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Abstract: The increasing pressure and intensity of world competition in business environments, which is ever-changing, has doubled the necessity of proper reactions by industrial manufacturing organisations and companies. Therefore, this paper proposes a novel design of a closed-loop supply chain with multiple forms of product distribution and collection that aim to maximise profit and social responsibility while minimising delays in delivery and environmental pollution. The proposed model uses two indices, local employment and the number of jobs created, to show the performance of the function of social responsibility. Further, by mentioning pricing and greenness levels for the products in the paper, we formulate customer demands dependent on the price and greenness of the products. Also, RFID technology is considered for every vehicle to reduce time lags during transportation. Besides, the modelling is performed according to a possibilistic mean-absolute deviation approach due to the uncertain nature of some parameters. Eventually, the augmented ε-constraint method is utilised to solve and its validation. The results revealed that the proposed model could provide efficient decisions that can be a suitable tool for managers and experts, and it can have extensive application, particularly from a strategic perspective. [Received: 9 October 2022; Accepted: 6 April 2023]

Keywords: multi-channel; pricing; RFID; possibilistic programming.

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1 Introduction

The consciousness of society regarding environmental, social, and scarcity of natural resources challenges are increased. Hence, businesses encounter increasing pressure from customers, policymakers, and eco-friendly groups. It leads to the particular attention of all society's circles (such as consumers, governments, and companies) to the environmental and social impacts of their activities and adopting and implementing the closed-loop supply chain (CLSC) logical activities with sustainable features. Consequently, they can maintain their position, obtain competitive benefits, and meet the wants and expectations of customers (Kaoud et al., 2020; Zenouz et al., 2021). Implementing sustainable CLSC requires performing various activities like the forward flow of management of materials and final goods from suppliers to final consumers and the reverse flow of consumer goods from final consumers to recycling centres considering three sustainability pillars (economic, environmental, and social) (Zenouz et al., 2021; Barbosa-Póvoa et al., 2018), which lead to production cost reduction, gradual enhancement of producer income, input resources reduction, environmental pollution reduction, energy-wasting, creating social benefits, and rapid development of economic sources (Kaoud et al., 2020; Tombido and Baihaqi, 2021). The end-of-use (EoU) or end-of-life (EoL) is one of the effective solutions for product control (Taleizadeh et al., 2019). Accordingly, scholars have been particular attention to the design of sustainable CLSC networks.

Considering the several sale and distribution channels in the supply chain (SC) network is another critical point that attracted in recent years. The growth of internet technology and the need to gather more products from end-users have led complies to utilise more than one channel in CLSC. Increasing numbers of people have begun to purchase online; however, some prefer traditional purchasing ways. Accordingly, many factories consider different channels for selling products to customers (Rahmani et al., 2020). In addition, the collection of EoU products and their re-production can not only ameliorate the use of resources and create a desirable social image but also can be profitable and increase competitiveness. Thereby, the need to gather more products from end-users led companies to utilise more than one collection channel in CLSC (Hong et al., 2013).

The survey findings revealed that the more delivery options were offered, the higher was the likelihood of online buying in 2018. Nearly 90% of Russian customers chose the availability of several delivery options as the most attractive delivery feature. Moreover, 85% of the respondents mentioned the next day delivery and real-time tracking as positive incentives to place an order online (https://www.statista.com).

The SCs have become larger, more scattered, and more complex than previous. Consequently, there is a need for transparency, sharing information in time to facilitate in-time programming, control, and coordination of the SC. In this regard, one of the critical internet of things (IoT) technologies, called RFID, helps SC (Ben-Daya et al., 2019; Ellis et al., 2015). Such tools can have a critical role in agility and accelerating activities in the SC and create value in the organisation. In 2020, the industry that used RFID technology the most in South Korea was the agricultural sector. It was followed by the transportation and storage sector (https://www.statista.com).

Recently, a continuous trend has been seen in which consumers tend to change their purchasing habits, change their loyalty to their brand, and pay a premium for eco-friendly products. Pursuant to a CarbonTrust examination in 2011, approximately 56% of customers will be loyal to a brand if they know it is trying to decrease its carbon footprint. Moreover, 21% of customers choose products with carbon labels, even if those products are more expensive. Therefore, considering the relationship between green products and customer demand is vital. Given the current business space, price decisions also are critical in designing the SC network, apart from environmental decisions, since the interface between a firm and its customers is the price (Wang and Wan, 2022).

Moreover, uncertainty is a crucial concern in the dynamic and complex SC environment and creates a great challenge for supply chain management (SCM). For this purpose, assessing the uncertainties is critical.

This paper presents a revised and more comprehensive design of multi-channel CLSCs based on the following:

Accordingly, in summary, the innovations of the proposed model are as follows:

1 Designing green sustainable multi-channel CLSC with dependent demand to price and greenness that its objective is to maximise profit and social responsibility and minimise the delay in delivery time and environmental pollution. The provided model here uses two indicators of local employment and the number of created careers to demonstrate the performance of the social responsibility function. The nearness of employees that live near the workplace leads to local employment. Since local employment reduces the distance travelled, the carbon footprint due to transportation will reduce; consequently, the environmental performance will improve.

2 Considering the RFID technologies for transportation states: the utilisation of RFID technology in the SC leads to acceleration of information transactions, reduction of time lag in transportation, electronic toll collection without a stop on highways, in-time delivery of orders, more rapid transportation, elimination of inaccurate transportations, etc. Consequently, it can shorten the chain of order and better the agility and responsitivity of the chain.

3 Considering many channels of direct and indirect collection and distribution: the utilisation of direct and indirect distribution channels leads to industries and companies accessing sections of customers that they can not access through traditional retailer channels. Moreover, considering direct and indirect may not only improve the usage of resources and creates a desired social vision but also may have profit, enhance competitiveness, and help the improvement of environmental responsibility.

4 To face the uncertainty of the parameters, the model is modelled according to the possibilistic mean-absolute deviation approach.

Thereby, the structure of the present study is as follows to provide the proposed model. The related literature is described in Section 2. Section 3 defines the parameters and variables of the proposed model, and the presented model defines based on them. Section 4 will mention the solving method. Section 5 allocates to expressing numerical tests and analysis of results. The conclusion, Management insight and recommendations for future studies are presented in Section 6.

2 Literature review

Based on the issue of the presented paper, the related literature has been briefly examined in three main sections: sustainability, greenness and pricing in SC, IOT in the CLSC, and design of two or multi-channel CLSC.

2.1 Sustainability, greenness and pricing in SC

Consumers have enhanced the acceptance of green products and sustainable lifestyles, along with continuous development of the global economy and promotion of consumption structure. Today, SC networks that traditionally operate without considering environmental issues such as greenhouse gas emissions are unable to survive in these competitive markets (Diabat and Al-Salem, 2015; Heidari et al., 2022). Hence, studies have combined environmental considerations with traditional SCs. Moreover, pricing decisions in markets and SC is vital as customers select the products based on many logic. Hence, pricing can be a crucial factor that affects purchasing behaviour (Raza, 2021). Wang et al. (2011) developed an optimisation model that has been considered to determine the potential suppliers, decision-making regarding dedication, and the way of product distribution. They aimed to minimise carbon emissions and reduce costs through a multi-objective mathematical. Ameknassi et al. (2016) designed a SC problem aiming to reduce network costs and entire greenhouse gas emissions under uncertain environments. They utilised clustering to assessment the factors of emission for insourcing and outsourcing. Reddy et al. (2018) presented a reverse supply network to minimise all company' costs, such as related costs with emission, operation, and transportation. Moreover, this SC network has been considered greenhouse gases and the selection of vehicle types for transportation. Yang and Xiao (2017) investigated the impact of government involvement on pricing and green strategies in green product SCs under fuzzy uncertainty. In the context of Pakistan manufacturing companies, Khan and Qianli (2017) investigated the impact of five determinants of green SC practices; including green manufacture, green purchase, green information systems, cooperation with customers, and ecological design; on organisational performance. According to their findings, green and sustainable methods in logistics have a significant correlation with renewable energy consumption (REC).

Palacio et al. (2018) designed a multi-product, two-objective, and multi-echelon distribution/production SC. Minimising all costs of the SC and the entire CO_2 emissions due to production and transportation is the purpose of the mathematical model. Qiu et al. (2019) use mixed-integer linear programming (MILP) to formulate the multi-product green sc network with restrictions on carbon price uncertainty. Hence, they developed a designing model of a green SC network under p-robust criteria and used the scenario tree method for uncertainty modelling. Heydari et al. (2019) addressed optimal and coordinated decision-making for a two-channel three-layer SC in their study and compared the open and close triple decision-making structures. Zhen et al. (2019) expanded a two-objective optimisation model focusing on two objectives (CO_2 emissions and the entire operational costs). The decisions regarding environmental levels and effective factors on facilities' capacity levels have been included in the proposed model. Moreover, the scenario-based method was used to indicate the uncertain demand in the random programming model. Mohebalizadehgashti et al. (2020) suggested a multi-objective mixed-integer linear programming (MOMILP) for configuring a meat SC network. The purpose of this model is to minimise the entire cost of the SC and the entire carbon emissions due to transportation simultaneously and maximise the utilisation of facilities' capacity. In a study, Saha and Nielsen (2020) examined the pricing decisions of substitutable products in two competing SCs in the presence of an online channel. Each SC consists of one manufacturer and an exclusive retailer, and one of the manufacturers distributes products through the online channel. According to the results, in the absence of an online channel, cooperation with the respective retailer can lead to a higher SC profit. Nonetheless, if a manufacturer opens an online channel, cooperation with competing manufacturers could lead to higher SC profits. Under vertical integration, total SC profits may be lower compared to a scenario where members of each SC remain independent. Consumers should also pay more for products. Khorshidvand et al. (2021) configured a combined nonlinear programming model for designing sustainable and green CLSC networks to optimise mended product pricing. Initially, decisions about price, greenness, and advertising are adopted; then, profit maximisation and CO_2 emissions minimisation are addressed. They developed a nonlinear programming model based on the sensitivity of the rate of return to green quality and maximum tolerance of customers (while the demands are uncertain). Moreover, they utilised a robust optimisation model to overcome uncertain demands. Furthermore, they applied a Lagrangian Relaxation algorithm according to large-scale cases to solve the model. Boronoos et al. (2020) introduced a green CLSC network. Their model aims to reduce the entire cost and the entire CO_2 emissions. A flexible and robust possibilistic approach was presented to address the model's parameters' soft restrictions and inherent uncertainties. Yu and Rehman Khan (2021) designed a financing system for the green agricultural product sc based on agricultural product suppliers as financiers and residents as investors. Shoaeinaeini et al. (2021) provided a MINLP for designing a green CLSC, including combined factories, combined collection centres, customer regions, secondary markets, and disposal centres. Their model determined the rate of return for each customer region according to consumers' environmental consciousness and presented optimal purchasing prices for returned products to ensure a smooth reverse flow. The cost functions and specific prices for green products have been proposed considering the environmental consciousness levels and optimal green levels. Moreover, the government subsidy has been considered a financial motivation for producers to make the model more real and challenging. Wang and Wan (2022) provided a multi-period and multi-product green SC considering dependent demand to price and greenness of product. Their model aims to maximise SC profit and minimise the whole carbon emissions for designing the CLSC network. The scenario-based method and random programming are used to control the uncertainty. The results revealed the efficiency and effectiveness of their proposed approach. Kaviyani-Charati et al. (2022) developed two bi-level Stackelberg models (BLSM) under non-agile conditions and in the presence of strategic customers. It considered retailers and manufacturers competing with each other in a sequential game to determine optimal production, and order quantities and prices with and without agile abilities. In a study, Liu et al. (2022) examined the pricing decisions and coordinating mechanisms of the green product SC under the behavioural pricing model. Boskabadi et al. (2022) provided a fuzzy mathematical model for designing a distribution network problem in a multi-product, multi-period, multi-layer, multi-factory, and multi-retailer green SC system. Minimising the entire cost of the network, maximising net per capita profit for each human resource, and reducing CO_2 emissions throughout the network are three purposes of this model. Paul and Giri (2022) examined government involvement in a three-level SC, including a producer and a retailer. The government is a high-level member that tries to reduce environmental effects based on the number of carbon emissions during the process of production. The government controls the chain by tax levying from retailers (directly paid by the customer) and payment of subsidy or penalty for the producer. Through subsidies, the government encourages producers to reduce carbon emissions. Moreover, the government tries to create government net revenue (GNR) with taxation. The GNR is created by tax levying from the retailer on sold products and penalising producers with transaction prices for greenhouse gas addition amounts. The retailing price is determined based on the sales price, tax, and green level. They aimed to determine optimal pricing levels, becoming green, and tax amounts that should be taken. Rehman Khan et al. (2022) developed a conceptual model based on the resource-based view (RBV) and technology, organisation, and environment (TOE) theories. Further, they validated data from 375 professionals in the manufacturing industry have been collected for experiments through simple random sampling. Results regarding the relationship between sustainable development strategy (SDS), eco-innovation (EI), digital transformation (DT), smart technologies (ST), and sustainable supply chain performance (SSCP) demonstrate a positive strong association between SDS, EI, DT, ST, and SSCP. The results showed, even if organisations manage to implement SDS and EI without DT and ST, they cannot achieve SSCP. Therefore, managers were advised that managers to use DT and ST to ensure sustainable performance and assist sustainable development goals. Since not all customers tend to buy green products, Heidari et al. (2021) explored a multi-objective hub location problem in their study to design a sustainable SC network based on customer segmentation. In their study, customers fall into three categories: green customers, incompatible customers, and indifferent customers in terms of their need type. Akbari-Kasgari et al. (2022) designed a multi-objective sustainable CLSC for a copper network, in which backup suppliers are used as a resilience strategy to decrease the impacts of earthquakes on mining operations. It aims to maximise sc, minimise water consumption and air pollutants, and maximise social desirability by considering security and unemployment rates. Gholian-Jouybari et al. (2023) first explored an agricultural food sc network under marketing methods by developing a stochastic multi-objective programming model to effectively enhance three main aspects of sustainability. A convex robust optimisation technique is used to address the uncertainty of farm production capacity and saffron demand in the sc. The effectiveness of their proposed mathematical model was certified by a case study on saffron business through the LP-metric method. A metaheuristic method comprising a modified Keshtel Algorithm was adapted to address the NP-hardness of the problems.

2.2 IoT in CLSC

The way to ensure the reduction of SC risk for the SC's members and final consumers is provided through transparency. In addition to risk reduction, transparency allows the SC members to track products to ensure accuracy (Zelbst et al., 2019). The following studies can be pointed out for the carried out research regarding the utilisation of IoT in the CLSC.

Kim and Glock (2014) utilised an RFID system (in which transportation was performed from supplier to retailer) in a CLSC to manage the container. They used the implementation of the RFID technology in the return path to support tracking the container position in the SC. Hajipour et al. (2019) presented a CLSC problem considering RFID technology to minimise the objectives of performing work time, social, and environmental simultaneously as a single target. They used random programming to encounter uncertainty. Jahanshahee Nezhad et al. (2022) addressed optimising profit and environmental targets in multi-product RFID closed-loop chains, tending to green entrepreneurship in the food industry. Shambayati et al. (2022) provided a multi-period and multi-product virtual closed-loop supply chain (VCLSC) using IoT. Their proposed model considers profit-maximising. For this purpose, related costs to virtualisation (such as security, energy consumption, call, and IoT facility), along with SC common costs, are considered in the model. Fuzzy demand has been considered according to demand fluctuations, and the model is solved using the grey wolf algorithm and firefly algorithm. Prajapati et al. (2022) created a framework for a VCLSC that they are based on blockchain and IoT novel technologies, sustainable concepts, and a circular economy. This paper combined the normal and virtual SCs in a unique structure. Its main target is to maximise total expected revenue and minimise the VCLSC network cost. Sadri et al. (2022) presented a new approach in the field of port performance evaluation based on the components of greenness and intelligence. The evaluations are conducted in two stages in the form of networks. In this study, the performance of 11 ports in Iran was evaluated based on the network data envelopment analysis approach in two stages of greenness and intelligence over four years. According to the results, only 5% of ports have intelligence and greenness standards.

2.3 Designing a two/multi-channel CLSC

In a paper, Hong et al. (2013) addressed the selection of a proper reverse channel for the producer to gather EoU products from customers. They supposed that a producer has three reverse combined collection channels:

a producer and retailer gather EoU products simultaneously

b producer contracts with a retailer and a third party to collect EOU products

c the producer and third-party gathers the EoU products simultaneously.

