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Omid Keramatlou

islamic azad university, ali abad katoul

Nikbakhsh Javadian

islamic azad university, ali abd katoul

Hosein Didekhani (✉ didekhanihosein10@gmail.com)

islamic azad university, ali abd katoul

Mohammad Amirkhan

islamic azad university, ali abd katoul

Research Article

Keywords: Closed-loop supply chain, Probabilistic customer, expected time, Expected coverage, possibility allocating

Posted Date: January 25th, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1283714/v1>

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A bi-objective green closed-loop supply chain with retailer's location and possibility allocating vertices by probabilistic customers

Omid Keramatlou^a, Nikbakhsh Javadian^{a, b*}, Mohammad Amirkhan^a, Hosin Didehkhani

^a Department of industrial engineering, Aliabad Katoul Branch, Islamic Azad University, Aliabad Katoul, Iran, Email: ms53omid@yahoo.com, Nijavadian@ustmb.ac.ir, m.amirkhan.ie@gmail.co, h.didehkhani@gmail.com

^b Department of Industrial Engineering, Mazandaran University of Science and Technology, babol, Iran, Email: Nijavadian@ustmb.ac.ir

Abstract

The closed-loop supply chain networks include the return processes and the producers aim to capture additional values by considering further integration of all supply chain activities. In this paper, a closed-loop supply chain is modeled to obtain the best allocation and location of retailers including production and distribution centers, the warehouse of manufactured products, retailers' centers, probabilistic customers, collection, repair, and disposal centers so that the amount of environmental pollution and CO₂ emissions by taking into account the conversion of CO₂ to O₂ in vehicles' gas converters, is minimized. In this research, two strategies are considered to find the best places for retailers by focusing on 1- the type of expected movement (Rectangular, Euclidean, Euclidean Square, and Chebyshev); 2- expected coverage (distance and time). To this end, a bi-objective nonlinear programming model is proposed. This model concurrently compares strategies 1 and 2 and selects the best competitor. Based on the selected strategy, the best allocation is made by employing a heuristic algorithm and the locations of the best retailers are determined. As the proposed model is NP-hard in the nature of the problem, a meta-heuristics, namely, non-dominated sorting genetic algorithm is employed for the solution

process. Eventually, to authenticate and confirm the effectiveness of the suggested model, a numerical example is given and solved utilizing optimization software, and the results are analyzed.

Keywords: Green Closed-loop supply chain, Probabilistic customer, Expected distance, Expected coverage

1. Introduction

Supply chain network design (SCND) is one of the most important strategic decisions that recently has been received growing attention from researchers ([Ramezani et al., 2013](#)). Many organizations may include firms producing raw materials and products and providing services such as distribution, storage, wholesale, and retail. These sets are growing and becoming more complex as demands increase. Moreover, consumers tend to require higher-quality products. This leads to a large number of returns, translating directly to increased environmental impacts. Thus, the urgent need to reduce those impacts has aroused broad attention from governments, academia, and industries. Various measures are developed to meet the trade-off between environmental protection and cost reduction by many large economic entities ([Huang et al., 2020](#)). To reduce the negative environmental impacts from supply chain (SC), legislation and social concerns have been motivating firms to plan their SC structures for handling both forward and reverse product flows. close loop supply chain (CLSC) network forward flows satisfy demands for new products, while reverse flows represent the collection and remanufacturing or recycling of returned products ([Haddadsisakht & Ryan, 2018](#)). Many big companies such as Xerox, Canon, Kodak, Dell, and Acer have put efforts into green operations. Xerox, for example, has successfully reduced 42% emissions and 31% energy consumptions by 2012. The US Newsweek Green Rankings 2016 has placed Xerox in the top 50 of 500 world's largest

companies on corporate sustainability and environmental impact. Meanwhile, Canon engaged in green operations by saving energy, reducing waste, and minimizing chemical usage in the production processes.¹ Waste diversion, energy conservation, water reprocessing, and energy-efficient manufacturing are among Kodak's efforts to reach a 25% reduction of greenhouse-gas emissions and water consumption by 2025. Recently, Dell changed their business approach that leads to zero-waste manufacturing and renewable-energy usage. They claimed more than 94% of product packaging was made from sustainable materials.² According to Acer (2016); Acer has successfully reduced the total CO₂ emissions and recycled papers' usage by 53% and 97%, respectively. The reduction of CO₂ emissions was partly due to the use of green energy from the Solar Power Generation System (C.-K. Chen & Ulya, 2019). Note that in various situations different SC processes do not experience certainty, but rather probable events in one or more divisions. That is why most decision-makers further face the difficulty of optimizing uncertain models (Tosarkani & Amin, 2018). The occurrence of probable events in the process provokes many complexities and realism. It should be perceived that uncertainty, as a significant factor in SC decision-making, can alter the chain movement structure. In other words, the existence of uncertainty at each stage of the chain has a significant impact on its movements and coverage of the facilities in such a way that devising suitable approaches to control this uncertainty results in reduced costs and quicker services (Zhen et al., 2019). While composing a supply chain network (SCN), it should be heeded that SC breakdowns are unplanned and erratic events that upset the normal flow of goods and supplies in the chain. Consequently, corporations in the SC are prone to commercial and operational risks (Ghomi-Avili et al., 2018). Therefore, disruption in infrastructures has relatively significant impacts on the operation and performance of the supply chain (Yavari & Zaker, 2019).

