doi:10.1109/tevc.2013.2281535

[12] Demirel, N. Ö., & Gökçen, H. (2008). A mixed integer programming model for remanufacturing in reverse logistics environment. *The International Journal of Advanced Manufacturing Technology, 39*(11-12), 1197-1206. doi:10.1007/s00170-007-1290-7

[13] Deutch, J. M., & Lester, R. K. (2004). *Making technology work: applications in energy and the environment*: Cambridge University Press.

[14] Ebrahimi, S. B., & Bagheri, E. (2022). A multi-objective formulation for the closed-loop plastic supply chain under uncertainty. *Operational Research*, 1-44. doi:10.1007/s12351-022-00716-y

[15] Fang, I., Lin, W. J. A. i. P. E., & Management. (2021). A multi-objective optimal decision model for a green closed-loop supply chain under uncertainty: A real industrial case study. *16*(2), 161-172. doi:0.14743/apem2021.2.391

[16] Fathollahi-Fard, A. M., Dulebenets, M. A., Hajiaghaei–Keshteli, M., Tavakkoli-Moghaddam, R., Safaeian, M., & Mirzahosseinian, H. (2021). Two hybrid meta-heuristic algorithms for a dual-channel closed-loop supply chain network design problem in the tire industry under uncertainty. *Advanced Engineering Informatics, 50*, 101418. doi:10.1016/j.aei.2021.101418

[17] Feng, L., Govindan, K., & Li, C. (2017). Strategic planning: Design and coordination for dual-recycling channel reverse supply chain considering consumer behavior. *European Journal of Operational Research, 260*(2), 601-612. doi:10.1016/j.ejor.2016.12.050

[18] Gharye Mirzaei, M., Goodarzian, F., Maddah, S., Abraham, A., & Abdelkareim Gabralla, L. (2022). Investigating a Dual-Channel Network in a Sustainable Closed-Loop Supply Chain Considering Energy Sources and Consumption Tax. *Sensors (Basel), 22*(9), 3547. doi:10.3390/s22093547

[19] Gholami, F., Paydar, M. M., Hajiaghaei-Keshteli, M., & Cheraghalipour, A. (2019). A multi-objective robust supply chain design considering reliability. *Journal of Industrial and Production Engineering, 36*(6), 385-400. doi:10.1080/21681015.2019.1658136

[20] Gholizadeh, H., & Fazlollahtabar, H. (2020). Robust optimization and modified genetic algorithm for a closed loop green supply chain under uncertainty: Case study in melting industry. *Computers & Industrial Engineering, 147*, 106653. doi:10.1016/j.cie.2020.106653

[21] Gholizadeh, H., Jahani, H., Abareshi, A., & Goh, M. (2021). Sustainable closed-loop supply chain for dairy industry with robust and heuristic optimization. *Computers & Industrial Engineering, 157*, 107324. doi:10.1016/j.cie.2021.107324

[22] Gholizadeh, H., Tajdin, A., & Javadian, N. (2018). A closed-loop supply chain robust optimization for disposable appliances. *Neural Computing and Applications, 32*(8), 3967-3985. doi:10.1007/s00521-018-3847-9

[23] Glassmeyer, S. T., Hinchey, E. K., Boehme, S. E., Daughton, C. G., Ruhoy, I. S., Conerly, O., . . . Thompson, V. G. (2009). Disposal practices for unwanted residential medications in the United States. *Environ Int, 35*(3), 566-572. doi:10.1016/j.envint.2008.10.007

[24] Hajipour, V., Tavana, M., Di Caprio, D., Akhgar, M., & Jabbari, Y. (2019). An optimization model for traceable closed-loop supply chain networks. *Applied Mathematical Modelling, 71*, 673-699. doi:10.1016/j.apm.2019.03.007

[25] Ho, C.-J. (2007). Evaluating the impact of operating environments on MRP system nervousness. *International Journal of Production Research, 27*(7), 1115-1135. doi:10.1080/00207548908942611

[26] Honarvar, M., & Ahmadi Yazdi, A. J. I. J. o. E. (2015). A Two Stage Stochastic Programming Model of the Price Decision Problem in the Dual-channel Closed-loop Supply Chain. *International Journal of Engineering, 28*(5 (B)), 738-745. doi:10.5829/idosi.ije.2015.28.05b.12

[27] Hong, X., Wang, Z., Wang, D., & Zhang, H. (2013). Decision models of closed-loop supply chain with remanufacturing under hybrid dual-channel collection. *The International Journal of Advanced Manufacturing Technology, 68*(5-8), 1851-1865. doi:10.1007/s00170-013-4982-1