Based on their obtained results, the ceteris paribus, the producer's most effective reverse channel configuration, relates to the situation (a). Moreover, the (a) approach is better than the single-channel collection approach under similar conditions. Honarvar and Ahmadi Yazdi (2015) proposed a new model to design forward or reverse integrated logistics based on the pricing policy in direct and indirect sales channels. Their suggested model includes producers, disposal centres, distributors, and final users. In their model, the optimal amounts of sales prices in direct and indirect sale channels can obtain considering forward and reverse flow simultaneously. Sun and Xiao (2018) considered the government replacement subsidy policy to analyse the channel selection of the automotive parts remanufacturer. Further, they constructed two-channel models in which the automotive parts remanufacturer may select supplier or competitor modes. Next, they discussed the impacts of the government replacement subsidy policy on the strategy of channel selection through the game theory method. They ascertained that the scope of the automotive parts remanufacturer's net cost is extremely vital, determined by the government replacement price, subsidy, and expenses of the remanufacturer. Within a certain range, subsidies and replacement prices for consumers have a positive impact on environmental protection. Taleizadeh et al. (2018) addressed the problem of the joint determination of the optimal selling price, refund policy, and quality level for complementary products in online purchasing. The demand for each product is assumed to be a function of price, refund, and quality level. Additionally, the return policy is also a function of refund and quality level, and the return quantity of the products is influenced by the return quantity of the other product. Moon et al. (2018) revealed the impact of online sales on centralised and decentralised dual-channel SCs. The structure of their SC consists of two different types of distribution channels, through which manufacturers sell their products. The analytical study indicates that the manufacturer always earns maximum profit in decentralised distribution systems without coordination among the channel members. Nevertheless, the manufacturer earns more benefits from using centralised distribution systems under certain conditions if the SC is coordinated. Chen et al. (2019) proposed a MINLP to model the reproduction network for two-channel CLSC. Niranjan et al. (2019) provided a model for an integrated multi-channel CLSC network problem that includes the selection of an entity that meets the customer needs for the Omni channel in various periods. Reduction of the entire imposed costs by the customer, the entire performed costs in SC implementation, and total pollution emissions due to product transportation among various chain steps are the purposes of this model. Mondal et al. (2019) examined pricing and green being of green products strategies in reverse and forward two-channel green CLSC. Kaoud et al. (2020) suggested a mathematical model that combined electronic commerce with multi-echelon CLSC, with the time horizon of multi-period programming in production and recycled centres considering dual channels. Rahmani et al. (2020) provided a mathematical model based on a two-channel system to design a green SC. The first sales channel is based on a traditional retailer purchasing system. However, customers purchase the products from the factory directly in the second channel. Moreover, government subsidy policies were applied to motivate management to produce green products. Furthermore, a robust possibilistic optimisation approach is utilised due to the uncertain nature of some parameters. Besides, they proposed an invasive weed optimisation (IWO) algorithm for obtaining efficient solutions. Fathollahi-Fard et al. (2021) designed a two-channel CLSC network under uncertainty for the tire industry. A fuzzy approach (known as the Jimenez method) was utilised to deal with the problem's uncertain parameters (for instance, price and demand). Besides, presenting two novel combined meta-heuristic algorithms with new procedures is another main innovation of theirs. In other words, they have hybridised the red deer algorithm and whale optimisation with the genetics algorithm (GA) and simulated annealing (SA), respectively, to improve the intensification and diversity of phases. Mirzagoltabar et al. (2021) designed a sustainable two-channel CLSC network with new products for the lighting industry. Gharye Mirzaei et al. (2022) proposed a two-channel network of sustainable CLSC for rice, considering energy resources and tax on consumption. They formulated a MILP model to optimise the cost, amount of pollutants, and the number of created career opportunities in their SC network under cost, demand, and supply uncertainties. Besides, fuzzy logic is utilised to deal with uncertainty in their study. Experimental outcomes reveal that up to 19% of electricity utilisation has been saved by constructing solar panels and producing energy from rice waste. Soleimani et al. (2022) designed a sustainable CLSC considering energy utilisation, in which distribution centres play the warehouse and collection centres' role. Their Model objectives are profit, Energy consumption, and the number of created career opportunities. Besides, they addressed real restrictions for location, allocation, and inventory decisions in a CLSC framework. Niranjan et al. (2022) considered the concept of several channels for the traditional offline sc of battery makers in the south section of India. Their main purpose is to develop a mathematical model for multi-channel CLSC considering economic and environmental objectives. Chaotic initial population generation PSO with levy flight distribution is used to solve the problem. The outcomes indicated that the provided results of modified PSO (MPSO) are better. Kazancoglu et al. (2022) designed a multi-objective optimisation model for a green two-channel CLSC network that carries out the economic and environmental objectives for network flow optimisation. The main purpose of creating the MILP model is to assess the echelons' optimal selection and transportation alternatives' optimal selection among these levels in a CLSC network. This CLSC network includes the structure of electronic commerce channels based on environmental and economic considerations. Kouchaki Tajani et al. (2023) designed a robust green multi-channel sustainable SC by considering pricing strategy and subsidising policies. In a study, Kouchaki Tajani et al. (2022) designed a robust, agile, sustainable, CLSC network with different sales channels. In this study, a scenario-based stochastic optimisation technique was applied to address the uncertainty of the parameters. In addition, due to the multi-objective nature of the model and its validation and exact solution in small dimensions, a robust augmented ε-constraint optimisation method was used to optimise the balance between the objectives. Since the problem is of Np-hard class, two NSGA-II and MOPSO algorithms were applied to solve the model in larger dimensions. Given the significance of supply chain network design (SCND) in today's economy and recent advancements and technologies regarding current trends such as blockchain, the IOT, and the circular economy, Fathollahi-Fard et al. (2022) examined more than 57 manuscripts recently submitted to a journal, and excellent manuscripts related to the subject were accepted.

3 Research gap

Reviewing the literature regarding multi-channel CLSC design determines that no study simultaneously focuses on greenness and sustainability concepts. Besides, no study considers sensitive demand to price and greenness for a multi-channel, multi-product, and multi-period CLSC. In other words, many relevant researches have taken into account environmental issues (such as carbon emissions) in manufacturing or transportation operations. At the same time, Low attention has been paid to sensitive customers' wants for the environment.

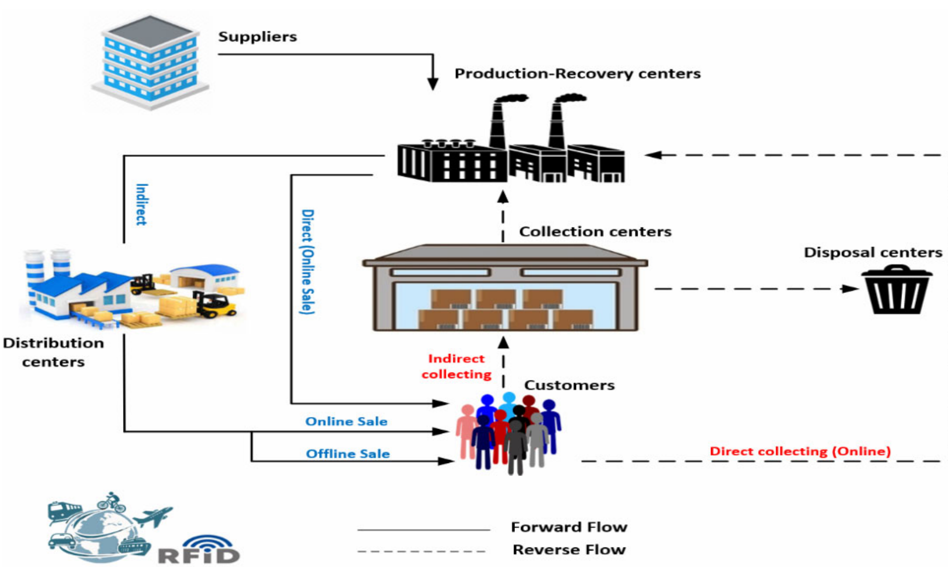
It should be known that bypassing the traditional methods and utilising novel technologies in economic and industrial fields predispose more productivity. It can be seen that the utilisation of RFID technologies in CLSC management literature is still limited according to the assessing the performed studies.

4 Description of problem

In the forward direction, the supplier provides the raw materials and is sent to Production-recovery centres for new product production. The newly produced products can be accommodated to customers directly (from production-recovery centres) and indirectly (from distribution centres in both online and traditional sales ways). In the reverse direction, the returned products from customers (they were purchased online and direct (online) forms) are dispatch to production-recovery centres directly (online). Moreover, customers' returned products (that are purchased offline) are gathered indirectly through collection centres. After performing the test and examination, recoverable products are sent to production-recovery centres, and non-recoverable products are dispatch to disposal centres. The schematic of the proposed SC is indicated in Figure 1.

In this chain, one transportation technology must be considered for each of the existing communications between chain members. For this purpose, several predefined transportation technologies have been examined, each of which establishes communication among different members of the chain. These transportation technologies differ in terms of cost and delivery time; the management of the sc should select the most proper of them in terms of economics and minimise the entire delay of delivery time. These technologies are utilised in the transport fleet. Their responsibility is the observation of customers' orders in the online form, and they try to minimise the distance between order sending and receiving by integrating the information with their origin and destination. Overall, the utilisation of RFID technology can enhance the availability time of vehicles. Thereby, various types of RFID technologies are used in this study, and the SCM must make a design regarding their selection. The selection of RFID technology type influences two targets, a minimum of the entire delay of delivery time and economical. In terms of agility, higher RFID technologies lead to reduced delivery times (improvement of agility). On the other hand, the higher RFID technologies have higher initial costs. Consequently, it weakens the economic performance of the chain.

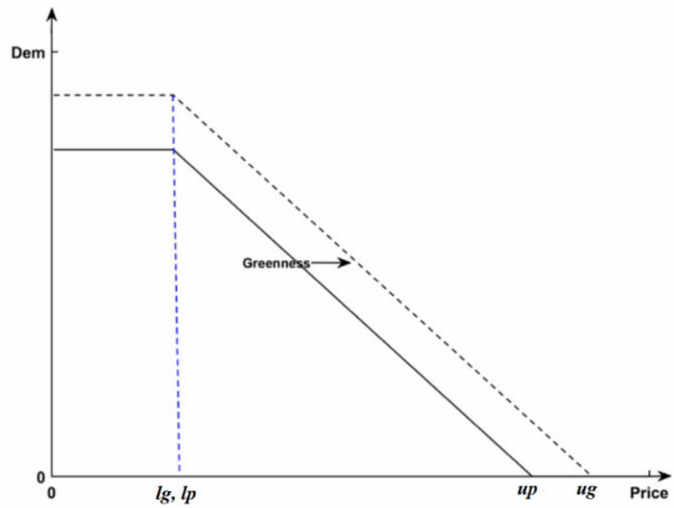
Figure 1 The schematic of the proposed multi-channel CLSC (see online version for colours)



This paper assumes that each customer's demand in each region is sensitive to the green being of product and product price. The product's green being is also relevant to the production's carbon emissions. A binary linear function has been considered to determine the sensitivity of customer demand. As it has been indicated in Figure 2, the solid line demonstrates the demand-price linear function when the greenness of the product is fixed. Moreover, the dotted line demonstrates the change in customer demand when the green being of the product increases. Both the maximum product demand and a maximum affordable price are partly enhanced by the enhancement of the green being of the product.

The sensitive response function to price and greenness can take into account as logit response-price function modification, which is proper for forecasting consumer behaviour when the purchasing tendency of customers is easily affected by small changes in products. The linear response-price function has been used to demonstrate the relationship between price and customer demands. The explained demand-price relation has an extensive range of applications in SCM. For example, this relation can be applied in companies where other competitor companies provide similar products without fundamental differences for the similar target market. Nevertheless, the continuous price and environment-sensitive response function cause the mixed integer nonlinear programming problem due to the nonlinearity of the model's objective function. The utilisation of discretisation is essential for converting the MINLP model to applicable MILP since solving the MINLP problem is hard and time-consuming (Wang and Wan, 2022).

Figure 2 Demand linear demand (see online version for colours)



Here, several levels of prices and the green being of the product are considered in each period to reform the demand function. Where e and τ are the set of products and periods, respectively. Therefore, the relationship between the price of the product, greenness, and customer demand is obtained in each period given the maximum amount of (up) and (ug) and a minimum amount of (lp) and (lg) of the product price and greenness as follows:

$$DEM_{ceb_1b_2}^{\tau} = \left(\alpha \frac{ug_{ce}^{\tau} - GR_{ceb_2}^{\tau}}{ug_{ce}^{\tau} - lg_{ce}^{\tau}} + (1-\alpha) \frac{up_{ce}^{\tau} - PR_{ceb_1}^{\tau}}{up_{ce}^{\tau} - lp_{ce}^{\tau}} D_{ce}^{\tau} \right) \quad \forall c, e, b_1, b_2, \tau \tag{1}$$

In which $PR_{ceb_1}^{\tau}$ and $GR_{ceb_2}^{\tau}$ indicate product price in the price level of b_1, product greenness level of b_2 for product e, customer c, and period d, respectively. α and D_{ce}^{τ} demonstrate the impact indicator of product green being and basis demand for a customer region, respectively. The price of the product in the level of b_1 and product green being in the level of b_2 is calculated as follows utilising the discretisation method:

$$PR_{ceb_1}^{\tau} = lp_{ce}^{\tau} + \frac{b_1 - 1}{|b_1| - 1}\left(up_{ce}^{\tau} - lp_{ce}^{\tau}\right) \quad \forall c, e, \tau, b_1 \tag{2}$$

$$GR_{ceb_2}^{\tau} = lg_{ce}^{\tau} + \frac{b_2 - 1}{|b_2| - 1}\left(ug_{ce}^{\tau} - lg_{ce}^{\tau}\right) \quad \forall c, e, \tau, b_2 \tag{3}$$

In more detail, the assumptions of this research can be expressed as follows:

- The examined multi-channel CLSC is multi-echelon, multi-product, multi-period, and multi-objective.
- In this chain, the locations of suppliers and customers are fixed and well-known.
- A set of potential points exist that can be one of the production-recovery, distribution, and collection and disposal centres.
- Each customer's demand can meet from one of the direct (production-recovery centres)/indirect (distribution centres) sale channels.
- The distribution centres (indirect channels) can sell in traditional and online forms.
- The returned products can send both directly (from customers to production-recovery centres) and indirectly (from customers to collection centres and then to production-recovery and disposal centres).
- Products sent to customers directly and indirectly (online) can be returned indirectly (from customers to production-recovery centres).
- Products sent to customers indirectly (offline) can be returned indirectly through collection centres to production-recovery centres.
- The capacity of all production-recovery, distribution, collection and disposal centres is limited.
- The capacity of transportation between different levels of the chain is limited.
- Different types of RFID systems for various transportation systems are usable.
- The demand for each product for each customer in each period depends on product price and the green being of the product.
- The employees should commute from their habitat to the workplace.

4.1 The proposed multi-channel CLSC under uncertainty

In this section, the proposed multi-channel CLSC under uncertainty (basis demand, the cost of raw materials purchasing unit, the cost of product production, and the cost of product recovery unit) are provided as follows:

Indices

f indices of suppliers' fixed locations $f = 1, 2, \ldots, F$

i indices of production-recovery centres' potential locations $i = 1, 2, \ldots, I$

p indices of potential locations for distribution and collection centres $p = 1, 2, \ldots, P$

c indices of customers' fixed locations $c = 1, 2, \ldots, C$

k indices of product disposal potential centres $k = 1, 2, \ldots, K$

e indices of products $e = 1, 2, \ldots, E$

a indices of raw materials $a = 1, 2, \ldots, A$

l indices of vehicles $l = 1, 2, \ldots, L$

τ indices of periods $\tau = 1, 2, \ldots, T$

u indices of employees' residential regions $u = 1, 2, \ldots, U$

o indices of considered RFID technology type in the transportation system $o = 1, 2, \ldots, O$

b_1 indices of price levels $b_1 = 1, 2, \ldots, B_1$

b_2 indices of greenness levels $b_2 = 1, 2, \ldots, B_2$.