the best allocating to retailers in a CLSC structure includes production centers, distribution centers, the warehouse of manufactured products, retailers' centers, probabilistic customers, collection, repair, and disposal centers, Factoring the comparison of the type of movement and possible coverage and the use of innovative algorithms in the allocation is one of the topics that is less addressed in recent articles ([A. Mondal & Roy, 2021](#)), ([C.-K. Chen & Ulya, 2019](#)), ([Tolooie et al., 2020](#)), ([Yavari & Zaker, 2019](#)), ([Ebrahimi-arjestan & Wang, 2017](#)), ([Gholizadeh & Fazlollahabbar, 2020](#)), ([H. Yu & Solvang, 2020](#)). ([Sazvar et al., 2021](#)),([Chai et al., 2021](#)), ([Johari & Hosseini-Motlagh, 2019](#)), ([Ghahremani Nahr et al., 2020](#)), ([J.-M. Chen & Chi, 2019](#)), ([C. Mondal et al., 2020](#))

In this study, a two-objective mathematical model is presented which covers the production, distribution, warehouse, retailers, probabilistic customers, collection, repairing, and disposal. Considering the amount of CO₂ gas production and emission by transportation machines, in the .in the first objective function, a comparison and optimal allocation are performed between the retailer and probabilistic customers by focusing on the different types of mobility (Rectilinear, Euclidean, Euclidean Square, and Chebyshev) and Maximum expected coverage distance (MECD) and, probabilistic customers and retailer by focusing on the different types of mobility (Rectilinear, Euclidean, Euclidean Square, and Chebyshev) and Maximum expected coverage time (MECT). The second objective function shows Increasing the amount of O₂ produced. Finally, two heuristic algorithms are showed the MECD in the retail center to provide services, and the MECT probabilistic customers to receive services.

Based on the above descriptions, the main contributions of this paper are as follows:

- The presented model is devised in such a way that enables the probabilistic customer to use all sorts of Rectangular, Euclidean, Euclidean Square, and Chebyshev motions to reach retailers and vice versa.
- The proposed model can formulate the expected distance of each probabilistic customer at any point on the space (not a pre-specified location).
- Considering the upper and lower bounds of standard coverage for the expected retailers' distance and customers' time, this model can calculate the predicted distance and time of each retailer and customers separately.
- To solve the proposed model, two heuristic algorithms are employed. The first algorithm, based on the expected time coverage, was used to allocate probabilistic customers to retailers. considering the expected distance coverage, the other heuristic algorithm is employed to allocate retailers to customers.

The outline of the current paper is as follows: In section 2, theoretical literature associated with the subject matter is studied individually. In section 3, the corresponding mathematical model is given, and using the expected time and distance coverage radius, their allocation is done initiatively. In addition, the entire problem is solved using NSGA II. Via a numerical illustration, the proposed model's outputs are examined in section 4. Finally, the results and suggestions for future studies are included in section 5.

2. Literature review

In this section, the related literature is reviewed across two research domains-green closed-loop supply chain (GCLSC) and the CLSC with different collection options

2.1. GCLSC with different collection options

(Ghosh & Shah, 2015) considered a green supply chain (GSC) under price and greening level-sensitive demand to investigate the cost-sharing coordination issue. They showed that a cost-sharing contract could benefit the customers and supply chain members by increasing product greening level and profit. Introducing E-commerce in the GSC management. (Hussain et al., 2016) provided a useful measure for SC managers to develop a green service SC. The evaluation method they proposed incorporated environmental factors, social factors, customer relationships, and risk evaluation. (Govindan et al., 2016) proposed a model that determines the best location for the hybrid recovery facility and optimal flow of products, recovered parts, and material in the network while it simultaneously maximizes profit, saves activity costs, helps to decrease the harmful effects of the manufacturing process, and makes a positive impact on societal development. (Basiri & Heydari, 2017) investigated GSC coordination issue for substitutable products with retail price, greening level, and sales effort dependent demand for a two-stage supply chain. They showed that the cooperative model supplies the product with a superior greening level and higher profit. (Fazli-Khalaf et al., 2017) developed a multi-objective model to minimize costs of network and gas emission in a green closed-loop supply chain. They presented a new fuzzy robust programming to control uncertainty in business as usual and disruptions in a CLSC. (Gao et al., 2018) presented a product supply network problem considering carbon emissions not only from firms but also from consumers. A two-step method of the Mixed-Integer nonlinear programming (MINLP) model was proposed to get the exact solutions. (Giri et al., 2018) considered a two-period CLSC model with two types of return, viz. instant return and return of used the product. They showed that if at the beginning of the first period, the manufacturer and the retailer announce their respective decisions for both periods and then they can get the best possible optimal result. (Sadeghi Rad & Nahavandi, 2018) proposed a novel