[28] Huang, S.-M., & Su, J. C. P. (2013). Impact of product proliferation on the reverse supply chain. *Omega, 41*(3), 626-639. doi:10.1016/j.omega.2012.08.003

[29] Kaoud, E., Abdel-Aal, M. A. M., Sakaguchi, T., & Uchiyama, N. (2020). Design and Optimization of the Dual-Channel Closed Loop Supply Chain with E-Commerce. *Sustainability, 12*(23), 10117. doi:10.3390/su122310117

[30] Khorshidvand, B., Soleimani, H., Sibdari, S., & Mehdi Seyyed Esfahani, M. (2021). A hybrid modeling approach for green and sustainable closed-loop supply chain considering price, advertisement and uncertain demands. *Computers & Industrial Engineering, 157*, 107326. doi:10.1016/j.cie.2021.107326

[31] Kim, T., & Glock, C. H. (2014). On the use of RFID in the management of reusable containers in closed-loop supply chains under stochastic container return quantities. *Transportation Research Part E: Logistics and Transportation Review, 64*, 12-27. doi:10.1016/j.tre.2014.01.011

[32] Liu, Z., Anderson, T. D., & Cruz, J. M. (2012). Consumer environmental awareness and competition in two-stage supply chains. *European Journal of Operational Research, 218*(3), 602-613. doi:10.1016/j.ejor.2011.11.027

[33] Ma, R., Yao, L., Jin, M., Ren, P., & Lv, Z. (2016). Robust environmental closed-loop supply chain design under uncertainty. *Chaos, Solitons & Fractals, 89*, 195-202. doi:10.1016/j.chaos.2015.10.028

[34] Mavrotas, G. (2009). Effective implementation of the ε-constraint method in Multi-Objective Mathematical Programming problems. *Applied Mathematics and Computation, 213*(2), 455-465. doi:10.1016/j.amc.2009.03.037

[35] Mavrotas, G., Figueira, J. R., & Antoniadis, A. J. J. o. G. O. (2011). Using the idea of expanded core for the exact solution of bi-objective multi-dimensional knapsack problems. *49*(4), 589-606.

[36] Mavrotas, G. J. A. m., & computation. (2009). Effective implementation of the ε-constraint method in multi-objective mathematical programming problems. *213*(2), 455-465.

[37] Mirjalili, S., Saremi, S., Mirjalili, S. M., & Coelho, L. d. S. J. E. S. w. A. (2016). Multi-objective grey wolf optimizer: a novel algorithm for multi-criterion optimization. *47*, 106-119.

[38] Mirzaee, H., Samarghandi, H., & Willoughby, K. J. a. p. a. (2022). A robust optimization model for green supplier selection and order allocation in a closed-loop supply chain considering cap-and-trade mechanism. doi:10.48550/arXiv.2208.02926

[39] Mulvey, J. M., Vanderbei, R. J., & Zenios, S. A. (1995). Robust Optimization of Large-Scale Systems. *Operations Research, 43*(2), 264-281. doi:10.1287/opre.43.2.264

[40] Nezhad, F. J., Taghizadeh-Yazdi, M., Dahooie, J. H., Babgohari, A. Z., & Sajadi, S. M. J. B. F. J. (2021). Designing a new mathematical model for optimising a multi-product RFID-based closed-loop food supply chain with a green entrepreneurial orientation.

[41] Nikas, A., Fountoulakis, A., Forouli, A., & Doukas, H. (2020). A robust augmented ε-constraint method (AUGMECON-R) for finding exact solutions of multi-objective linear programming problems. *Operational Research, 22*(2), 1291-1332. doi:10.1007/s12351-020-00574-6

[42] Niranjan, T., Parthiban, P., Sundaram, K., & Jeyaganesan, P. N. (2019). Designing a omnichannel closed loop green supply chain network adapting preferences of rational customers. *Sādhanā, 44*(3), 1-10. doi:10.1007/s12046-018-1038-0

[43] Niranjan, T., Thanigaivelan, R., & Singaravel, B. (2022). Analysis of a Multi-channel Closed Loop Green Supply Chain Using Modified Particle Swarm Optimization Algorithm. In *Innovations in Mechanical Engineering* (pp. 797-807): Springer.