Parameters

$\tilde{D}^{\tau}_{ce}$ the customer c's basis demand for product e in period τ

$PR^{\tau}_{ceb_1b_2}$ the sale price of each product e's unit to customer c with the price level of b_1 and greenness level of b_2 in period τ

$IT^{\tau}_{eb_2}$ investment in technology for producing product e with the greenness level of b_2 in period τ

$\tilde{FC}^{\tau}_{fa}$ the unit cost of purchasing raw material m from supplier f in period τ

$\tilde{MC}^{\tau}_{ieb_2}$ the unit cost of producing product e with the greenness level of b_2 in the production-recovery centre i in period τ

OC^{τ}_{pe} the cost of the operational unit on product e in distribution centre p in period τ

IC^{τ}_{pe} the cost of inspection unit and collection of returned product e in collection centre p in period τ

$\tilde{RC}^{\tau}_{ieb_2}$ the cost of recovery unit of the product e in the production-recovery centre i with the level of green being of b_2 in period τ

DC^{τ}_{ke} the cost of disposal unit of product e in disposal centre of k in period τ

HC^{τ}_{pe} the cost of inventory maintaining unit of the product e in collection centre p in period τ

FF^{τ}_{p} the fixed cost of the selection of a supplier f in the period τ

$FX^{\tau}_{ib_2}$ the fixed cost of open being or operating the production-recovery centre i with green being level of b_2 in period τ

FY^{τ}_{p} the fixed cost of open being of the distribution centre p in period τ

FZ^{τ}_{p} the fixed cost of open being of collection centre p in period τ

FV^{τ}_{k} the fixed cost of being open of disposal centre k in period τ

CF_{fa}^{τ}	the capacity of supplier f for raw material a in period τ
$CX_{ib_2}^{\tau}$	production capacity in the production-recovery centre i with the level of green being of b_2 in period τ
CY_{p}^{τ}	the capacity of the distribution centre p in period τ
CZ_{p}^{τ}	the capacity of collection centre p in period τ
$CR_{ib_2}^{\tau}$	the capacity of the production-recovery centre i for recovery of the returned products with the level of green being of b_2 in period τ
CV_{k}^{τ}	the capacity of disposal centre k in period τ
CFI_{fial}^{τ}	the cost of the transmission unit of carried raw material a from supplier f to production-recovery centre i with transportation system l in period τ
CIP_{ipel}^{τ}	the cost of the transmission unit of carried product e from production-recovery centre i to distribution centre p with transportation system l in period τ
CIC_{icel}^{τ}	the cost of the transmission unit of carried product e in the production-recovery centre i to customer c with transportation system l in period τ
CPC_{pcel}^{τ}	the cost of the transmission unit of carried product e from distribution centre p to customer c with transportation system l in period t
$CEPC_{pcel}^{\tau}$	the cost of the transmission unit for online shopping of carried product e from distribution centre e to customer c with transportation system l in period τ
CCP_{cpel}^{τ}	the cost of the transmission unit of carried returned product e from customer c to collection centre p with transportation system l in period τ
CCI_{ciel}^{τ}	the cost of the transmission unit of carried returned product e from customer c to production-recovery centre i with transportation system l in period τ
CPI_{piel}^{τ}	the cost of the transmission unit of carried inspected product e from collection centre p to production-recovery centre i for recovery with transportation system l in period τ
CPK_{pkel}^{τ}	the cost of the transmission unit of carried product e from collection centre p to disposal centre k with transportation system l in period τ
EFI_{fial}^{τ}	obtained environmental pollution from the transmission of raw material a from supplier f to production-recovery centre i with transportation system l in period τ

EIP_{ipel}^{τ} obtained environmental pollution from the transmission of product *e* from the production-recovery centre *I* to distribution centre *p* with transportation system *l* in period τ

EIC_{icel}^{τ} obtained environmental pollution from transmission product *e* from production-recovery centre *i* to customer *c* with transportation system *l* in period τ

EPC_{pcel}^{τ} obtained environmental pollution from the transmission product *e* from distribution centre *p* to customer *c* with transportation system *l* in period τ

ECP_{cpel}^{τ} obtained environmental pollution from the transmission product *e* from customer *c* to collection centre *p* with transportation system *l* in period τ

ECI_{ciel}^{τ} obtained environmental pollution from the transmission of product *e* from customer *c* to production-recovery centre *i* with the transportation system *l* in period τ

EPI_{piel}^{τ} obtained environmental pollution from the transmission of product *e* from collection centre *p* to production-recovery centre *i* for recovery with transportation system *l* in period τ

EPK_{pkel}^{τ} obtained environmental pollution from the transmission of product *e* from collection centre *p* to disposal centre *k* for evacuating with transportation system *l* in period τ

$EP_{ieb_1}^{\tau}$ obtained environmental pollution from each production unit of product *e* in the production-recovery centre *i* with green being level b_2 in period τ

TFI_{fialo}^{τ} delivery time of raw material a from supplier *f* to production-recovery centre *i* with transportation system *l* with RFID technology of type *o*, in period τ

TIP_{ipelo}^{τ} delivery time of product *e* from production-recovery centre *i* to distribution centre *p* with transportation system *l* with RFID technology of type *o*, in period τ

TIC_{icelo}^{τ} delivery time of product *e* from production-recovery centre *i* to customer *c* with transportation system *l* with RFID technology of type *o* in period τ

TPC_{pcelo}^{τ} delivery time of product *e* from distribution centre *p* to customer *c* with transportation system *l* with RFID technology of type *o* in period τ

$TEPC_{pcelo}^{\tau}$ delivery time of product *e* from distribution centre *p* to customer *c* for online shopping with transportation system *l* with RFID technology of type *o* in period τ

$TEPC_{pcelo}^{\tau}$ delivery time of product *e* from customer *c* to collection centre *p* with transportation system *l* with RFID technology of type *o* in period τ

TCI^{τ}_{cielo} delivery time of product e from customer c to production-recovery centre i with transportation system l with RFID technology of type o in period τ

TPI^{τ}_{pielo} delivery time of product e from collection centre p to production-recovery centre i to recovery with transportation system l with RFID technology of type o in period τ

TPK^{τ}_{pkelo} delivery time of product e from collection centre p to disposal centre k with transportation system l with RFID technology of type o in period τ

$TFI^{\tau}_{ialo}{}'$ expected delivery time of production-recovery centre i for receiving raw material a from suppliers f with transportation system l with RFID technology of type o in period τ

$TIP^{\tau}_{pelo}{}'$ expected delivery time of distribution centre p for receiving product e from production-recovery centre i with transportation system l with RFID technology of type o in period τ

$TIC^{\tau}_{celo}{}'$ customer c's expected delivery time for receiving product e from production-recovery centre i with transportation system l with RFID technology of type o in period τ

$TPC^{\tau}_{celo}{}'$ customer c's expected delivery time for receiving product e from distribution centre p with transportation system l with RFID technology of type o in period τ

$TEPC^{\tau}_{celo}{}'$ customer c's expected delivery time for receiving product e from distribution centre p for online sale with transportation system l with RFID technology of type o in period τ

$TCP^{\tau}_{pelo}{}'$ expected delivery time of collection centre p for receiving product e from customer c with transportation system l with RFID technology of type o in period τ

$TCI^{\tau}_{ielo}{}'$ expected delivery time of production-recovery centre i for receiving product e from customer c with transportation system l with RFID technology of type o in period τ

$TPI^{\tau}_{ielo}{}'$ expected delivery time of production-recovery centre i for receiving product e from collection centre p with transportation system l with RFID technology of type o in period τ

$TPK^{\tau}_{kelo}{}'$ expected delivery time of disposal centre k for receiving product e from collection centre p with transportation system l with RFID technology of type o in period τ

FFI^{τ}_{filo} fixed cost of utilising RFID technology of type o for sending from supplier f to production-recovery centre i with transportation system l with RFID technology of type o in period τ

FIP^{τ}_{iplo} fixed cost of utilising RFID technology of type o for sending from production-recovery centre i to distribution centre p with transportation system l in period τ

FIC^{τ}_{iclo} fixed cost of utilising RFID technology of type o for sending from production-recovery centre i to customer c with transportation system l in period τ

FPC^{τ}_{pclo} fixed cost of utilising RFID technology of type o for sending from distribution centre p to customer c with transportation system l in period τ

FCP^{τ}_{cplo} fixed cost of utilising RFID technology of type o for sending from customer to collection centre p with transportation system l in period τ

FCI^{τ}_{cilo} fixed cost of utilising RFID technology of type o for sending from customer c to production-recovery centre i with transportation system l in period τ

FPI^{τ}_{pilo} fixed cost of utilising RFID technology of type o for sending from collection centre p to production-recovery centre i for recovery with transportation system l in period τ

FPK^{τ}_{pklo} fixed cost of utilising RFID technology of type o for sending from collection centre p to disposal centre k with transportation system l in period τ

$TCAFI^{\tau}_{fil}$ transportation capacity for sending from supplier f to production-recovery centre i with transportation system l in period τ

$TCAIP^{\tau}_{ipl}$ transportation capacity for sending from production-recovery centre i to distribution centre p with transportation system l in period τ

$TCAIC^{\tau}_{icl}$ transportation capacity for sending from production-recovery centre i to customer c with transportation system l in period τ

$TCAPC^{\tau}_{pcl}$ transportation capacity for sending from distribution centre p to customer c with transportation system l in period τ

$TCAEPC^{\tau}_{pcl}$ transportation capacity for sending of online shopping from distribution centre p to customer c with transportation system l in period τ

$TCACP^{\tau}_{cpl}$ transportation capacity for sending from customer c to collection centre p with transportation system l in period τ

$TCACI^{\tau}_{cil}$ transportation capacity from sending from customer c to production-recovery centre i with transportation system l in period τ

$TCAPI^{\tau}_{pil}$ transportation capacity for sending from collection centre p to the production-recovery centre I with transportation system l in period τ

$TCAPK^{\tau}_{pkl}$ transportation capacity for sending from collection centre p to disposal centre k with transportation system l in period τ

NE^{τ}_{u} the number of exiting employees in residential region u

$WX^{\tau}_{ib_2}$ the number of career opportunities per activity of production-recovery centre i with green being level b_2 in period τ

WY^{τ}_{p} the number of career opportunities per activity of a distribution centre in point p in period τ

WZ^{τ}_{p} the career opportunities per activity of a collection centre in point p in period τ

WV^{τ}_{k} the number of career opportunities per activity of a disposal centre in point k in period τ

$DX^{\tau}_{ib_2}$ economic development value per activity of production-recovery centre i with green being level b_2 in period τ

DY^{τ}_{p} economic development value per activity of a distribution centre in point p in period τ

DZ^{τ}_{p} economic development value per activity of a collection centre in point p in period τ

DV^{τ}_{k} economic development value per activity of a disposal centre in point k in period τ

$LX^{\tau}_{ib_2}$ the numbers of lost days for injuring of workers per activity of production-recovery centre i with green being level b_2 in period τ

LY^{τ}_{p} the numbers of lost days for injuring of workers per activity of a distribution centre in point p in period τ

LZ^{τ}_{p} the numbers of lost days for injuring of workers per activity of a collection centre in point p in period τ

LV^{τ}_{k} the number of lost days for injuring of workers per activity of a disposal centre in point k in period τ

HX_i the required person-hour number for distributing the product in a production-recovery centre i

HY_P the required person-hour number for distributing the product in a distribution centre p

HZ_P	the required person-hour number for distributing the product in a collection centre p
BH	working capacity of an employee in a day
n_{ae}	rate of utilising of raw material in the production of product e
m_e	rate of utilising of capacity in each production unit of product e
$mcont_\tau$	the possible value of contract's order with collection centre p to production-recovery centre i in period τ
RR_e	return rate of EOU products e
RXi_e	recovery rate of EOU products e
RXd_e	disposal rate of EOU products e
β	weight coefficient of importance (responding) of the forward chain
$1-\beta$	weight coefficient of importance (response) of return chain
ς_1	descaling coefficient of created careers number in social responsibility index
ς_2	descaling coefficient of economic development value in social responsibility index
ς_3	descaling coefficient of lost working days in social responsibility index
BM	a very large number
$M1^\tau_{ialo}=\left\{b \middle| TFI^\tau_{fialo}\geq TFI^\tau_{ialo}{}'\right\}$	centres of supplier f that have a delay in delivery time of raw material to production-recovery centres i in period τ
$M2^\tau_{pelo}=\left\{i \middle| TIP^\tau_{ipelo}\geq TIP^\tau_{pelo}{}'\right\}$	centres of production-recovery i that have a delay in delivery time to distribution centres p in period τ
$M3^\tau_{ceo}=\left\{i \middle| TIC^\tau_{icelo}\geq TIC^\tau_{celo}{}'\right\}$	centres of production-recovery i that have a delay in delivery time to customers c in period τ
$M4^\tau_{celo}=\left\{p \middle| TPC^\tau_{pcelo}\geq TPC^\tau_{celo}{}'\right\}$	distribution centres p that has a delay in delivery time to customers c in period τ
$M5^\tau_{celo}=\left\{p \middle| TEPC^\tau_{pcelo}\geq TEPC^\tau_{celo}{}'\right\}$	distribution centres p that has a delay in delivery time to customers c in period τ
$M6^\tau_{pelo}=\left\{c \middle| TCP^\tau_{cpelo}\geq TCP^\tau_{pelo}{}'\right\}$	customers c that has a delay in delivery time to collection centres p in period τ
$M7^\tau_{ielo}=\left\{c \middle| TCI^\tau_{cielo}\geq TCI^\tau_{ielo}{}'\right\}$	customers c that has a delay in delivery time in production-recovery centres p in period τ

$M8_{ielo}^{\tau} = \left\{ p \middle| TPI_{pielo}^{\tau} \geq TPI_{ielo}^{\tau}{}' \right\}$ collection centres p that has a delay in delivery time to production-recovery centres i in period τ

$M9_{kelo}^{\tau} = \left\{ p \middle| TPK_{pkelo}^{\tau} \geq TPk_{kelo}^{\tau}{}' \right\}$ collection centres p that has a delay in delivery time to disposal centres k in period τ.

Decision variables

QFI_{fial}^{τ} the amount of raw material a from supplier f to production-recovery centre i with transportation system l in period τ

QIP_{ipel}^{τ} the amount of carried product e from production-recovery centre i to distribution centre p with transportation system l in period τ

QIC_{icel}^{τ} the amount of carried product e from production-recovery centre i to customer c with transportation system l in period τ

QPC_{pcel}^{τ} the amount of carried product e from distribution centre p to customer c with transportation system l in period τ

$QEPC_{pcel}^{\tau}$ the amount of product e in carried online shopping from distribution centre p to customer c with transportation system l in period τ

QCP_{cpel}^{τ} the amount of carried return products e from customer c to collection centre p with transportation system l in period τ

QCI_{ciel}^{τ} the amount of carried return products e from customer c to production-recovery centre i with transportation system l in period τ

QPI_{piel}^{τ} the amount of carried type-e products from collection centre p to production-recovery centre i with transportation system l in period τ

QPK_{pkel}^{τ} the amount of carried type-e recovery products from collection centre p to disposal centre k with transportation system l in period τ

PEX_{ui} the number of resident employees in residential region u and work in production-recovery location i

PEY_{up} the number of resident employees in residential region u and work in distribution location p

PEZ_{up} the number of resident employees in residential region u and work in collection location p

INV_{pe}^{τ} inventory of product e in distribution centre p in the end of the period τ

OS_{cpe}^{τ} 1 if meet the request of customer c through online shopping by distribution centre j in the period τ, otherwise 0

$W_{b_1 b_2}^{\tau}$ 1 if the price level b_1 and green being level b_2 are selected in the period τ, otherwise 0

H_{ie}^{τ} the amount of produced product e in the production-recovery centre i in period

F_{f}^{τ} 1 if is selected as supplier f in the period τ; otherwise, 0

$X_{ib_2}^{\tau}$ 1 if is an open production-recovery centre i with green being level b_2 in the period τ, otherwise 0

Y_{p}^{τ} 1 if is an open distribution centre in point p in the period τ; otherwise, 0

Z_{p}^{τ} 1 if is an open collection centre in point p in the period τ; otherwise, 0

V_{k}^{τ} 1 if is an open disposal centre in point k in the period τ; otherwise, 0

OFI_{filo}^{τ} 1 if is transportation system l with RFID technology of type o and connect supplier f to production-recovery centre i in the period τ, otherwise 0

OIP_{iplo}^{τ} 1 if is transportation system l with RFID technology of type o and connect production-recovery centre i and distribution centre p in the period τ, otherwise 0

OIC_{iclo}^{τ} 1 if is transportation system l with RFID technology of type o and connect production-recovery centre i to customer c in the period τ, otherwise 0

OPC_{pclo}^{τ} 1 if is transportation system l with RFID technology of type o and connect distribution centre p to customer c in the period τ, otherwise 0

$OEPC_{pclo}^{\tau}$ 1 if is transportation system l with RFID technology of type o and connect distribution centre p to customer c for online shopping in the period τ, otherwise 0

OCP_{cplo}^{τ} 1 if is transportation system l with RFID technology of type o and connect customer c to collection centre p in the period τ, otherwise 0

OCI_{cilo}^{τ} 1 if is transportation system l with RFID technology of type o and connect customer c to production-recovery centre i in the period τ, otherwise 0

OPI_{pilo}^{τ} 1 if is transportation system l with RFID technology of type o, and collection centre p to production-recovery centre i in the period τ, otherwise 0

OPK_{pklo}^{τ} 1 if is transportation system l with RFID technology of type o and connect collection centre p to disposal centre k in the period τ, otherwise 0.