mathematical model for multi-period, multi-echelon, multi-product, and capacitated a closed-loop green supply chain network (CLGSCN). The model includes four layers in the forward flow (suppliers, manufacturing/remanufacturing centers, distribution centers, and customer zone) and three layers in the reverse flow (collection/inspection centers, disposal centers, and manufacturing/remanufacturing centers). The model objectives could minimize the cost and environmental pollution and maximize the customers' satisfaction. (Y. Zhang et al., 2018) considered the reverse logistics SC model with a remanufacturing option to reduce carbon emissions. The proposed mathematical model is provided in deterministic and two-stage stochastic versions to account for demand uncertainty. The main aim of this model is optimal production, inventory, and delivery quantities along with delivery and pickup routes under a carbon cap-and-trade emissions policy. (Noh & Kim, 2019) investigated contract between single manufacturers and multiple retailers with limited resources for several types of products under greenhouse-gas emission regulations. Most of the above studies only involve green preference behavior; rarely consider green degree as a parameter. (Gholizadeh & Fazlollahtabar, 2020) investigated a CLSC with different grades extracted from a melting process in a reverse flow based on demand planning to handle the uncertainty of the model. Modeling emphasizes high profitability due to uncertainty in demand. They investigated various issues in this field, and a robust optimization approach was used and embedded with a modified GA as an optimization approach. (Guo et al., 2020) presented the effect of such as E-commerce environment, government subsidies, and product greenness to establish a profit model of the GCLSC system. (Ma et al., 2020) focused on the optimal design problem of multi-period the CLSC network of hazardous products considering uncertain demands and returns, expandable facility capacities and, socially acceptable risk simultaneously. In each period, the built facilities can expand within

a certain scope. (Mehrerjedi & Shafiee, 2020) suggested a profit model of the GCLSC system. GA and PSO are used to find and compare the approximate optimal. (Mohtashami et al., 2020) suggested a bi-objective nonlinear programming model (BONLP) model for GSC network with reverse logistics. Their model in real-world conditions, four levels for forwarding flow and four levels for reverse flow are considered. For the first time, transportation fleets are assumed as customers of a G/M/S queueing system with finite sources in each part of the supply chain. (Pourjavad & Shahin, 2020) proposed a new approach for prioritizing the risks of GSC in a fuzzy environment.

2.2. CLSC with different collection options

(Pasandideh et al., 2015) suggested a two-objective optimization model of an SC that involves distribution centers and customers. They solved the problem using the NSGA-II. They further considered most parameters in this network, such as fixed and variable costs, customer demand, ready production time, adjustment time, and production time, to be more like reality. Besides, they used another GA-based algorithm, the NSGA-II, to verify the results. (Dai & Dai, 2016) proposed a model that integrated risks into the design of closed-loop supply chain network and proposes a multi-period, multi-echelon, and bi-objective closed-loop Supply chain network model in a fuzzy environment. (Zhalechian et al., 2016) developed a CLSC network with location-routing-inventory under mixed uncertainty. (Z.-H. Zhang & Unnikrishnan, 2016) studied a model of an inventory pattern in a CLSC with uncertain demand. Besides determining the place of distribution centers, this model gives inventory policy in distribution centers and its allocation to retailers. (Üster & Hwang, 2016) studied a CLSC, the corresponding mathematical model of which is an integer and complex number. In the case of uncertainty about the demands and returned products, this model determines the optimal location for manufacturing facilities.

(Babaveisi et al., 2018) proposed a three-level model of a multi-product CLSC. This model minimizes risk and production expenses and maximizes the dividends. They also employed multi-functional models to solve the problem and analyze and compare the results. (Samadi et al., 2018) suggested a sustainable closed-loop supply chain network problem by proposing some new real-world assumptions and objectives. They developed some strong heuristics through meta-heuristics to solve the proposed problem. (Zeballos et al., 2018) proposed a two-stage mixed-integer problem (MIP) model that combines the conditional value at risk and the structure of a CLSC network. End-customer areas are divided into two parts, namely, the primary market and the secondary market. This approach can prevent a distinct impact on economic performance via changes in quality. (Dey et al., 2019) considered a two-period SC to study the impact of strategic inventory on green product design under procurement strategies and presented some useful results using a game-theoretic approach. (J. C. P. Yu et al., 2019) studied an integrated manufacturer retailer closed-loop supply chain (CLSC) system. To compare the effects regarding integration and recycling, they also classified the decision-making policies into four types according to the relationship of the manufacturer and the retailer (buyer). (Nayeri et al., 2020) Develops a multi-objective mathematical model to configure a Sustainable Closed-Loop Supply Chain (SCLSC) network for a water tank considering sustainability measures. (Rabbani et al., 2020) developed a multi-objective mixed robust possibility model to investigate the location-allocation problem in the configuration of a Sustainable CLSC net.

Table1. Summarized literature review

Reference	Layer of network														
	Type of network	close loop supply chain	Green close-loop supply chain	Supply Center	Manufacturing\assemble Center	Distribution Center	Warehouse Center	Retailer Center		Probabilistic Customer		Customer	Collection Center	Repairing Center	Disposing Center
								Expected Converge Distance	Expected Distance Between Retailers and Customers	Expected Coverage Time	Expected Distance Between Customers and Retailers				
(Amin & Zhang, 2013)	✓				✓								✓	✓	✓
(Zeballos et al., 2014)		✓		✓	✓	✓								✓	✓
(Pasandideh et al., 2015)	✓				✓	✓						✓			
(Üster & Hwang, 2016)	✓	✓	✓	✓	✓								✓	✓	
(Hussain et al., 2016)		✓	✓	✓								✓	✓	✓	
(Basiri & Heydari, 2017)		✓			✓										
(Gao et al., 2018)		✓		✓		✓									
(Babaveisi et al., 2018)	✓				✓	✓							✓	✓	
(Noh & Kim, 2019)		✓			✓		✓								
(Mohtashami et al., 2020)		✓	✓	✓	✓	✓						✓	✓	✓	✓
(Yun et al., 2020)		✓			✓	✓						✓	✓	✓	✓
This paper		✓			✓	✓	✓	✓	✓		✓		✓	✓	✓

Regarding the literature, the main contributions of the current study are summarized as follows:

1) As is illustrated in Table 1 fewer studies are conducted on the expected coverage distance and time in CLSC.