[44] Paydar, M. M., Babaveisi, V., & Safaei, A. S. (2017). An engine oil closed-loop supply chain design considering collection risk. *Computers & Chemical Engineering, 104*, 38-55. doi:10.1016/j.compchemeng.2017.04.005

[45] Persson, M., Sabelström, E., & Gunnarsson, B. J. E. i. (2009). Handling of unused prescription drugs—knowledge, behaviour and attitude among Swedish people. *35*(5), 771-774. doi:10.1016/j.envint.2008.10.002

[46] Rahmani, D., Hasan Abadi, M. Q., & Hosseininezhad, S. J. (2020). Joint decision on product greenness strategies and pricing in a dual-channel supply chain: A robust possibilistic approach. *Journal of Cleaner Production, 256*, 120437. doi:10.1016/j.jclepro.2020.120437

[47] Ramezani, M., Kimiagari, A. M., Karimi, B., & Hejazi, T. H. (2014). Closed-loop supply chain network design under a fuzzy environment. *Knowledge-Based Systems, 59*, 108-120. doi:10.1016/j.knosys.2014.01.016

[48] Ross, D. F., Weston, F. S., & Stephen, W. (2010). *Introduction to supply chain management technologies*: Crc Press.

[49] Sadeghi Rad, R., & Nahavandi, N. (2018). A novel multi-objective optimization model for integrated problem of green closed loop supply chain network design and quantity discount. *Journal of Cleaner Production, 196*, 1549-1565. doi:10.1016/j.jclepro.2018.06.034

[50] Safaei, A. S., Roozbeh, A., & Paydar, M. M. (2017). A robust optimization model for the design of a cardboard closed-loop supply chain. *Journal of Cleaner Production, 166*, 1154-1168. doi:10.1016/j.jclepro.2017.08.085

[51] Saffari, H., Makui, A., Mahmoodian, V., Pishvaee, M. S. J. J. o. I., & Engineering, S. (2015). Multi-objective robust optimization model for social responsible closed-loop supply chain solved by non-dominated sorting genetic algorithm. *8*(3), 42-58.

[52] Şakar, C. T., & Köksalan, M. J. J. o. G. O. (2013). A stochastic programming approach to multicriteria portfolio optimization. *57*(2), 299-314.

[53] Samuel, C. N., Venkatadri, U., Diallo, C., & Khatab, A. (2020). Robust closed-loop supply chain design with presorting, return quality and carbon emission considerations. *Journal of Cleaner Production, 247*, 119086. doi:10.1016/j.jclepro.2019.119086

[54] Soleimani, H., Chhetri, P., Fathollahi-Fard, A. M., Mirzapour Al-e-Hashem, S. M. J., & Shahparvari, S. (2022). Sustainable closed-loop supply chain with energy efficiency: Lagrangian relaxation, reformulations and heuristics. *Annals of Operations Research*, 1-26. doi:10.1007/s10479-022-04661-z

[55] Tohidi, H., Jabbari, M.M., (2012). “Decision role in management to increase effectiveness of an organization”. Procedia-social and behavioral sciences, 32: 825-828. doi:10.1016/j.sbspro.2011.12.149

[56] Tong, A. Y., Peake, B. M., & Braund, R. (2011). Disposal practices for unused medications around the world. *Environ Int, 37*(1), 292-298. doi:10.1016/j.envint.2010.10.002

[57] Vidal, C. J., & Goetschalckx, M. (2001). A global supply chain model with transfer pricing and transportation cost allocation. *European Journal of Operational Research, 129*(1), 134-158. doi:10.1016/s0377-2217(99)00431-2

[58] Wang, Z.-B., Wang, Y.-Y., & Wang, J.-C. (2016). Optimal distribution channel strategy for new and remanufactured products. *Electronic Commerce Research, 16*(2), 269-295. doi:10.1007/s10660-016-9225-8

[59] Yan, W., Xiong, Y., Xiong, Z., & Guo, N. (2015). Bricks vs. clicks: Which is better for marketing remanufactured products? *European Journal of Operational Research, 242*(2), 434-444. doi:10.1016/j.ejor.2014.10.023

[60] Yu, Y., Han, X., & Hu, G. (2016). Optimal production for manufacturers considering consumer environmental awareness and green subsidies. *International Journal of Production Economics, 182*, 397-408. doi:10.1016/j.ijpe.2016.09.014

[61] Zelbst, P. J., Green, K. W., Sower, V. E., & Bond, P. L. (2019). The impact of RFID, IIoT, and Blockchain technologies on supply chain transparency. *Journal of Manufacturing Technology Management, 31*(3), 441-457. doi:10.1108/jmtm-03-2019-0118

[62] Zhou, Z., Hu, F., & Xiao, D. (2020). Optimal pricing strategy of competing manufacturers under carbon policy and consumer environmental awareness. *Computers & Industrial Engineering, 150*, 106918. doi:10.1016/j.cie.2020.106918