Objective functions

$$Max\ Objective1 = \sum_{\tau} \left(Income_{\tau} - cost_{\tau} \right) \tag{4}$$

$$Income_{\tau} = \sum_{ceb_1b_2} PR^{\tau}_{ceb_1b_2} D^{\tau}_{ce} W^{\tau}_{b_1b_2} \tag{4.1}$$

$$\begin{aligned}
Cost_{\tau} = & \sum_{i,b_2} FX^{\tau}_{ib_2}\left(X^{\tau}_{ib_2} - X^{\tau-1}_{ib_2}\right) + \sum_{p} FY^{\tau}_{p}\left(Y^{\tau}_{p} - Y^{\tau-1}_{p}\right) + \sum_{p} FZ^{\tau}_{p}\left(Z^{\tau}_{p} - Z^{\tau-1}_{p}\right) \\
& + \sum_{p} FV^{\tau}_{k}\left(V^{\tau}_{k} - V^{\tau-1}_{k}\right) + \sum_{b} FB^{\tau}_{b} B^{\tau}_{b} + \sum_{eb_1b_2} IT^{\tau}_{eb_2} W^{\tau}_{b_1b_2} \\
& + \Bigg(\sum_{f,i,a,l} QFI^{\tau}_{fial} FC^{\tau}_{fa} + \sum_{i,p,e,b_2,l} QIP^{\tau}_{ipel} MC^{\tau}_{ieb_2} + \sum_{i,c,e,b_2,l} QIC^{\tau}_{iceb_2l} MC^{\tau}_{ieb_2} \\
& + \sum_{p,c,e,l} \left(QPC^{\tau}_{pcel} + QEPC^{\tau}_{pcel}\right) OC^{\tau}_{pe} + \sum_{c,p,e,l} QCP^{\tau}_{cpel} IC^{\tau}_{pe} \\
& + \sum_{p,i,e,b_2,l} QPI^{\tau}_{piel} RC^{\tau}_{ieb_2} + \sum_{c,i,e,b_2,l} QCI^{\tau}_{cpel} RC^{\tau}_{ieb_2} \\
& + \sum_{p,k,e,l} QPK^{\tau}_{pkel} DC^{\tau}_{ke} + \sum_{p}\sum_{e} INV^{\tau}_{pe} HC^{\tau}_{pe} \Bigg) \\
& + \Bigg(\sum_{f,i,a,l} QFI^{\tau}_{fial} CFI^{\tau}_{fial} + \sum_{i,p,e,l} QIP^{\tau}_{ipel} CIP^{\tau}_{ipel} + \sum_{i,c,e,l} QIC^{\tau}_{icel} CIC^{\tau}_{icel} \\
& + \sum_{i,c,e,l} QPC^{\tau}_{pcel} CPC^{\tau}_{pcel} + \sum_{p,c,e,l} QEPC^{\tau}_{pcel} CEPC^{\tau}_{pcel} + \sum_{c,p,e,l} QCP^{\tau}_{cpel} CCP^{\tau}_{cpel} \\
& + \sum_{p,i,e,l} QPI^{\tau}_{piel} CPI^{\tau}_{piel} + \sum_{c,i,e,l} QCI^{\tau}_{ciel} CCI^{\tau}_{ciel} + \sum_{p,k,e,l} QPK^{\tau}_{pkel} CPK^{\tau}_{pkel} \Bigg) \\
& + \Bigg(\sum_{f,i,l,o} OFI^{\tau}_{filo} FFI^{\tau}_{filo} + \sum_{i,p,l,o} OIP^{\tau}_{iplo} FIP^{\tau}_{iplo} + \sum_{i,c,l,o} OIC^{\tau}_{iclo} FIC^{\tau}_{iclo} \\
& + \sum_{p,c,l,o} \left(OPC^{\tau}_{pclo} + OEPC^{\tau}_{pclo}\right) FPC^{\tau}_{pclo} + \sum_{c,p,l,o} OCP^{\tau}_{cplo} FCP^{\tau}_{cplo} \\
& + \sum_{p,i,l,o} OPI^{\tau}_{pilo} FPI^{\tau}_{pilo} + \sum_{c,i,l,o} OCI^{\tau}_{cilo} FCI^{\tau}_{cilo} + \sum_{p,k,l,o} OPK^{\tau}_{pklo} FPK^{\tau}_{pklo} \Bigg)
\end{aligned} \tag{4.2}$$

$$
\begin{aligned}
Min\ Objective2 = \beta \Bigg(& \Bigg(\sum_{f \in M1^{\tau}_{ialo}, i,a,l,o,\tau} OFI^{\tau}_{filo} \left(TFI^{\tau}_{fialo} - TFI^{\tau}_{ialo}{}' \right) \\
& + \sum_{i \in M2^{\tau}_{pelo}, p,e,l,o,\tau} OIP^{\tau}_{iplo} \left(TIP^{\tau}_{ipelo} - TIC^{\tau}_{celo}{}' \right) + \sum_{i \in M3^{\tau}_{celo}, c,e,l,o,\tau} OIC^{\tau}_{iclo} \left(TIC^{\tau}_{icelo} - TIP^{\tau}_{pelo}{}' \right) \\
& + \sum_{p \in M4^{\tau}_{celo}, c,e,l,o,\tau} OPC^{\tau}_{celo} \left(TPC^{\tau}_{pcelo} - TPC^{\tau}_{celo}{}' \right) \\
& + \sum_{p \in M5^{\tau}_{celo}, c,e,l,o,\tau} OEPC^{\tau}_{pclo} \left(TEPC^{\tau}_{pcelo} - TEPC^{\tau}_{celo}{}' \right) \Bigg) \\
& + (1-\beta) \Bigg(\sum_{c \in M6^{\tau}_{pelo}, p,e,l,o,\tau} OCP^{\tau}_{cplo} \left(TCP^{\tau}_{cpelo} - TCP^{\tau}_{pelo}{}' \right) \\
& + \sum_{p \in M7^{\tau}_{ielo}, i,e,l,o,\tau} OPI^{\tau}_{pilo} \left(TPI^{\tau}_{pielo} - TPI^{\tau}_{ielo}{}' \right) \\
& + \sum_{c \in M8^{\tau}_{ielo}, i,e,l,o,\tau} OCI^{\tau}_{cilo} \left(TCI^{\tau}_{cielo} - TCI^{\tau}_{ielo}{}' \right) \\
& + \sum_{p \in M9^{\tau}_{kel}, k,e,l,o,\tau} OPK^{\tau}_{pklo} \left(TPK^{\tau}_{pkelo} - TPK^{\tau}_{kelo}{}' \right) \Bigg)
\end{aligned}
\tag{5}
$$

$$
\begin{aligned}
Max\ Objective3 = \varsigma_1 \Bigg(& \Bigg(\sum_{e,i} PEX^{\tau}_{ei} + \sum_{e,p} PEY^{\tau}_{ep} + \sum_{e,i} PEZ^{\tau}_{ep} \Bigg) \\
& + \Bigg(\sum_{i,b_2,\tau} WX^{\tau}_{ib_2} X^{\tau}_{ib_2} + \sum_{p,\tau} WY^{\tau}_{p} Y^{\tau}_{p} + \sum_{p,\tau} WZ^{\tau}_{p} Z^{\tau}_{p} + \sum_{k,\tau} WV^{\tau}_{k} V^{\tau}_{k} \Bigg) \Bigg) \\
& + \varsigma_2 \Bigg(\sum_{i,b_2,\tau} LX^{\tau}_{ib_2} X^{\tau}_{ib_2} + \sum_{p,\tau} LY^{\tau}_{p} Y^{\tau}_{p} + \sum_{p,\tau} LZ^{\tau}_{p} Z^{\tau}_{p} + \sum_{k,\tau} LV^{\tau}_{k} V^{\tau}_{k} \Bigg) \\
& - \varsigma_3 \Bigg(\sum_{i,h,\tau} DX^{\tau}_{ib_2} X^{\tau}_{ib_2} + \sum_{p,\tau} DY^{\tau}_{p} Y^{\tau}_{p} + \sum_{p,\tau} DZ^{\tau}_{p} Z^{\tau}_{p} + \sum_{k,\tau} DV^{\tau}_{k} V^{\tau}_{k} \Bigg)
\end{aligned}
\tag{6}
$$

$$
\begin{aligned}
Min\ Objective4 = & \sum_{f,i,a,l,\tau} QFI^{\tau}_{fial} EFI^{\tau}_{fial} + \sum_{i,p,e,l,h,\tau} QIP^{\tau}_{ipel} EIP^{\tau}_{ipel} \\
& + \sum_{i,c,e,l,h,\tau} QIC^{\tau}_{icel} EIC^{\tau}_{icel} + \sum_{p,c,e,l,\tau} \left(QPC^{\tau}_{pcel} + QEPC^{\tau}_{pcel} \right) EPC^{\tau}_{pcel} \\
& + \sum_{c,p,e,l,\tau} QCP^{\tau}_{cpel} ECP^{\tau}_{cpel} + \sum_{p,i,e,l,\tau} QPI^{\tau}_{piel} EPI^{\tau}_{piel} \\
& + \sum_{c,i,e,l,\tau} QCI^{\tau}_{ciel} ECI^{\tau}_{ciel} + \sum_{p,k,e,l,\tau} QPK^{\tau}_{pkel} EPK^{\tau}_{pkel} + \sum_{i,e,b_1,\tau} EP^{\tau}_{ieb_1} H^{\tau}_{ie}
\end{aligned}
\tag{7}
$$

Relation (4) is the first objective function which is the maximisation of the total profit of the chain and is obtained from the difference between incomes from costs. Relation (4.1) determines income obtained from selling products in each period. Relation (4.2) denotes the entire sc costs. These costs consist the fixed costs of being open of each centre and the fixed cost of selecting a supplier, the cost of purchasing raw materials from suppliers, products production costs in collection centres, the costs of products recovery in production and recovery centres, disposal costs, the cost of maintaining inventory in collection centres, the costs of transmission by different transportation systems in the SC, and eventually fixed cost of utilising various RFID systems for transportation systems of the SC.

Relation (5) is the second objective function and demonstrates the minimisation of the total delay of the delivery time in the forward and return chains addressed in the model to consider customer satisfaction.

Relation (6) is the third objective function and maximises the SC's social responsibility. This objective consists of three sections. The total created careers are calculated in the first section. It indicates the created career opportunities due to the establishment of production-recovery, distribution, and collection centres; it is expressed in the form of total fixed and variable employees' number that works in every centre. The first term indicates the variable employees and the second term indicates the fixed employees in production-recovery, distribution and collection centres.

The total obtained economic development from the SC is calculated in the second section. The total lost working days due to workers' injuries in the SC has been calculated in the third section. The social responsibility chain is the result of these three mentioned sections.

Relation (7) is the fourth objective function and expresses the minimising of the entire SC pollution. The mentioned pollution is created based on the transmission of products between various centres. Furthermore, it considers the pollution from the Production-recovery centre.

Constraints

$$\sum_{p,e,l} n_{ae} QIP^{\tau}_{ijel} + \sum_{c,e,l} n_{ae} QIC^{\tau}_{icel} = \sum_{f,l} QFI^{\tau}_{fial} + \sum_{p,e,l} n_{ae} QPI^{\tau}_{jiel} + \sum_{c,e,l} n_{ae} QCI^{\tau}_{ciel} \quad \forall i, a, \tau \tag{8}$$

Limitation (8): it indicates that the total input flows to each production-recovery from the entire suppliers, collection centres, and customers are equal to output flow from the production-recovery centre in each period.

$$INV^{\tau-1}_{pe} + \sum_{i,l} QIP^{\tau}_{ipel} = INV^{\tau}_{pe} + \sum_{c,l} QPC^{\tau}_{pcel} + \sum_{c,l} QEPC^{\tau}_{pcel} \quad \forall p, e, \tau \tag{9}$$

Limitation (9): it expresses that the entire entered flow to each distribution centre from the production-recovery centre and remaining inventory from previous periods are equal to the total carried flow from distributors in online and offline forms to customers and remaining inventory in the current period for each product and each period.

$$\sum_{p,l} QPC^{\tau}_{pcel} + \sum_{p,l} QEPC^{\tau}_{pcel} + \sum_{i,l} QIC^{\tau}_{icel} = DEM^{\tau}_{ceb_1b_2} \qquad \forall c, e, \tau \tag{10}$$

Limitation (10): it ensures that output flow from distribution centres (in online and offline forms) and production-recovery centres to each customer must be met through the customer's demand for each product in each period.

$$\sum_{p,l} QCP^{\tau}_{cpel} = \sum_{p,l} QPC^{\tau}_{pcel} RR_e \qquad \forall c, e, \tau \tag{11}$$

Limitation (11): it expresses the relationship between allocated product amount to customers and returned value from customers to collection centres.

$$\sum_{i,l} QPI_{piel}^{\tau} = \sum_{c,l} QCP_{cpel}^{\tau} RXi_e \qquad \forall p, e, \tau \tag{12}$$

Limitation (12): it expresses that the entire amount of sent products from collection centres to production-recovery centres (that is recoverable) is equal to the ratio of entered flow to collection centres from customers for each product in each period.

$$\sum_{k,l} QPK_{pkel}^{\tau} = \sum_{c,l} QCP_{cpel}^{\tau} RXd_e \qquad \forall p, e, \tau \tag{13}$$

Limitation (13): it expresses that the entire amount of sent products from collection centres to disposal centres equals the ratio of entered flow to collection centres from customers for each product in each period.

$$\sum_{k,l} QPK_{pkel}^{\tau} + \sum_{i,l} QPI_{piel}^{\tau} = \sum_{c,l} QCP_{cpel}^{\tau} \qquad \forall p, e, \tau \tag{14}$$

Limitation (14): it expresses that the entire received value from customers equals the total sent amount to each production-recovery centre for recovery and to each disposal centre for disposal.

$$\sum_{c} QPC_{pcel}^{\tau} + \sum_{c} QEPC_{pcel}^{\tau} = \sum_{i} QIP_{ipel}^{\tau} \qquad \forall p, e, l, \tau \tag{15}$$

Limitation (15): it expresses that the total amount of sent products from production-recovery centres to distribution centres equals the total indirect sent amount to customers in online and offline forms.

$$\left(\sum_{P} QEPC_{pcel}^{\tau} + \sum_{i} QIC_{icel}^{\tau}\right) 0.40 = \sum_{c} QCI_{ciel}^{\tau} \qquad \forall p, e, l, \tau \tag{16}$$

Limitation (16): it expresses that the entire amount of returned sent products from customers to production-recovery centres equals the percentage of products entered flow from production-recovery centres (online) and online distribution centres to customers.

$$\sum_{i,l} QFI_{fial}^{\tau} \le F_f^{\tau} CF_{fa}^{\tau} \qquad \forall f, a, \tau \tag{17}$$

Limitation (17): it ensures that the entire output flow from each supplier to all production-recovery centres should not be more than the capacity of this supplier for each raw material in each period.

$$\sum_{p,e,l} m_e QIP_{ipel}^{\tau} + \sum_{c,e,l} m_e QIC_{icel}^{\tau} \le CX_{ib_2}^{\tau} X_{ib_2}^{\tau} \qquad \forall i, h, \tau \tag{18}$$

Limitation (18): it indicates that the total output flow from each production-recovery centre is not more than the production capacity of these production-recovery centres in each period.

$$\sum_{p,e,l} m_e QIP_{ipel}^{\tau} \leq mcon_{\tau} CX_{ib_2}^{\tau} X_{ib_2}^{\tau} \qquad \forall i, b_2\ \tau \qquad (19)$$

Limitation (19): it indicates that the summation output flow from each production-recovery centre to the total distribution centres is at most equal to the capacity amount of that Production-recovery centre in each period.

$$\sum_{c,e,l} m_e QIC_{icel}^{\tau} \leq (1 - mcon_{\tau}) CX_{ib_2}^{\tau} X_{ib_2}^{\tau} \qquad \forall i, h\ \tau \qquad (20)$$