2) The literature shows fewer studies are conducted on the relation to the types of movement for customers probabilistic to receive service.

3) The literature shows fewer studies are conducted on the relation to the types of movement for a retailer to send service.

Allocating retailers in a closed-loop supply chain structure includes production centers, retailers centers, probabilistic customers, collection, and disposal centers, Factoring the comparison of the type of movement and possible coverage and the use of innovative algorithms in the allocation is one of the topics that is less addressed in recent articles ([Sazvar et al., 2021](#)),([Chai et al., 2021](#)), ([Johari & Hosseini-Motlagh, 2019](#)) ([Tolooie et al., 2020](#)), ([Yavari & Zaker, 2019](#)), ([Ebrahimiarjestan & Wang, 2017](#)), ([Gholizadeh & Fazlollahtabar, 2020](#)), ([H. Yu & Solvang, 2020](#)).

3. Mathematical Model

3.1. Network structure

The formation of the CLSC network is presented in Figure 1. The principal arrangement of this model is developed by ([Zeballos et al., 2014](#)) but here it is presented with minor modifications and involves production centers, warehousing centers, distribution centers, retail centers, probabilistic customers, collection centers, revival centers, and disposing centers.

Figure1. Schematic diagram of the modeled GCLSC

In Figure 1, the customers are considered probabilistically with lower and upper time bounds and have minimum and maximum coverage radius to reach retailers. Also, retailers too have lower and upper bounds such that they have minimum and maximum coverage ranges to provide customer service.

3.2. Model Assumption

In this part, all the assumptions related to the problem are declared. According to these assumptions, the problem is modeled.

1. The single-period model is recognized;
2. Insufficiency is not allowed in any section;

3. Transportation costs are fixed over a period;
4. Products returned by the customer are subject to penalties;
5. All customers must take their service;
6. Every customer can visit more than one retail center to receive services;
7. The customers' and retailers' motion type is either Rectangular, Euclidean, Euclidean Square, or Chebychev;
8. The motion happens on a page;
9. Based on the relocation distance, the transportation time is constant and invariable;
10. All chain parameters and variables are definite, excluding the customer place, customer coverage time, and retailer coverage distance;
11. Raw materials are provided by production centers. Hence, in this model, supply centers are not counted;
12. No cost is considered for keeping the goods;
13. The retail coverage distance for random customers is not constant at each stage;
14. The probabilistic customer time coverage of retailers is not consistent at every stage.
15. Via new converters, transportation devices can convert CO₂ gas to O₂.

3.3. Sets

In this section, all the indexes used in modeling the problem are included.

$p = 1, 2, \dots P$	Index of collection centers that have the potential to produce
$dc = 1, 2, \dots DC$	Index of collection of distribution centers that have the distribution potential
$w = 1, 2, \dots W$	Index of collection warehouse centers that have the potential to store goods
$j = 1, 2, \dots J$	Index of collection of retail centers that have the selling potential
$i = 1, 2, \dots I$	Index of a collection of probabilistic customers
$cc = 1, 2, \dots CC$	Index of collection centers that have the potential to collect

$re = 1, 2, \dots RE$ Index of a collection of Repairing centers that have the potential for Repairing and reconstruction

$dis = 1, 2, \dots DIS$ Index of collection of disposal centers that have the elimination potential

$r = 1, 2, \dots R$ Index of the produced goods

$e, e' =$ set of all echelons $(e, e' \in \{p, dc, w, j, i, cc, re, dis\})$

$k, k' =$ Set of facilities in echelon $(k_e, k'_e \in \{1, \dots K_e\})$

3.4. Model Parameters

In this section, all the parameters associated with the problem are presented.

cap_e	capacity of facility $e \in \{p, dc, w, j, i, cc, re, dis\}$,
cap_{k_e}	capacity of facility $k_e e \in \{p, dc, w, j, cc, re, dis\}$,
τ_{k_e}	The Amount of facility $k_e e \in \{p, dc, w, j, cc, re, dis\}$,
U_i	Demand capacity of the i probabilistic customers
v_r	The amount of the type r production
FC_{k_e}	Fixed cost of the facility $k_e e \in \{p, dc, w\}$
FC_j	Fixed cost of the j potential retailer center
FC'_{k_e}	Fixed cost of the facility $k_e e \in \{cc, re, dis\}$
L_j	Standard radius of the service distance for the j retailer (See this parameter in supplemental file part A- Lemma A.5)
T_i	Standard radius of time of service receiving for the i probabilistic customers (See this parameter in supplemental file part A- Lemma A.6)
$l_{j,i,r}$	Distance covered by the j retailer transfer to provide service for the i probabilistic customers due to send the type r product (See this parameter in supplemental file part A- Lemma A.5)
$t_{i,j,r}$	Time covered by the i probabilistic customers spend to gain service for the j retailer due to receive the type r product (See this parameter in supplemental file part A- Lemma A.6)
e_j	Upper and lower limit values from the standard distance radius (See this parameter in supplemental file part A- Lemma A.5)
θ_i	Upper and lower limit values from the standard time radius (See this parameter in supplemental file part A- Lemma A.6)
μ_{i1}	The average horizontal coordinates of the i probabilistic customer (See this parameter in supplemental file part A)
μ_{i2}	The average vertical coordinates of the i probabilistic customer (See this