Limitation (20): it expresses that the total output flow from each production-recovery centre to the total customers is at most equal to the remained capacity value of production-recovery centres in each period.

$$\sum_{e} m_e INV_{pe}^{\tau} + \sum_{c,e,l} m_e \left(QPC_{pcel}^{\tau} + QEPC_{pcel}^{\tau} \right) \leq CY_p^{\tau} Y_p^{\tau} \qquad \forall p, \tau \qquad (21)$$

Limitation (21): it expresses that the remained inventory in each distribution centre must not be more than the capacity of distribution centres in each period.

$$\sum_{c,e,l} m_e QCP_{cpel}^{\tau} \leq CZ_p^{\tau} Z_p^{\tau} \qquad \forall p, \tau \qquad (22)$$

Limitation (22): it expresses that the amount of customers' returned products to the collection centre must not be more than the capacity of the collection centre in each period.

$$\sum_{p,e,l} m_e QPI_{piel}^{\tau} + \sum_{c,e,l} m_e QCI_{ciel}^{\tau} \leq CR_{ib_2}^{\tau} X_{ib_2}^{\tau} \qquad \forall i, h, \tau \qquad (23)$$

Limitation (23): it expresses that the total amount of returned products to each production-recovery centre must not be more than the recovery capacity in that production-recovery centre in each period.

$$\sum_{p,e,l} m_e QPK_{pkel}^{\tau} \leq CV_k^{\tau} V_k^{\tau} \qquad \forall k, \tau \qquad (24)$$

Limitation (24): it expresses that the entire sent amount from collection centres to disposal centres must not be more than the capacity of these disposal centres in each period.

$$\sum_{b_1 b_2} A_{b_1 b_2}^{\tau} = 1 \qquad \forall \tau \qquad (25)$$

Limitation (25): it expresses that only one product price and green being level can be selected for each product in a period.

$$QEPC_{pcel}^{\tau} \leq BM.OS_{cpe}^{\tau} \qquad \forall p, c, e, l, \tau \qquad (26)$$

$$QPC_{pcel}^{\tau} \leq BM.\left(1 - OS_{cpe}^{\tau}\right) \qquad \forall p, c, e, l, \tau \qquad (27)$$

Limitations (26) and (27) indicate customers' online and offline shopping relations.

$$Y_p^\tau + Z_p^\tau \leq 1 \qquad \forall p, \tau \qquad (28)$$

Limitation (28): it limits the maximum facilities number that can be opened in each period. Based on this relation, we can have one of the distribution and collection centres for each p in each period.

$$\sum_{l,o} OFI_{filo}^\tau \leq 1 \qquad \forall f, i, \tau \qquad (29)$$

$$\sum_{l,o} OIP_{iplo}^\tau \leq 1 \qquad \forall i, p, \tau \qquad (30)$$

$$\sum_{l,o} OIC_{iclo}^\tau \leq 1 \qquad \forall i, c, \tau \qquad (31)$$

$$\sum_{l,o} OPC_{pclo}^\tau \leq 1 \qquad \forall p, c, \tau \qquad (32)$$

$$\sum_{l,o} OEPC_{pclo}^\tau \leq 1 \qquad \forall p, c, \tau \qquad (33)$$

$$\sum_{l,o} OCP_{cplo}^\tau \leq 1 \qquad \forall c, p, \tau \qquad (34)$$

$$\sum_{l,o} OCI_{cilo}^\tau \leq 1 \qquad \forall c, i, \tau \qquad (35)$$

$$\sum_{l,o} OPI_{pilo}^\tau \leq 1 \qquad \forall p, i, \tau \qquad (36)$$

$$\sum_{l} OPK_{pklo}^\tau \leq 1 \qquad \forall p, k, \tau \qquad (37)$$

Limitations (29) to (37) express that only one transportation system in each chain member can be used for product carrying.

$$\sum_{l} QFI_{fial}^\tau \leq BM \cdot \sum_{o} OFI_{filo}^\tau \qquad \forall f, i, l, \tau \qquad (38)$$

$$\sum_{e} QIP_{ipel}^\tau \leq BM \cdot \sum_{o} OIP_{iplo}^\tau \qquad \forall i, p, l, \tau \qquad (39)$$

$$\sum_{e} QIC_{icel}^\tau \leq BM \cdot \sum_{o} OIC_{iclo}^\tau \qquad \forall i, c, l, \tau \qquad (40)$$

$$\sum_{e} QPC_{pcel}^\tau \leq BM \cdot \sum_{o} OPC_{pclo}^\tau \qquad \forall p, c, l, \tau \qquad (41)$$

$$\sum_{e} QEPC_{pcel}^\tau \leq BM \cdot \sum_{o} OEPC_{pclo}^\tau \qquad \forall p, c, l, \tau \qquad (42)$$

$$\sum_{e} QCP_{pcel}^\tau \leq BM \cdot \sum_{o} OCP_{cplo}^\tau \qquad \forall c, p, l, \tau \qquad (43)$$

$$\sum_{e} QCPI_{ciel}^{\tau} \leq BM \cdot \sum_{o} OCI_{cilo}^{\tau} \qquad \forall c, i, l, \tau \tag{44}$$

$$\sum_{e} QPI_{piel}^{\tau} \leq BM \cdot \sum_{o} OPI_{pilo}^{\tau} \qquad \forall p, i, l, \tau \tag{45}$$

$$\sum_{e} QPK_{pkel}^{\tau} \leq BM \cdot \sum_{o} OPK_{pklo}^{\tau} \qquad \forall p, k, l, \tau \tag{46}$$

Limitations (38) to (46) express that the transportation system is used among chain members that send the product to each other.

$$\sum_{a} QFI_{fial}^{\tau} \leq TCAFI_{fil}^{\tau} \cdot \sum_{o} OFI_{filo}^{\tau} \qquad \forall f, i, l, \tau \tag{47}$$

$$\sum_{e} QIP_{ipel}^{\tau} \leq TCAIP_{ipl}^{\tau} \cdot \sum_{o} OIP_{iplo}^{\tau} \qquad \forall i, p, l, \tau \tag{48}$$

$$\sum_{e} QIC_{icel}^{\tau} \leq TCAIC_{icl}^{\tau} \cdot \sum_{o} OIC_{iclo}^{\tau} \qquad \forall i, c, l, \tau \tag{49}$$

$$\sum_{e} QPC_{pcel}^{\tau} \leq TCAPC_{icl}^{\tau} \cdot \sum_{o} OPC_{pclo}^{\tau} \qquad \forall p, c, l, \tau \tag{50}$$

$$\sum_{e} QEPC_{pcel}^{\tau} \leq TCAPC_{pcl}^{\tau} \cdot \sum_{o} OEPC_{pclo}^{\tau} \qquad \forall p, c, l, \tau \tag{51}$$

$$\sum_{e} QCP_{cpel}^{\tau} \leq TCACP_{cpl}^{\tau} \cdot \sum_{o} OCP_{cplo}^{\tau} \qquad \forall c, p, l, \tau \tag{52}$$

$$\sum_{e} QCI_{ciel}^{\tau} \leq TCACI_{cil}^{\tau} \cdot \sum_{o} OCI_{cilo}^{\tau} \qquad \forall c, i, l, \tau \tag{53}$$

$$\sum_{e} QPI_{piel}^{\tau} \leq TCAPI_{pil}^{\tau} \cdot \sum_{o} OPI_{pilo}^{\tau} \qquad \forall p, i, l, \tau \tag{54}$$

$$\sum_{e} QPK_{pkel}^{\tau} \leq TCAIK_{pklo}^{\tau} \cdot \sum_{o} OPK_{pklo}^{\tau} \qquad \forall p, k, l, \tau \tag{55}$$

Limitations (47) to (55) indicate the transportation system's capacity among chain members that send the product to each other.

$$\sum_{u} PEX_{ui}^{\tau} \left\lceil \left(HX_i \times \left(\sum_{i,c,e,l,\tau} QIC_{icel}^{\tau} + \sum_{i,p,e,l,\tau} QIP_{ipel}^{\tau} \right) \right) \Big/ BH \right\rceil \qquad \forall i \tag{56}$$

Limitation (56): it indicates the total number of employees that work in the production-recovery centre *i*. In other words, the number of resident employees in the residential region (urban) *u* is calculated by the division of the required person-hour number (for producing a product in a production-recovery centre) by the working capacity of an employee.

$$\sum_{u} PEZ_{up}^{\tau} \left\lceil \left(HZ_p \times \left(\sum_{p,i,e,l,\tau} QPI_{piel}^{\tau} + \sum_{p,k,e,l,\tau} QPK_{pkel}^{\tau} \right) \right) \Big/ BH \right\rceil \qquad \forall p \qquad (57)$$

Limitation (57): it indicates the total number of employees that work in the collection centre p. The number of resident employees in the residential region (urban) u can be calculated through the division of the required person-hour number (to gather the product in a collection centre) by the working capacity of an employee.

$$\sum_{u} PEY_{up}^{\tau} \left\lceil \left(HY_p \times \left(\sum_{p,c,e,l,\tau} QPC_{pcel}^{\tau} + \sum_{p,c,e,l,\tau} QEPC_{pcel}^{\tau} \right) \right) \Big/ BH \right\rceil \qquad \forall p \qquad (58)$$

Limitation (58): it indicates the total number of employees that work in the distribution centre p. In other words, the number of resident employees in the residential region (urban) u is calculated through the division of the required person-hour number (for distribution of the product in a distribution centre) by the working capacity of an employee.

$$\sum_{i} PEX_{ui}^{\tau} + \sum_{p} PEY_{up}^{\tau} + \sum_{p} PEZ_{up}^{\tau} \leq \tilde{N}N_{u}^{\tau} Z \qquad \forall u, \tau \qquad (59)$$

Limitation (59): it indicates the number of hired employees from a definite region must not exceed the total number of existing potential employees in that region.

$$\sum_{u} PEX_{ui}^{\tau} + BM.\sum_{b_2} X_{ib_2}^{\tau} \qquad \forall i, \tau \qquad (60)$$

$$\sum_{u} PEY_{up}^{\tau} \leq BM.Y_{p}^{\tau} \qquad \forall p, \tau \qquad (61)$$

$$\sum_{u} PEZ_{up}^{\tau} \leq BM.Z_{p}^{\tau} \qquad \forall p, \tau \qquad (62)$$

Limitations (60)–(62) indicate centres' open or closed status. Moreover, they express that employees only commute to open centres (which are operating).

$$\begin{aligned} & QFI_{fiel}^{\tau} QIP_{ipel}^{\tau}, QIC_{icel}^{\tau}, QPC_{pcel}^{\tau}, QEPC_{pcel}^{\tau}, \\ & QCP_{cpel}^{\tau}, QCI_{ciel}^{\tau}, QPI_{piel}^{\tau} QPK_{pkel}^{\tau}, H_{ie}^{\tau}, INV_{pe}^{\tau}, \quad \forall f, i, a, l, \tau, p, e, c, k, u \qquad (63) \\ & PEX_{ui}^{\tau},, PEY_{up}^{\tau}, PEZ_{up}^{\tau} \geq 0 \end{aligned}$$

$$\begin{aligned} & OS_{cpe}^{\tau}, W_{b_1b_2}^{\tau}, F_{f}^{\tau}, X_{ib_2}^{\tau}, Y_{p}^{\tau}, Z_{p}^{\tau}, V_{k}^{\tau}, \\ & OFI_{filo}^{\tau}, OIP_{iplo}^{\tau}, OIC_{iclo}^{\tau}, OPC_{pclo}^{\tau}, \qquad \forall c, p, e, f, i, h, k, c, l, o, b_1, b_2, \tau \qquad (64) \\ & OEPC_{pclo}^{\tau}, OCP_{cplo}^{\tau}, OCI_{pilo}^{\tau}, OPK_{pklo}^{\tau} \in \{0, 1\} \end{aligned}$$

Relations (63) and (64) express that the decision variables are not negative and are correct, respectively.

4.2 Possibilistic mean-absolute deviation modelling

Only the expected values or mean of the objective function are considered in the development of solving methods based on possibilistic, and it is one of the main disadvantages of various existing possibilistic programming methods based on the expected amount or mean amount. Meanwhile, the risk control of objective function has been ignored in these models. Moreover, all decisions are adopted in the average conditions of realising non-deterministic parameters. Nevertheless, in applicable programs in the real world, managers prefer to involve investment risk in the decision-making process. The risk issue is extensively studied in random environments in various regions. Nevertheless, its examination is scarce in epistemic and fuzzy conditions. Babazadeh et al. (2017) and Babazadeh (2019) proposed a novel formula of a possibilistic programming method that combines the mean and absolute deviation of the uncertain objective function. In this formulating, the uncertain objective function's possibilistic absolute deviation is considered the risk criteria. In other words, Babazadeh et al. combine the risk factor in the objective function to become optimal along with the mean value of possibilistic objective function means. Babazadeh et al. (2017) and Babazadeh (2019) mathematical programming model has been provided with uncertain coefficients in both objective function and limitation. It is according to the mean and absolute deviation of fuzzy numbers.

$$
\begin{aligned}
&Min \quad && Z = \bar{M}(\tilde{c}x) + \gamma \left| \sigma(\tilde{c}x) \right| \\
&s.t. \quad && \tilde{a}_i x \geq \tilde{b}_i \qquad i = 1, \ldots, l \\
& && \tilde{a}_i x = \tilde{b}_i \qquad i = l+1, \ldots, m \\
& && x \geq 0
\end{aligned}
\tag{65}
$$

In the above model, the first expression of the objective function minimises the possibilistic-mean value $\tilde{c}x$. At the same time, the second expression minimises the possibilistic absolute deviation $\tilde{c}x$. The trade-off between the possibilistic mean value and absolute deviation of the objective function can be specified through MCDM using γ (the risk coefficient). The expressed possibilistic programming approach is similar to the robust stochastic programming approach presented in Mulvey et al. (1995) with the difference that it is presented for fuzzy environments. Moreover, the presented formula of the possibilistic programming approach can be classified in the form of realistic robust possibilistic programming approaches. Indeed, achieving robust solutions is not ensured by minimising the objective function's expected net values or mean values in the possibilistic mathematical programming model. To put it simply, these models are risk-neutral. Nevertheless, the possibilistic absolute mean-deviation model allows decision-makers, in addition to considering the uncertainty mean status, to take into account risk aversion in decision-making.

In continue, the crisp model equivalent to the proposed possibilistic absolute mean-deviation will be as follows given the presented definitions and principles in Babazadeh et al. (2017) and Babazadeh (2019) for fuzzy trapezoidal numbers:

$$
\begin{aligned}
&Min\ Z = \left(\frac{c^1 + 2c^2 + 2c^3 + c^4}{6} \right) x + \gamma \left(c^3 - c^2 + \frac{c^4 - c^3 + c^2 - c^1}{3} \right) x \\
&s.t. \\
&\left[(1-\alpha)\left(\frac{2}{3}a^2 + \frac{1}{3}a^4 \right) + \alpha \left(\frac{2}{3}a^2 + \frac{1}{3}a^1 \right) \right] x \ge \alpha \left(\frac{2}{3}b^2 + \frac{1}{3}b^4 \right) \\
&\quad + (1-\alpha)\left(\frac{2}{3}b^2 + \frac{1}{3}b^1 \right), i = 1, ..., l \\
&\left[\left(1 - \frac{\alpha}{2}\right)\left(\frac{2}{3}a^2 + \frac{1}{3}a^4 \right) + \frac{\alpha}{2}\left(\frac{2}{3}a^2 + \frac{1}{3}a^1 \right) \right] x \ge \frac{\alpha}{2}\left(\frac{2}{3}b^2 + \frac{1}{3}b^4 \right) \\
&\quad + \left(1 - \frac{\alpha}{2}\right)\left(\frac{2}{3}b^2 + \frac{1}{3}b^1 \right), i = l+1, ..., m \\
&\left[\frac{\alpha}{2}\left(\frac{2}{3}a^2 + \frac{1}{3}a^4 \right) + \left(1 - \frac{\alpha}{2}\right)\left(\frac{2}{3}a^2 + \frac{1}{3}a^1 \right) \right] x \le \left(1 - \frac{\alpha}{2}\right)\left(\frac{2}{3}b^2 + \frac{1}{3}b^4 \right) \\
&\quad + \frac{\alpha}{2}\left(\frac{2}{3}b^2 + \frac{1}{3}b^1 \right), i = l+1, ..., m \\
&x \ge 0
\end{aligned}
\tag{66}
$$

Some parameters in this study have uncertain and fluctuated features, such as basis demand, cost of purchasing the raw material unit, cost of the product production unit, and cost of product recovery unit. Hence, these parameters have been expressed as follows in fuzzy trapezoidal numbers form, given the experts' opinions and experiences.

$$
\begin{aligned}
&\tilde{D}_{ce}^{\tau} = \left(D_{ce}^{\tau\,1}, D_{ce}^{\tau\,2}, D_{ce}^{\tau\,3}, D_{ce}^{\tau\,4} \right) \\
&\tilde{F}C_{fa}^{\tau} = \left(FC_{fa}^{\tau\,1}, FC_{fa}^{\tau\,2}, FC_{fa}^{\tau\,3}, FC_{fa}^{\tau\,4} \right) \\
&\tilde{M}C_{ieb_2}^{\tau} = \left(MC_{ieb_2}^{\tau\,1}, MC_{ieb_2}^{\tau\,2}, MC_{ieb_2}^{\tau\,3}, MC_{ieb_2}^{\tau\,4} \right) \\
&\tilde{R}C_{ieb_2}^{\tau} = \left(RC_{ieb_2}^{\tau\,1}, RC_{ieb_2}^{\tau\,2}, RC_{ieb_2}^{\tau\,3}, RC_{ieb_2}^{\tau\,4} \right)
\end{aligned}
$$

Accordingly, the possibilistic absolute mean-deviation approach is used to rewrite the objective functions and limitations with uncertain parameters. These new equations are replaced with their previous forms:

$$
\begin{aligned}
&DEM_{ceb_1b_2}^{\tau} \ge \left(\alpha \frac{ug_{ce}^{\tau} - GR_{ceb_2}^{\tau}}{ug_{ce}^{\tau} - lg_{ce}^{\tau}} + (1-\alpha) \frac{up_{ce}^{\tau} - PR_{ceb_1}^{\tau}}{up_{ce}^{\tau} - lp_{ce}^{\tau}} \right. \\
&\qquad \left. \left(\frac{\psi}{2}\left(\frac{2}{3}D_{ce}^{\tau\,2} + \frac{1}{3}D_{ce}^{\tau\,4} \right) + \left(1 - \frac{\psi}{2}\right)\left(\frac{2}{3}D_{ce}^{\tau\,2} + \frac{1}{3}D_{ce}^{\tau\,1} \right) \right) \right) \\
&DEM_{ceb_1b_2}^{\tau} \le \left(\alpha \frac{ug_{ce}^{\tau} - GR_{ceb_2}^{\tau}}{ug_{ce}^{\tau} - lg_{ce}^{\tau}} + (1-\alpha) \frac{up_{ce}^{\tau} - PR_{ceb_1}^{\tau}}{up_{ce}^{\tau} - lp_{ce}^{\tau}} \right. \\
&\qquad \left. \left(\left(1 - \frac{\psi}{2}\right)\left(\frac{2}{3}D_{ce}^{\tau\,2} + \frac{1}{3}D_{ce}^{\tau\,4} \right) + \frac{\psi}{2}\left(\frac{2}{3}D_{ce}^{\tau\,2} + \frac{1}{3}D_{ce}^{\tau\,1} \right) \right) \right)
\end{aligned}
\quad \forall c, e, b_1, b_2, \tau \tag{1$'$}
$$

$$
\begin{aligned}
Income_\tau = & \sum_{ceb_1b_2} PR^{\tau}_{ceb_1b_2}\left(\frac{D^{\tau}_{ce}{}^{1}+2D^{\tau}_{ce}{}^{2}+2D^{\tau}_{ce}{}^{3}+D^{\tau}_{ce}{}^{4}}{6}\right)W^{\tau}_{b_1b_2} \\
& +\gamma\sum_{ceb_1b_2} PR^{\tau}_{ceb_1b_2}\left(D^{\tau}_{ce}{}^{3}-D^{\tau}_{ce}{}^{2}+\frac{D^{\tau}_{ce}{}^{4}-D^{\tau}_{ce}{}^{3}+D^{\tau}_{ce}{}^{2}-D^{\tau}_{ce}{}^{1}}{3}\right)W^{\tau}_{b_1b_2}
\end{aligned}
\tag{4.1)$'$ (}
$$

$$
\begin{aligned}
Cost_\tau = & \sum_{i,b_2} FX^{\tau}_{ib_2}\left(X^{\tau}_{ib_2}-X^{\tau\text{-}1}_{ib_2}\right)+\sum_{p} FY^{\tau}_{p}\left(Y^{\tau}_{p}-Y^{\tau\text{-}1}_{p}\right)+\sum_{p} FZ^{\tau}_{p}\left(Z^{\tau}_{p}-Z^{\tau\text{-}1}_{p}\right) \\
& +\sum_{k} FV^{\tau}_{k}\left(V^{\tau}_{k}-V^{\tau\text{-}1}_{k}\right)+\sum_{b} FB^{\tau}_{b}B^{\tau}_{b}+\sum_{eb_1b_2} IT^{\tau}_{eb_2}W^{\tau}_{b_1b_2} \\
& +\left(\sum_{f,i,a,l} QFI^{\tau}_{fial}\left(\frac{FC^{\tau}_{fa}{}^{1}+2FC^{\tau}_{fa}{}^{2}+2FC^{\tau}_{fa}{}^{3}+FC^{\tau}_{fa}{}^{4}}{6}\right)\right. \\
& +\gamma\sum_{f,i,a,l} QFI^{\tau}_{fial}\left(FC^{\tau}_{fa}{}^{3}-FC^{\tau}_{fa}{}^{2}+\frac{FC^{\tau}_{fa}{}^{4}-2FC^{\tau}_{fa}{}^{3}+2FC^{\tau}_{fa}{}^{2}-FC^{\tau}_{fa}{}^{1}}{3}\right) \\
& +\sum_{i,p,e,b_2,l} QIP^{\tau}_{ipel}\left(\frac{MC^{\tau}_{ieb_2}{}^{1}+2MC^{\tau}_{ieb_2}{}^{2}+2MC^{\tau}_{ieb_2}{}^{3}+MC^{\tau}_{ieb_2}{}^{4}}{6}\right) \\
& +\gamma\sum_{i,p,e,b_2,l} QIP^{\tau}_{ipel}\left(MC^{\tau}_{ieb_2}{}^{3}-MC^{\tau}_{ieb_2}{}^{2}+\frac{MC^{\tau}_{ieb_2}{}^{4}-2MC^{\tau}_{ieb_2}{}^{3}+2MC^{\tau}_{ieb_2}{}^{2}-MC^{\tau}_{ieb_2}{}^{1}}{3}\right) \\
& +\sum_{i,c,e,b_2,l} QIC^{\tau}_{iceb_2l}\left(\frac{MC^{\tau}_{ieb_2}{}^{1}+2MC^{\tau}_{ieb_2}{}^{2}+2MC^{\tau}_{ieb_2}{}^{3}+MC^{\tau}_{ieb_2}{}^{4}}{6}\right) \\
& +\gamma\sum_{i,c,e,b_2,l} QIC^{\tau}_{iceb_2l}\left(MC^{\tau}_{ieb_2}{}^{3}-MC^{\tau}_{ieb_2}{}^{2}+\frac{MC^{\tau}_{ieb_2}{}^{4}-2MC^{\tau}_{ieb_2}{}^{3}+2MC^{\tau}_{ieb_2}{}^{2}-MC^{\tau}_{ieb_2}{}^{1}}{3}\right) \\
& \sum_{p,c,e,l}\left(QPC^{\tau}_{pcel}+QEPC^{\tau}_{pcel}\right)OC^{\tau}_{pe}+\sum_{c,p,e,l} QCP^{\tau}_{cpel}IC^{\tau}_{pe} \\
& +\sum_{p,i,e,b_2,l} QPI^{\tau}_{piel}\left(\frac{RC^{\tau}_{ieb_2}{}^{1}+2RC^{\tau}_{ieb_2}{}^{2}+2RC^{\tau}_{ieb_2}{}^{3}+RC^{\tau}_{ieb_2}{}^{4}}{6}\right) \\
& +\gamma\sum_{p,i,e,b_2,l} QPI^{\tau}_{piel}\left(RC^{\tau}_{ieb_2}{}^{3}-RC^{\tau}_{ieb_2}{}^{2}+\frac{RC^{\tau}_{ieb_2}{}^{4}-2RC^{\tau}_{ieb_2}{}^{3}+2RC^{\tau}_{ieb_2}{}^{2}-RC^{\tau}_{ieb_2}{}^{1}}{3}\right) \\
& +\sum_{c,i,e,b_2,l} QCI^{\tau}_{cpel}\left(\frac{RC^{\tau}_{ieb_2}{}^{1}+2RC^{\tau}_{ieb_2}{}^{2}+2RC^{\tau}_{ieb_2}{}^{3}+RC^{\tau}_{ieb_2}{}^{4}}{6}\right)+\gamma \\
& +\sum_{c,i,e,b_2,l} QCI^{\tau}_{cpel}\left(RC^{\tau}_{ieb_2}{}^{3}-RC^{\tau}_{ieb_2}{}^{2}+\frac{RC^{\tau}_{ieb_2}{}^{4}-2RC^{\tau}_{ieb_2}{}^{3}+2RC^{\tau}_{ieb_2}{}^{2}-RC^{\tau}_{ieb_2}{}^{1}}{3}\right) \\
& \left.+\sum_{p,k,e,l} QPK^{\tau}_{pkel}DC^{\tau}_{ke}+\sum_{p}\sum_{e} INV^{\tau}_{pe}HC^{\tau}_{pe}\right) \\
& +\left(\sum_{f,i,a,l} QFI^{\tau}_{fial}CFI^{\tau}_{fial}+\sum_{i,p,e,l} QIP^{\tau}_{ipel}CIP^{\tau}_{ipel}+\sum_{i,c,e,l} QIC^{\tau}_{icel}CIC^{\tau}_{icel}\right.
\end{aligned}
\tag{4.2)$'$ (}
$$

$$+\sum_{p,c,e,l} QPC_{pcel}^{\tau} CPC_{pcel}^{\tau} + \sum_{p,c,e,l} QEPC_{pcel}^{\tau} CEPC_{pcel}^{\tau} + \sum_{c,p,e,l} QCP_{cpel}^{\tau} CCP_{cpel}^{\tau}$$

$$\left. + \sum_{p,i,e,l} QPI_{piel}^{\tau} CPI_{piel}^{\tau} + \sum_{c,i,e,l} QCI_{ciel}^{\tau} CCI_{ciel}^{\tau} + \sum_{p,k,e,l} QPK_{pkel}^{\tau} CPK_{pkel}^{\tau} \right)$$

$$+\left(\sum_{f,i,l,o} OFI_{filo}^{\tau} FFI_{filo}^{\tau} + \sum_{i,p,l,o} OIP_{iplo}^{\tau} FIP_{iplo}^{\tau} + \sum_{i,c,l,o} OIC_{iclo}^{\tau} FIC_{iclo}^{\tau} \right.$$

$$+ \sum_{p,c,l,o} \left(OPC_{pclo}^{\tau} + OEPC_{pclo}^{\tau} \right) FPC_{pclo}^{\tau} + \sum_{c,p,l,o} OCP_{cplo}^{\tau} FCP_{cplo}^{\tau}$$

$$\left. + \sum_{p,i,l,o} OPI_{pilo}^{\tau} FPI_{pilo}^{\tau} + \sum_{c,i,l,o} OCI_{cilo}^{\tau} FCI_{cilo}^{\tau} + \sum_{p,k,l,o} OPK_{pklo}^{\tau} FPK_{pklo}^{\tau} \right)$$

5 Solving method

The presented model in this study has four objective functions with variant directions (two minimising functions and two maximising functions), and it requires the creation of interactions between objective functions. The authors have presented four incompatible objectives, and finding a globally optimal solution is impossible. Hence, a Pareto-optimal (non-dominated/non-inferior/efficient solution) is required. Here, the augmented ε-constraint approach (Mavrotas, 2009) is applied for the multi-objective proposed model to find the optimal Pareto solutions (feasible).

5.1 Augmented ε-constraint method

Step 1 Choose one of the objective functions to be the main objective function.

Step 2 Solve the problem with one of the objective functions every time and obtain the optimal values of the objective function.

Step 3 Divide the distance between two optimal values of sub-objective functions by a predefined number and obtain a table for $\varepsilon_2, \ldots, \varepsilon_n$.

Step 4 Solve the main objective function by bypassing the $\varepsilon_2, \ldots, \varepsilon_n$ values of the problem every time.

Step 5 Report the Pareto answers (Ghalandari et al., 2023; Hajghani et al., 2023; Shafiee et al., 2021; Soon et al., 2022).

$$\begin{aligned} & Max\left(f_1(x) + eps \times \left(\frac{s_2}{r_2} + 10^{-1} \frac{s_3}{r_3} + \ldots + 10^{-(p-2)} \frac{s_p}{r_p} \right) \right) \\ & s.t. \\ & \qquad X \in F \\ & \qquad f_k(X) - S_k = e_k \quad k = 2, \ldots, p \\ & e_k = lb_k + i_k * step_k \quad k = 2, \ldots, p \end{aligned} \tag{67}$$

$f_k(X)$ main objective functions of the model to be optimised

lb_k the lower bound for the objective function k

$step_k = \frac{r_k}{g_k}$ the step size of the objective function k

r_k the variation range of objective function k

g_k the number of intervals needed for the objective function k

S_k the surplus of variable for the objective function k

F acceptable range

eps a very small number (usually $10^{-3} - 10^{-6}$).

6 Numerical tests and analysis of results

This section initially presents a numerical example for evaluating the proposed model's validity and performance, the solving approach of augmented ε-constraint, and the examination of the problem's variables. The related results will be presented in the following. This problem is programmed in GAMS 24.1.2 Software. Table 1 indicates the size of the designed test. Moreover, Table 2 indicates the produced random data based on the uniform distribution for the model's parameters.

Table 1 The size of the designed problem

$\|F\|$	$\|I\|$	$\|P\|$	$\|C\|$	$\|K\|$	$\|E\|$	$\|A\|$	$\|L\|$	$\|U\|$	$\|B_1\|$	$\|B_2\|$	$\|O\|$	$\|T\|$
2	2	2	5	2	2	3	2	3	3	3	2	2

Therefore, the optimal values of objective functions are as Table 3 after solving the problem.

The obtained range from the objective functions of this paper has been used to a satisfaction degree of 0.5 ($\psi = 0.5$) in the augmented ε-constraint approach to find the efficient answers from the Pareto-optimal set. Table 4 reveals that the objectives are conflict with each other. So, decision maker can select the most preferred solution among the presented efficient solutions. Initially, many efficient solutions from the total range of optimal Pareto sets are selected to choose an efficient solution from the optimal Pareto set. If DM is not pleased with these solutions, it can change the ε vectors to produce more efficient solutions. The mentioned process is carried out continuously till the most preferred data is selected.

The product optimal flow path and obtained output variables' value for the final repetition have been indicated in Figure 3 and Tables 6 to 12 to examine the proposed model.

Moreover, the total amount of SC revenue is 3,864,354,000 and 3,937,217,000 in periods 1 and 2, respectively. The total amount of SC cost is 684,832,900 and 728,800,000 in periods 1 and 2, respectively.