	parameter in supplemental file part A)
σ_{i1}^2	The variance of horizontal coordinates of the i probabilistic customer (See this parameter in supplemental file part A)
σ_{i2}^2	The variance of vertical coordinates of the i probabilistic customers (See this parameter in supplemental file part A)
d_{j1}	Spatial horizontal coordinates of the j retailer(See this parameter in supplemental file part A)
d_{j2}	Spatial vertical coordinates of the j retailer(See this parameter in supplemental file part A)
$\Omega_{cc,i,r}$	The penalty paid by the collection center to the i probabilistic customers for the return of the type r product
α	The percentage of the costumer's returned goods. ($\alpha \leq 1$)
β^1, β^2	The percentage of the products that can be revived in the collection center and eliminated in the disposal center. ($\beta^1 + \beta^2 = \alpha$)
$\lambda^1, \lambda^2, \lambda^3$	The percentage of the products repaired in the revival center and sends to the distribution center, disposal center, warehouse center. ($\lambda^1 + \lambda^2 + \lambda^3 = \beta^1$)
$Cost_{k_e k_{e'}, r}$	The relocation cost of the type r product from the facility center k_e to facility center $k_{e'}$ ($e, e' \in \{p, dc, w, j\}$)
$Cost_{j,i,r}$	The relocation cost of the type r product from the j potential retailer center to the i potential customer
$Cost'_{i,j,r}$	The relocation cost of the type r product from the i probabilistic potential customer to the j potential retailer center
$Cost'_{k_e k_{e'}, r}$	The relocation cost of the type r product from the facility center k_e to facility center $k_{e'}$ ($e, e' \in \{i, cc, re, dis, dc, w\}$)
$dic_{k_e k_{e'}, r}$	The transferring distance of the type r product from the facility center k_e to facility center $k_{e'}$ ($e, e' \in \{p, dc, w, j\}$)
$dic_{j,i,r}$	The transferring distance of the type r product from the j potential retailer center to the i probabilistic customer
$dic'_{i,j,r}$	The transferring distance of the type r product from the i the probabilistic customer to the j potential retailer center
$dic'_{k_e k_{e'}, r}$	The transferring distance of the type r product from the facility center k_e to facility center $k_{e'}$ ($e, e' \in \{i, cc, re, dis, dc, w\}$)
$x_{k_e k_{e'}, r}$	The amount of the type r product send from the facility center k_e to facility center $k_{e'}$ ($e, e' \in \{p, dc, w, j\}$)
$x_{j,i,r}$	The amount of the type r product send from j potential retailer center to the i probabilistic customer
$x'_{i,j,r}$	The amount of the type r product send from the i probabilistic customer to the j potential retailer center
$x'_{k_e k_{e'}, r}$	The amount of the type r product send from the facility center k_e to facility center $k_{e'}$ ($e, e' \in \{i, cc, re, dis, dc, w\}$)

$CO2AIR_{k_e k_{e'}, r}$	The amount of CO ₂ produced due to relocation of the type r from the facility center k_e to facility center $k_{e'}$ ($e, e' \in \{p, dc, w, j\}$)
$Co2AIR_{j,i,r}$	The amount of CO ₂ produced due to relocation of the type r from the j potential retailer center to the i probabilistic customer in time or meters
$CO2AIR'_{i,j,r}$	The amount of CO ₂ produced due to relocation of the type r from the i probabilistic customer to the j potential retailer center in time or meters
$CO2AIR'_{k_e k_{e'}, r}$	The amount of CO ₂ produced due to relocation of the type r from the facility center k_e to facility center $k_{e'}$ ($e, e' \in \{i, cc, re, dis, dc, w\}$)
$dicR$	Rectangular motion
$dicED$	Euclidean motion
$dicEDS$	Euclidean Square motion
$dicCH$	chebyshev motion
$AIR02$	The Percentage of carbon dioxide to oxygen
$COVER^1$	Expected distance coverage
$COVER^2$	Expected time coverage
$O2STANDARD$	The amount of O ₂ standard emissions

3.5. Decision variable

In this paper, only one decision variable is used as 0 and 1 to designate customers to retailers or vice versa.

$$Q_1 = \begin{cases} 1 & \text{if the retailer is allocated to the costumer} \\ 0 & \text{otherwise} \end{cases}$$

3.6. Model formulation

The mathematical model of this chain is in two stages. In the first step, the mathematical model is formulated among probabilistic customers and retailers, and in the second stage, the entire problem is formulated.