Table 2 The values of the model's parameters

$D_{ce}^{\tau\,1} \sim u(50,150)$	$CF_{fa}^{\tau} \sim u(780,200,8,903,000)$	$EPK_{pkel}^{\tau} \sim u(1,6)$	$FCP_{cplo}^{\tau} \sim u(30,80)$
$D_{ce}^{\tau\,2} \sim u(75,100)$	$CX_{ib_2}^{\tau} \sim u(780,400,8,905,500)$	$EP_{ieb_1}^{\tau} \sim u(1,3)$	$FCI_{cilo}^{\tau} \sim u(30,300)$
$D_{ce}^{\tau\,3} \sim u(100,125)$	$CY_{p}^{\tau} \sim u(780,500,8,901,500)$	$TFI_{fialo}^{\tau} \sim u(5,8)$	$FPI_{pilo}^{\tau} \sim u(30,100)$
$D_{ce}^{\tau\,4} \sim u(125,150)$	$CZ_{p}^{\tau} \sim u(780,100,8,900,250)$	$TIP_{ipelo}^{\tau} \sim u(3,23)$	$FPK_{pklo}^{\tau} \sim u(20,100)$
$PR_{ceb_1b_2}^{\tau} \sim u(5,000,10,000)$	$CR_{ib_2}^{\tau} \sim u(780,100,8,900,250)$	$TIC_{icelo}^{\tau} \sim u(3,19)$	$WX_{ib_2}^{\tau} \sim u(20,20)$
$IT_{eb_2}^{\tau} \sim u(50,150)$	$CV_{k}^{\tau} \sim u(780,100,8,900,250)$	$TPC_{pcelo}^{\tau} \sim u(5,23)$	$WY_{p}^{\tau} \sim u(20,40)$
$FC_{fa}^{\tau\,1} \sim u(3,3.5)$	$TCAFI_{fil}^{\tau} \sim u(800,000,15,000,000)$	$TEPC_{pcelo}^{\tau} \sim u(2,20)$	$WZ_{p}^{\tau} \sim u(40,60)$
$FC_{fa}^{\tau\,2} \sim u(3.5,4)$	$TCAIP_{ipl}^{\tau} \sim u(80,10,000,000)$	$TCP_{cpelo}^{\tau} \sim u(5,9)$	$WV_{p}^{\tau} \sim u(20,60)$
$FC_{fa}^{\tau\,3} \sim u(4,4.5)$	$TCAIC_{icl}^{\tau} \sim u(30,100)$	$TCI_{cielo}^{\tau} \sim u(5,18)$	$DX_{ib_2}^{\tau} \sim u(200,400)$
$FC_{fa}^{\tau\,4} \sim u(4.5,5)$	$TCAPC_{pcl}^{\tau} \sim u(14,000,18,000)$	$TPI_{pielo}^{\tau} \sim u(5,18)$	$DY_{p}^{\tau} \sim u(256,456)$
$MC_{ieb_2}^{\tau\,1} \sim u(50,62.5)$	$TCACP_{cpl}^{\tau} \sim u(12,000,13,000)$	$TPK_{pkelo}^{\tau} \sim u(9,19)$	$DZ_{p}^{\tau} \sim u(223,454)$
$MC_{ieb_2}^{\tau\,2} \sim u(62.5,75)$	$TCACI_{cil}^{\tau} \sim u(12,000,13,000)$	$TFI_{ialo}^{\tau}{}' \sim u(2,10)$	$DV_{k}^{\tau} \sim u(202,404)$
$MC_{ieb_2}^{\tau\,3} \sim u(75,87.5)$	$TCAPI_{pil}^{\tau} \sim u(10,000,19,000)$	$TIP_{pelo}^{\tau}{}' \sim u(3,10)$	$LX_{ib_2}^{\tau} \sim u(5,7)$
$MC_{ieb_2}^{\tau\,4} \sim u(87.5,100)$	$TCAPK_{pkl}^{\tau} \sim u(14,500,20,000)$	$TIC_{icelo}^{\tau}{}' \sim u(1,6)$	$LY_{p}^{\tau} \sim u(2,4)$
$OC_{pe}^{\tau} \sim u(2,4)$	$CFI_{fial}^{\tau} \sim u(2,3)$	$TPC_{celo}^{\tau}{}' \sim u(3,10)$	$LZ_{p}^{\tau} \sim u(2,4)$
$IC_{pe}^{\tau} \sim u(2,4)$	$CIP_{ipel}^{\tau} \sim u(2,3)$	$TEPC_{celo}^{\tau}{}' \sim u(3,10)$	$LV_{k}^{\tau} \sim u(2,3)$
$RC_{ieb_2}^{\tau\,1} \sim u(20,22.5)$	$CIC_{icel}^{\tau} \sim u(1,3)$	$TCP_{pelo}^{\tau}{}' \sim u(3,10)$	$NE_{u}^{\tau} \sim u(1,050,1,550)$
$RC_{ieb_2}^{\tau\,2} \sim u(22.5,25)$	$CPC_{pcel}^{\tau} \sim u(2,3)$	$TCI_{ielo}^{\tau}{}' \sim u(3,10)$	$HX_{i} = 0.218181$
$RC_{ieb_2}^{\tau\,3} \sim u(25,27.5)$	$CEPC_{pcel}^{\tau} \sim u(3,4)$	$TPI_{ielo}^{\tau}{}' \sim u(1,10)$	$HY_{p} = 0.218181$
$RC_{ieb_2}^{\tau\,4} \sim u(27.5,30)$	$CCP_{cpel}^{\tau} \sim u(2,4)$	$TPK_{kelo}^{\tau}{}' \sim u(4,10)$	$HZ_{p} = 0.218181$
$DC_{ke}^{\tau} \sim u(2,3)$	$CCI_{ciel}^{\tau} \sim u(2,4)$	$FFI_{filo}^{\tau} \sim u(10,200)$	$BH = 8$
$HC_{pe}^{\tau} \sim u(10,50)$	$CPI_{piel}^{\tau} \sim u(2,4)$	$FIP_{iplo}^{\tau} \sim u(10,150)$	$n_{ae}, m_{e} = 1$
$FF_{f}^{\tau} \sim u(200,300)$	$CPK_{pkel}^{\tau} \sim u(2,4)$	$ECP_{cpel}^{\tau} \sim u(1,3)$	$mcont_{\tau} = 0.70$
$FX_{ib_2}^{\tau} \sim u(300,600)$	$EFI_{fial}^{\tau} \sim u(2,5)$	$ECI_{cpel}^{\tau} \sim u(1,3)$	$PR_{e} = 0.70$
$FY_{p}^{\tau} \sim u(300,600)$	$EIP_{ipel}^{\tau} \sim u(2,4)$	$EPI_{piel}^{\tau} \sim u(1,4)$	$PXi_{e} = 0.60$
$FZ_{p}^{\tau} \sim u(200,400)$	$EIC_{icel}^{\tau} \sim u(2,2)$	$FIC_{iclo}^{\tau} \sim u(80,150)$	$PXd_{e} = 0.40$
$FV_{k}^{\tau} \sim u(200,400)$	$EPC_{pcel}^{\tau} \sim u(2,3)$	$FPC_{pclo}^{\tau} \sim u(10,100)$	$\beta = 0.5$
			$\xi_1 = 0.5, \xi_2, \xi_3 = 0.25$
			$BM = 10^8$

Figure 3 The optimal flow of product (see online version for colours)

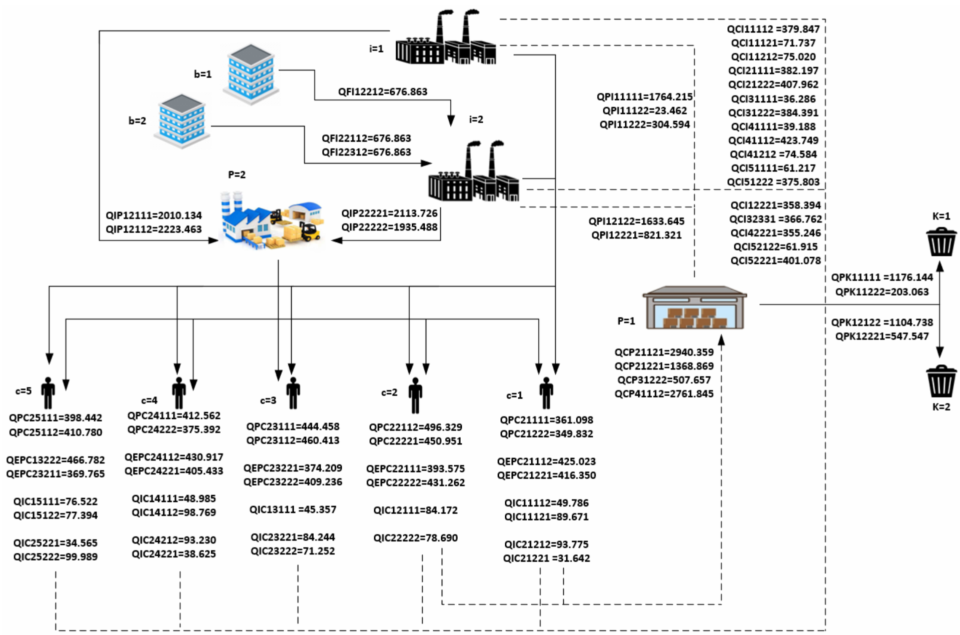


Table 3 The optimal values of objective functions

Iteration	*f1*	*f2*	*f3*	*f4*
1	6.379111E+9	150.181	2,538.774	144,810.036
2	6.368904E+9	341.122	2,457.549	129,266.660
3	6.299711E+9	174.066	2,594.786	164,587.549
4	6.489845E+9	397.513	2,431.083	167,458.579
5	6.491280E+9	349.498	2,452.986	183,056.646
6	6.432451E+9	348.091	2,521.222	179,318.365
7	6.436421E+9	170.791	2,497.324	157,080.276
6	6.455876E+9	255.831	2,464.870	158,770.551
9	6.330788E+9	146.519	2,466.958	126,842.273
10	6.387938E+9	174.997	2,471.814	134,267.898

Table 4 Pay-off

Functions	*f1*	*f2*	*f3*	*f4*
f1	650,324,2000	6,274,931,000	6,086,915,000	6,285,646,000
f2	130/888	39/843	133/75	480/114
f3	2,412/188	2,421/465	2,629/517	2,395/098
f4	202,821/981	175,991/253	188,900/734	117,563/368

Table 5 The range of objective functions

Functions	*f1*	*f2*	*f3*	*f4*
Minimum of the objective functions	6.086915E+9	39.843	2,395.098	117,563.368
The maximum of the objective functions	6.503242E+9	480.114	2,629.517	202,821.981
Range of objective functions	4.163276E+8	440.271	234.419	85,258.613

Table 6 The product price in price level b_1 for product *e*, customer *c*, and in period τ

$PR^{\tau}_{ceb_1}$	*Value*	$PR^{\tau}_{ceb_1}$	*Value*	$PR^{\tau}_{ceb_1}$	*Value*	$PR^{\tau}_{ceb_1}$	*Value*
1.1.1.1	0.535	2.1.2.2	3,470.591	3.2.1.1	0.327	4.2.2.2	4,472.110
1.1.1.2	0.542	2.1.3.1	6,322.720	3.2.1.2	0.447	4.2.3.1	9,599.515
1.1.2.1	3,902.949	2.1.3.2	6,940.867	3.2.2.1	3,967.507	4.2.3.2	8,943.990
1.1.2.2	3,127.669	2.2.1.1	0.768	3.2.2.2	3,204.415	5.1.1.1	0.800
1.1.3.1	7,805.363	2.2.1.2	0.391	3.2.3.1	7,934.687	5.1.1.2	0.143
1.1.3.2	6,254.796	2.2.2.1	1,203.982	3.2.3.2	6,408.383	5.1.2.1	773.121
1.2.1.1	0.350	2.2.2.2	3,016.209	4.1.1.1	0.124	5.1.2.2	3,248.837
1.2.1.2	0.635	2.2.3.1	2,407.197	4.1.1.2	0.875	5.1.3.1	1,545.441
1.2.2.1	2,809.243	2.2.3.2	6,032.027	4.1.2.1	3,219.595	5.1.3.2	6,497.531
1.2.2.2	2,904.502	3.1.1.1	0.839	4.1.2.2	2,621.518	5.2.1.1	0.168
1.2.3.1	5,618.136	3.1.1.2	0.663	4.1.3.1	6,439.067	5.2.1.2	0.649
1.2.3.2	5,808.369	3.1.2.1	1,524.827	4.1.3.2	5,242.162	5.2.2.1	1,396.005
2.1.1.1	0.536	3.1.2.2	1,567.713	4.2.1.1	0.857	5.2.2.2	591.063
2.1.1.2	0.315	3.1.3.1	3,048.815	4.2.1.2	0.230	5.2.3.1	2,791.841
2.1.2.1	3,161.628	3.1.3.2	3,134.764	4.2.2.1	4,800.186	5.2.3.2	1,181.477

Table 7 The green being level of product b_2 for product *e*, customer *c*, and period τ

$GR^{\tau}_{ceb_2}$	*Value*	$GR^{\tau}_{ceb_2}$	*Value*	$GR^{\tau}_{ceb_2}$	*Value*	$GR^{\tau}_{ceb_2}$	*Value*
1.1.1.1	0.855	2.1.2.2	3.724	3.2.1.1	0.616	4.2.2.2	3.218
1.1.1.2	0.649	2.1.3.1	6.214	3.2.1.2	0.512	4.2.3.1	9.083
1.1.2.1	1.437	2.1.3.2	6.644	3.2.2.1	3.351	4.2.3.2	6.205
1.1.2.2	4.929	2.2.1.1	0.512	3.2.2.2	3.325	5.1.1.1	0.136
1.1.3.1	2.019	2.2.1.2	0.276	3.2.3.1	6.086	5.1.1.2	0.257
1.1.3.2	9.209	2.2.2.1	1.473	3.2.3.2	6.139	5.1.2.1	1.517
1.2.1.1	0.136	2.2.2.2	3.144	4.1.1.1	0.415	5.1.2.2	4.117
1.2.1.2	0.481	2.2.3.1	2.433	4.1.1.2	0.525	5.1.3.1	2.897
1.2.2.1	2.144	2.2.3.2	6.011	4.1.2.1	2.217	5.1.3.2	7.976
1.2.2.2	3.368	3.1.1.1	0.804	4.1.2.2	5.191	5.2.1.1	0.747
1.2.3.1	4.151	3.1.1.2	0.846	4.1.3.1	4.019	5.2.1.2	0.258

Table 7 The green being level of product b_2 for product e, customer c, and period τ (continued)

$GR^{\tau}_{ceb_2}$	*Value*	$GR^{\tau}_{ceb_2}$	*Value*	$GR^{\tau}_{ceb_2}$	*Value*	$GR^{\tau}_{ceb_2}$	*Value*
1.2.3.2	6.255	3.1.2.1	3.656	4.1.3.2	9.857	5.2.2.1	4.509
2.1.1.1	0.580	3.1.2.2	2.522	4.2.1.1	0.884	5.2.2.2	3.024
2.1.1.2	0.805	3.1.3.1	6.507	4.2.1.2	0.231	5.2.3.1	8.272
2.1.2.1	3.397	3.1.3.2	4.198	4.2.2.1	4.983	5.2.3.2	5.789

Table 8 The resident employees number in residential region u that are working in production-recovery location i, distribution location p, and collection location p

PEX_{ui}	*Value*	PEY_{up}	*Value*	PEZ_{up}	*Value*
3.1.1	64.223	1.2.1	112.468	1.1.1	117.524
3.1.2	66.802	1.2.2	113.425	1.1.2	89.168
3.2.1	62.803				
3.2.2	64.702				

Table 9 The selected price level of b_1 and the level of green being of b_2 in period τ

$W^{\tau}_{b_1b_2}$	*Value*
2.1.1	1
2.2.2	1

In the possibilistic absolute-mean approach, the parameter ψ is used in limitations and effectively impacts the feasibility of the problem's answer environment. Furthermore, the parameter γ penalises existing contravenes in the problem and seeks to control the obtained deviations from the problem's answer in a robust model. Consequently, we examine the changes in objective functions by changing each parameter. Table 13 determines the obtained results.