Step 1: Given that calculations are quite influential among retailers and probabilistic customers, first, assuming the type of movement by retailers to customers or vice versa and calculating the distance coverage radius of the retailers and the time coverage radius of customers and

comparing them with each other according to the heuristic algorithms, their minimum value is chosen and considered as the output of this section.

$$f = \min \left(\left\{ \sum_j^J FC_j + \sum_{i=1}^I \sum_{j=1}^J \sum_{r=1}^R x_{j,i,r} \times Cost_{j,i,r} \times \min(f_{1(j,i)}, f_{3(j,i)}) \right\} \times Q_1 \right. \\ \left. + \left\{ \sum_j^J FC_j + \sum_{j=1}^J \sum_{i=1}^I \sum_{r=1}^R x'_{i,j,r} \times Cost'_{i,j,r} \times \min(f_{2(i,j)}, f_{4(i,j)}) \right\} \right. \\ \left. \times (1 - Q_1) \right) \quad (1)$$

S.T

$$\theta_i < T_i \quad \forall i \in I \quad (2)$$

$$e_j < L_j \quad \forall j \in J \quad (3)$$

$$Q_1 + (1 - Q_1) = 1 \quad (4)$$

Equation (1) presents the objective function of the first step of the process among retailers and probabilistic customers within a parenthesis, which has two parts. The parts are distinguished by "{}". The first part of the selection is the calculation of the minimum coverage of the expected distance and the expected motion (Rectangular, Euclidean, Euclidean Square, and Chebyshev) of retailers to grant services to customers. The second part of the selection includes the minimum calculation of the amount of expected time coverage and the expected motion (Rectangular, Euclidean, Euclidean Square, and Chebyshev) of customers to receive services from retailers. Lastly, by comparing the chosen minimum costs, the lowest value is selected as the output. The output of this part explains whether the retailers convey the goods or the customers come to receive them. (2) Gives the maximum amount of time coverage radius of the customer. Constraint (3) gives the maximum motion radius of retailers. Equation (4) displays choosing the

decision variable. Step 2: In this step, according to Figure 1 of the modeling process, each of the input and output parts of the desired chain are calculated. Finally, it shows the value of the first target function (displacement cost) and the second objective function (the carbon dioxide emissions generated by the means of transport). See the related equation $f_{1(j,i)}$, $f_{2(i,j)}$, $f_{3(j,i)}$ and $f_{4(i,j)}$ In supplemental file part A.

$$TOTAL OBJECT1 = \min \left(\left\{ \sum_{k_e \in \{p, dc, w\}} FC_{k_e} + \sum_{k_e \in \{p, dc, w, j\}} \sum_r x_{k_e k'_e, r} \times \right. \right. \quad (5)$$

$$Cost_{k_e k'_e, r} \times dic_{k_e k'_e, r} \left. \right\} + \min\{f\} + \left\{ \sum_{k_e \in \{cc, re, dis\}} FC'_{k_e} + \right.$$

$$\left. \sum_{k_e \in \{i, cc, re, dis, dc, w\}} \sum_r x'_{k_e k'_e, r} \times Cost'_{k_e k'_e, r} \times dic'_{k_e k'_e, r} \right\} + \Omega_{cc, i, r}$$

$$TOTAL OBJECT2 = \max \left(AIRO2 \times \left(\min \left(\sum_{k_e \in \{p, dc, w\}} \sum_r CO2AIR_{k_e k'_e, r} \times \right. \right. \quad (6)$$

$$dic_{k_e k'_e, r} + \left(\sum_{i=1}^I \sum_{j=1}^J \sum_{r=1}^R \left(CO2AIR_{j, i, r} \times \left(\min(f_{1(j,i)}, f_{3(j,i)} \right) \right) \times Q_1 \right) + \right.$$

$$\left. \sum_{j=1}^J \sum_{i=1}^I \sum_{r=1}^R \left(CO2AIR'_{i, j, r} \times \left(\min(f_{2(i,j)}, f_{4(i,j)} \right) \right) \times (1 - Q_1) \right) \right) +$$

$$\sum_{k_e \in \{i, cc, re, dis, dc, w\}} \sum_r CO2AIR'_{k_e k'_e, r} \times dic'_{k_e k'_e, r} \left. \right) \left. \right)$$

S.T

$$\sum_{k_e | e \in \{p, dc, w, j, cc, re, dis\}} \tau_{k_e, r} \leq cap_{e \in \{p, dc, w, j, cc, re, dis\}} \quad \forall r \quad (7)$$

$$\sum_r \tau_{k_e, r} \leq cap_{k_e} \quad \forall k_e | e \in \{p, dc, w, j, cc, re, dis\} \quad (8)$$

$$\sum_{k_e | e \in \{p, dc, w, j, cc, re, dis\}} \tau_{k_e, r} \leq v_r \quad \forall r \quad (9)$$

$$\sum_{r=1}^R \mathfrak{W}_{i,r} \geq \mathfrak{W} \quad \forall r \quad (10)$$

$$\sum_{r=1}^R \mathfrak{W}_{i,r} \geq \mathfrak{W}_i \quad \forall i \quad (11)$$

$$\sum_{i=1}^I \mathfrak{W}_{i,r} \geq v_r \quad \forall r \quad (12)$$

$$\sum_{k_e, k'_{e'} | e, e' \in \{p, dc\}} x_{k_e k'_{e'}, r} + \sum_{k_e, k'_{e'} | e, e' \in \{p, w\}} x_{k_e k'_{e'}, r} = \sum_{k_e | e \in \{p\}} \tau_{k_e, r} \quad \forall r \quad (13)$$

$$\sum_r x_{k_e k'_{e'}, r} + \sum_r x'_{k_e k'_{e'}, r} \leq \sum_r \tau_{k_e, r} \quad (14)$$

$$\forall x_{k_e k'_{e'}} \in (e, e' \in \{p, dc\})$$

$$\forall x'_{k_e k'_{e'}} \in (e, e' \in \{re, dc\})$$

$$\forall \tau_{k_e} | e \in \{dc\}$$

$$\sum_{k_e, k'_{e'} | e, e' \in \{p, dc\}} x_{k_e k'_{e'}, r} + \sum_{k_e, k'_{e'} | e, e' \in \{re, dc\}} x'_{k_e k'_{e'}, r} \quad \forall r \quad (15)$$

$$= \sum_{k_e, k'_{e'} | e, e' \in \{dc, w\}} x_{k_e k'_{e'}, r} + \sum_{k_e, k'_{e'} | e, e' \in \{dc, j\}} x_{k_e k'_{e'}, r}$$

$$\sum_r x_{k_e k'_{e'}, r} + \sum_r x_{k_e k'_{e'}, r} + \sum_r x'_{k_e k'_{e'}, r} \leq \sum_r \tau_{k_e, r} \quad (16)$$

$$\forall x_{k_e k'_{e'}} \in (e, e' \in \{p, w\})$$

$$\forall x_{k_e k'_{e'}} \in (e, e' \in \{dc, w\})$$

$$\forall x'_{k_e k'_{e'}} \in (e, e' \in \{re, w\})$$

$$\forall \tau_{k_e} | e \in \{w\}$$

$$\sum_{x_{k_e k'_{e'}} \in (e, e' \in \{p, w\})} x_{k_e k'_{e'}, r} + \sum_{x_{k_e k'_{e'}} \in (e, e' \in \{dc, w\})} x_{k_e k'_{e'}, r} \quad \forall r \quad (17)$$

$$+ \sum_{x'_{k_e k'_{e'}, r} \in (e, e' \in \{re, w\})} x'_{k_e k'_{e'}, r} = \sum_{x_{k_e k'_{e'}} \in (e, e' \in \{w, j\})} x_{k_e k'_{e'}, r}$$

$$\sum_r x_{k_e k'_{e'}, r} + \sum_r x_{k_e k'_{e'}, r} \leq \sum_r \tau_{k_e, r} \quad (18)$$

$$\begin{aligned} & \forall x_{k_e k'_{e'}, r} \in (e, e' \in \{dc, j\}) \\ & \forall x_{k_e k'_{e'}, r} \in (e, e' \in \{w, j\}) \\ & \forall \tau_{k_e} | e \in \{j\} \end{aligned}$$

$$\sum_{x_{k_e k'_{e'}, r} \in (e, e' \in \{dc, j\})} x_{k_e k'_{e'}, r} + \sum_{x_{k_e k'_{e'}, r} \in (e, e' \in \{w, j\})} x_{k_e k'_{e'}, r} = \quad \forall r \quad (19)$$

$$\begin{aligned} & \left(\sum_{i=1}^I \sum_{j=1}^J x_{j,i,r} \right) \times Q_1 + \left(\sum_{j=1}^J \sum_{i=1}^I x'_{i,j,r} \right) \times (1 - Q_1) \\ & \left(\sum_{i=1}^I \sum_{j=1}^J x_{j,i,r} \right) \times Q_1 + \left(\sum_{j=1}^J \sum_{i=1}^I x'_{i,j,r} \right) \times (1 - Q_1) \geq \mathbb{W}_i \quad \forall r \quad (20) \end{aligned}$$

$$\begin{aligned} & \left(\sum_i^I \sum_j^J \alpha_{j,i,r} \times \sum_{i=1}^I \sum_{j=1}^J x_{j,i,r} \right) \times Q_1 \\ & + \left(\sum_j^J \sum_i^I \alpha_{i,j,r} \times \sum_{j=1}^J \sum_{i=1}^I x'_{i,j,r} \right) \times (1 - Q_1) \\ & = \sum_{x'_{k_e k'_{e'}, r} \in (e, e' \in \{i, cc\})} x'_{k_e k'_{e'}, r} \quad \forall r \quad (21) \end{aligned}$$

$$\sum_i^I \sum_j^J \alpha_{j,i,r} \times Q_1 + \sum_j^J \sum_i^I \alpha_{i,j,r} \times (1 - Q_1) \leq 1 \quad \forall r \quad (22)$$

$$\sum_{x'_{k_e k'_{e'}, r} \in (e, e' \in \{i, cc\})} x'_{k_e k'_{e'}, r} \leq \sum_{k_e | e \in \{cc\}} \tau_{k_e, r} \quad \forall r \quad (23)$$

$$\sum_{cc=1}^{CC} \sum_{i=1}^I \beta_{i,cc,r}^1 \times \sum_{x'_{k_e k'_{e'}, r} \in (e, e' \in \{i, cc\})} x'_{k_e k'_{e'}, r} = \sum_{x'_{k_e k'_{e'}, r} \in (e, e' \in \{cc, re\})} x'_{k_e k'_{e'}, r} \quad \forall r \quad (24)$$