Table 10 The produced product e amount in the production-recovery centre i in period τ

H^{τ}_{ie}	*Value*
1.1.1	2,354.840
1.1.2	2,449.411
2.2.1	2,302.802
2.2.2	2,372.424

Table 11 The used RFID technology type in each flow

OFI(f, i, l, o, τ)	*Value*	*OIC(i, c, l, e, τ)*	*Value*	*OCI(c, i, l, o, τ)*	*Value*	*OCP(c, p, l, e, τ)*	*Value*
1.2.1.1.2	1	1.1.1.2.2	1	1.2.2.1.1	1	2.1.2.2.1	1
2.2.1.2.2	1	1.1.2.2.1	1	2.1.1.1.1	1	3.1.2.1.2	1
OIP(i, p, l, e, τ)	*Value*	1.2.1.1.1	1	2.1.2.1.2	1	4.1.1.2.2	1
1.2.1.1.1	1	1.3.1.1.1	1	3.1.1.2.1	1	*OPC(p, c, l, e, τ)*	*Value*
1.2.1.2.2	1	1.4.1.2.1	1	3.1.2.1.2	1	1.4.2.2.1	1
2.2.2.1.1	1	1.4.1.2.2	1	3.2.2.2.1	1	1.5.1.1.1	1
2.2.2.2.2	1	1.5.2.1.2	1	4.1.1.1.1	1	2.1.1.2.1	1
OEPC(p, c, l, e, τ)	*Value*	2.1.1.2.2	1	4.1.1.2.2	1	2.1.2.2.2	1
1.4.2.2.1	1	2.1.2.1.1	1	*OPI(p, i, l, o, τ)*	*Value*	2.2.1.1.2	1
2.1.1.2.2	1	2.2.2.2.2	1	1.1.1.2.1	1	2.2.2.1.1	1
2.1.2.2.1	1	2.3.2.2.1	1	1.1.2.1.2	1	2.3.1.1.1	1
2.2.1.1.1	1	2.3.2.2.2	1	1.2.2.1.1	1	2.3.1.1.2	1
2.2.2.2.2	1	2.4.1.1.2	1	1.2.2.1.2	1	2.4.1.1.1	1
2.3.2.2.1	1	2.4.2.2.1	1	*OPK(p, k, l, o, τ)*	*Value*	2.4.2.1.2	1
2.3.2.2.2	1	2.5.2.1.1	1	1.1.1.1.1	1	2.5.1.1.1	1
2.4.1.1.2	1	2.5.2.2.2	1	1.1.2.2.2	1	2.5.1.1.2	1
2.4.2.2.1	1	*OCI(c, i, l, o, τ)*	*Value*	1.2.2.2.1	1		
2.5.2.2.1	1	1.1.1.1.2	1	1.2.2.2.2	1		
2.5.2.2.2	1	1.1.2.2.1	1				

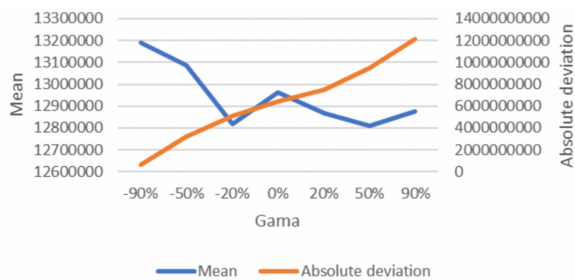
Table 12 The proposed demand of customer c for product e in the price level of b_1 and green being level of b_2 in period t

$DEM^{\tau}_{ceb_1b_2}$	*Value*	$DEM^{\tau}_{ceb_1b_2}$	*Value*	$DEM^{\tau}_{ceb_1b_2}$	*Value*	$DEM^{\tau}_{ceb_1b_2}$	*Value*	$DEM^{\tau}_{ceb_1b_2}$	*Value*	$DEM^{\tau}_{ceb_1b_2}$	*Value*	$DEM^{\tau}_{ceb_1b_2}$	*Value*	$DEM^{\tau}_{ceb_1b_2}$	*Value*	$DEM^{\tau}_{ceb_1b_2}$	*Value*
1.1.1.1.1	80.137	1.2.1.2.1	59.732	2.1.1.3.1	42.466	2.2.2.1.1	70.148	3.1.2.2.1	54.424	3.2.3.2.1	40.751	3.2.2.3.1	30.564	4.2.3.2.1	39.472	5.1.3.3.1	21.109
1.1.1.1.2	84.410	1.2.1.2.2	59.148	2.1.1.3.2	44.118	2.2.2.1.2	79.326	3.1.2.2.2	51.157	3.2.3.2.2	42.710	3.2.2.3.2	32.033	4.2.3.2.2	41.655	5.1.3.3.2	21.697
1.1.1.2.1	60.103	1.2.1.3.1	39.822	2.1.2.1.1	74.316	2.2.2.2.1	50.106	3.1.2.3.1	32.654	3.2.3.3.1	20.376	3.2.3.1.1	61.127	4.2.3.3.1	19.736	5.2.1.1.1	89.128
1.1.1.2.2	63.308	1.2.1.3.2	39.432	2.1.2.1.2	77.207	2.2.2.2.2	56.661	3.1.2.3.2	30.694	3.2.3.3.2	21.355	3.2.3.1.2	64.065	4.2.3.3.2	20.828	5.2.1.1.2	83.512
1.1.1.3.1	40.068	1.2.2.1.1	69.688	2.1.2.2.1	53.083	2.2.2.3.1	30.063	3.1.3.1.1	65.309	4.1.1.1.1	82.053	4.1.3.3.1	20.513	5.1.1.1.1	84.438	5.2.1.2.1	66.846
1.1.1.3.2	42.205	1.2.2.1.2	69.005	2.1.2.2.2	55.148	2.2.2.3.2	33.997	3.1.3.1.2	61.388	4.1.1.1.2	94.166	4.1.3.3.2	23.542	5.1.1.1.2	86.786	5.2.1.2.2	62.634
1.1.2.1.1	70.120	1.2.2.2.1	49.777	2.1.2.3.1	31.850	2.2.3.1.1	60.127	3.1.3.2.1	43.539	4.1.1.2.1	61.540	4.2.1.1.1	78.944	5.1.1.2.1	63.328	5.2.1.3.1	44.564
1.1.2.1.2	73.859	1.2.2.2.2	49.290	2.1.2.3.2	33.089	2.2.3.1.2	67.994	3.1.3.2.2	40.926	4.1.1.2.2	70.625	4.2.1.1.2	83.311	5.1.1.2.2	65.090	5.2.1.3.2	41.756
1.1.2.2.1	50.085	1.2.2.3.1	29.866	2.1.3.1.1	63.699	2.2.3.2.1	40.085	3.1.3.3.1	21.770	4.1.1.3.1	41.026	4.2.1.2.1	59.208	5.1.1.3.1	42.219	5.2.2.1.1	77.987
1.1.2.2.2	52.757	1.2.2.3.2	29.574	2.1.3.1.2	66.177	2.2.3.2.2	45.329	3.1.3.3.2	20.463	4.1.1.3.2	47.083	4.2.1.2.2	62.483	5.1.1.3.2	43.393	5.2.2.1.2	73.073
1.1.2.3.1	30.051	1.2.3.1.1	59.732	2.1.3.2.1	42.466	2.2.3.3.1	20.042	3.2.1.1.1	81.503	4.1.2.1.1	71.796	4.2.1.3.1	39.472	5.1.2.1.1	73.883	5.2.2.2.1	55.705
1.1.2.3.2	31.654	1.2.3.1.2	59.148	2.1.3.2.2	44.118	2.2.3.3.2	22.665	3.2.1.1.2	85.420	4.1.2.1.2	82.396	4.2.1.3.2	41.655	5.1.2.1.2	75.938	5.2.2.2.2	52.195
1.1.3.1.1	60.103	1.2.3.2.1	39.822	2.1.3.3.1	21.233	3.1.1.1.1	87.078	3.2.1.2.1	61.127	4.1.2.2.1	51.283	4.2.2.1.1	69.076	5.1.2.2.1	52.774	5.2.2.3.1	33.423
1.1.3.1.2	63.308	1.2.3.2.2	39.432	2.1.3.3.2	22.059	3.1.1.1.2	81.851	3.2.1.2.2	64.065	4.1.2.2.2	58.854	4.2.2.1.2	72.897	5.1.2.2.2	54.242	5.2.2.3.2	31.317
1.1.3.2.1	40.068	1.2.3.3.1	19.911	2.2.1.1.1	80.169	3.1.1.2.1	65.309	3.2.1.3.1	40.751	4.1.2.3.1	30.770	4.2.2.2.1	49.340	5.1.2.3.1	31.664	5.2.3.1.1	66.846
1.1.3.2.2	42.205	1.2.3.3.2	19.716	2.2.1.1.2	90.658	3.1.1.2.2	61.388	3.2.1.3.2	42.710	4.1.2.3.2	35.312	4.2.2.2.2	52.069	5.1.2.3.2	32.545	5.2.3.1.2	62.634
1.1.3.3.1	20.034	2.1.1.1.1	84.933	2.2.1.2.1	60.127	3.1.1.3.1	43.539	3.2.2.1.1	71.315	4.1.3.1.1	61.540	4.2.2.3.1	29.604	5.1.3.1.1	63.328	5.2.3.2.1	44.564
1.1.3.3.2	21.103	2.1.1.1.2	88.236	2.2.1.2.2	67.994	3.1.1.3.2	40.926	3.2.2.1.2	74.743	4.1.3.1.2	70.625	4.2.2.3.2	31.241	5.1.3.1.2	65.090	5.2.3.2.2	41.756
1.2.1.1.1	79.643	2.1.1.2.1	63.699	2.2.1.3.1	40.085	3.1.2.1.1	76.193	3.2.2.2.1	50.939	4.1.3.2.1	41.026	4.2.3.1.1	59.208	5.1.3.2.1	42.219	5.2.3.3.1	22.282
1.2.1.1.2	78.863	2.1.1.2.2	66.177	2.2.1.3.2	45.329	3.1.2.1.2	71.620	3.2.2.2.2	53.388	4.1.3.2.2	47.083	4.2.3.1.2	62.483	5.1.3.2.2	43.393	5.2.3.3.2	20.878

Table 13 Changes in the parameter ψ on the pay-off table of objective functions

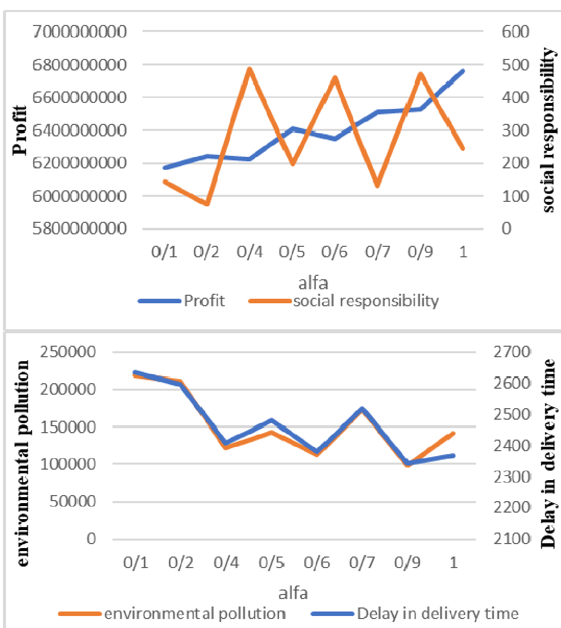
	ψ = 0/2					ψ = 0/3			
	f1	*f2*	*f3*	*f4*		*f1*	*f2*	*f3*	*f4*
f1	6,558,953,000	6,353,484,000	6,051,720,000	6,351,020,000	f1	6,540,383,000	6,418,234,000	6,061,559,000	6,329,229,000
f2	130/888	39/778	123/149	464/106	f2	130/888	39/843	129/203	472/2
f3	2,397/204	2,414/541	2,649/865	2,380/614	f3	2,402/198	2,380/687	2,643/082	2,385/442
f4	194,148/11	165,976/959	196,888/825	112,278/156	f4	197,039/4	162,769/484	194,861/86	114,039/893
	ψ =0/8					ψ = 1			
	f1	*f2*	*f3*	*f4*		*f1*	*f2*	*f3*	*f4*
f1	6,447,532,000	6,310,896,000	6,162,997,000	6,220,274,000	f1	6,410,391,000	6,263,708,000	6,210,968,000	6,176,693,000
f2	130/888	39/843	140/914	465/083	f2	130/888	39/843	150/114	465/492
f3	2,427/172	2,403/954	2,609/168	2,409/581	f3	2,437/161	2,420/11	2,595/602	2,419/237
f4	211,495/852	175,923/538	178,125/406	122,848/58	f4	217,278/433	179,273/764	185,205/835	126,372/054

Figure 4 The amount of possibilistic mean against the possibilistic absolute deviation in objective function's profit for various values of Gamma in feasibility degree of 0.5 (see online version for colours)



In Figure 4, we observe the mean and absolute deviation changes of the objective function's profit in terms of entered changes on the Gamma parameter (in terms of a percent). Figure 4 indicates that the absolute deviation of the profit function increases along with the enhancement of γ values in the objective function. Overall, the mean profit reduces. Indeed, the model opens more facilities or uses more capacities for overcoming the risk of uncertain parameters for higher γ values. Decision maker can determine the tendency value of γ, given the risk and importance of profit. It is obvious that risk-averse organisations prefer the higher values of γ.

Figure 5 Showing the changes of the effect indicator of product green being on the objective functions (see online version for colours)



In the following, Figure 5 demonstrates the impact of changes in the amount of the effect indicator of product green being. As can be seen, along with the enhancement of the amount of the effect indicator of product green being, the profitability amount is enhanced, and the environmental pollution objective function due to carbon emission is relatively reduced. Moreover, it expresses that more attention to product green forces the SC managers to produce more green products and reduce environmental pollution emissions in the SC.

7 Conclusions, management insight, recommendations for future studies and direction of future research

7.1 Conclusions

Optimal and proper SCND has several impacts on SC performance, productivity, and efficiency to achieve the expected objectives and meet the customers' needs. In this regard, the design of a CLSC network with various collection and distribution channels with sustainability, greenness, multi-echelon, multi-product, multi-period, and multi-objective is addressed in this study. Moreover, the mentioned model considers the RFID technology and dependent demand to price and greenness. Additionally, this model simultaneously seeks to maximise the profit and social responsibility of the SC network while minimising total delivery delays and environmental pollution. Besides, the possibilistic mean-deviation approach is used to encounter the uncertainty and fluctuations of parameters. This approach can minimise the mean and values of objective functions' risk under uncertainty based on possibilistic. The augmented ε-constraint approach is applied for solving the model due to the existence of four objective functions in the model.

A numerical example is designed, programmed with GAMS software, and solved; its computational results and its analysis are presented. Overall, this model is efficiently based on the computational results and can present an optimal model in terms of achieving profit and social responsibility and reducing delay in delivery time and environmental pollution, considering the uncertainty in some parameters. Besides, it can be understood that logical changes in products' prices are an efficient way to enhance profit. Moreover, encouraging producers to produce more green products (that customers prefer) is a logical tool for customer absorption and sales enhancement. Electronic commerce indicates income enhancement due to cost savings and reducing atmospheric pollution. Consequently, it has significant environmental effects on health and leads to saving in customers' time and endeavour. Also Results show that the possibilistic mean-absolute deviation model is able to efficiently balance the mean and risk values of an imprecise objective function according to the DM preferences. The possibilistic mean-absolute deviation model can achieve a solution that has a higher degree of robustness in comparison with a pure possibilistic one according to DM preferences.

The designed multi-channel CLSC can use in different industries such as the electronic industry, digital equipment, glass, plastic, and metals that are raw materials and obtained products from it is recoverable. Also, it is a tool for scholars to study interesting problems. Notably, no study is not free from limitations. Thereby, this paper also encounters some limitations. The lack of access to a case study to implement the proposed model is one of the limitations of the present paper.

7.2 Management insight

The proposed model gives a proper vision to the management section. The electronic commerce, logistics, and sc industries can use the presented model of this study to make their SC networks more intelligent, transparent, trackable, safe, and faster. The partners can use RFID technology in the sc to be able to know the product's life point, the current location of the product, and the location it will reach. Besides, it reduces the time lags in the transportation and in-time delivery of the order, faster transportation, elimination of incorrect transportation, and shortens the order chain. Overall, it leads to in-time and more confident managers' decisions, and they can address the required measures. Regarding online shopping programs, factory managers can decide whether they sell products through traditional sales channels or sell a part of their products in the online form, given the cost and income due to the creation of various distribution channels. Besides, if customers in the market pay more attention to the product's green being, In that case, SC managers must produce more green products to meet customers' expectations, reducing total carbon emissions.

Moreover, these managers can plan the number of careers that can create in each region. Eventually, the proposed model helps managers make an operational scheme of the sc at their required confidence level and address a proper level of required sources and supports in uncertain conditions to have the required preparation to overcome the large volume of changes due to uncertainty.

7.3 Recommendations for future studies

For future studies, scholars can consider the behaviour-based pricing (BBP) strategy as BBP consider the tendency to payment, behavioural features, and new and old customers' logical expectations entirely. Besides, it can adjust the pricing strategy based on purchasing history dynamically. Therefore, BBP can promote the development of green products in the market compared to the same pricing. Some other sustainability stimulations can consider in the model's formulation to provide a more comprehensive framework for the multi-channel CLSC network design problem. Other government support policies, different products and raw material purchasing discount policies, and existing components' reliability can be investigated. The development of accurate or exploratory efficient methods is another path for future studies in this regard. In addition, it is possible to mention more research on the modelling of the IoT in the field of warehousing and logistics in a sustainable green SC, because the research on the IOT in the field of warehousing and logistics is largely unknown. It is also possible to simultaneously consider and formulate the impact of IOT adoption on cost, service, satisfaction and competitive advantage of companies. And at the end, it is recommended that researchers consider the efficiency of using facility resources for this study by using data envelopment analysis models.

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