$$\sum_{x'_{k_e k'_{e'}, r} \in (e, e' \in \{cc, re\})} x'_{k_e k'_{e'}, r} \leq \sum_{x'_{k_e k'_{e'}, r} \in (e, e' \in \{i, cc\})} x'_{k_e k'_{e'}, r} \quad \forall r \quad (25)$$

$$\sum_{cc}^{CC} \sum_i^I \beta_{i,cc,r}^2 \times \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{i,cc\})} x'_{kek'_{e'},r} = \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{cc,dis\})} x'_{kek'_{e'},r} \quad \forall r \quad (26)$$

$$\sum_{x'_{kek'_{e'},r} \in (e,e' \in \{cc,dis\})} x'_{kek'_{e'},r} \leq \sum_{k_e | e \in \{dis\}} \tau_{k_e,r} \quad \forall r \quad (27)$$

$$\sum_{x'_{kek'_{e'},r} \in (e,e' \in \{cc,dis\})} x'_{kek'_{e'},r} \leq \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{i,cc\})} x'_{kek'_{e'},r} \quad \forall r \quad (28)$$

$$\begin{aligned} \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{cc,re\})} x'_{kek'_{e'},r} + \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{cc,dis\})} x'_{kek'_{e'},r} \\ = \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{i,cc\})} x'_{kek'_{e'},r} \end{aligned} \quad \forall r \quad (29)$$

$$\sum_{re}^{RE} \sum_{cc}^{CC} \lambda_{cc,re,r}^1 \times \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{cc,re\})} x'_{kek'_{e'},r} = \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{re,dc\})} x'_{kek'_{e'},r} \quad \forall r \quad (30)$$

$$\sum_{re}^{RE} \sum_{cc}^{CC} \lambda_{cc,re,r}^2 \times \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{cc,re\})} x'_{kek'_{e'},r} = \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{re,dis\})} x'_{kek'_{e'},r} \quad \forall r \quad (31)$$

$$\sum_{re}^{RE} \sum_{cc}^{CC} \lambda_{cc,re,r}^3 \times \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{cc,re\})} x'_{kek'_{e'},r} = \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{re,w\})} x'_{kek'_{e'},r} \quad \forall r \quad (32)$$

$$\begin{aligned} \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{re,dc\})} x'_{kek'_{e'},r} + \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{re,dis\})} x'_{kek'_{e'},r} \\ + \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{re,w\})} x'_{kek'_{e'},r} = \sum_{x'_{kek'_{e'},r} \in (e,e' \in \{cc,re\})} x'_{kek'_{e'},r} \end{aligned} \quad \forall r \quad (33)$$

$$AIRO2 \times \left(\min \left(\sum_{k_e \in \{p,dc,w,j\}} \sum_r CO2AIR_{k_e k'_{e'},r} \times dic_{k_e k'_{e'},r} + \right. \right. \quad (34)$$

$$\begin{aligned}
& \left(\sum_{i=1}^I \sum_{j=1}^J \sum_{r=1}^R \left(CO2AIR_{j,i,r} \times \left(\min(f_{1(j,i)}, f_{3(j,i)}) \right) \times Q_1 \right) + \right. \\
& \left. \sum_{j=1}^J \sum_{i=1}^I \sum_{r=1}^R \left(CO2AIR'_{i,j,r} \times \left(\min(f_{2(i,j)}, f_{4(i,j)}) \right) \times (1 - Q_1) \right) \right) + \\
& \left. \sum_{k_e \in \{i,cc,re,dis,dc,w,j\}} \sum_r CO2AIR'_{k_e k'_{e'},r} \times dic'_{k_e k'_{e'},r} \right) \geq O2STANDAR
\end{aligned}$$

all Parameters ≥ 0 and $Q_1 = 0,1$.

Equation (5) is the objective function of the process, which consists of 3 parts, each separated by a "{" from the others. Part one includes the sum of the fixed and the variable costs of the transfer of goods, which are shipped from the production centers to the distribution centers and warehouse, in addition, includes the sum of the fixed and the variable costs of the transfer of goods, which are shipped from distribution centers and warehouse to retailers centers. Part two is calculated using Equation (1). Part three includes the entire fixed and variable cost of products that are returned by customers to the collection centers. After this stage are calculated fixed and variable costs of the transfer of goods from collection centers to repair and disposing center and finally are calculated fixed and variable costs of the transfer of goods from repair center to distribution and warehouse and disposing centers. Equation (6) shows the objective function of carbon dioxide emissions and converted to oxygen on the type of movement or coverage selection. Constraint (7) gives the maximum capacity of all facility centers Constraint (8) gives the maximum capacity of each facility. Constraint (9) declares the maximum amount of production r in each facility center. Constraint (10) shows the minimum demand of all customers. Constraint (11) says the minimum demand of each customer. Constraint (12) shows the minimum demand of each customer for different types of products. Constraint (13) presents the balance of entry and exit of products in production centers. Constraint (14) shows the maximum distribution of different types of goods in distribution centers. Constraint (15) shows the balance of entry and exit of different types of products in distribution centers. Constraint (16) shows

the maximum entry of all types of goods in each of the warehouse centers. Constraint (17) shows the balance of entry and exit of products in the warehouse centers. Constraint (18) shows the maximum entry capacity of each retail center. Constraint (19) gives the balance of entry and exit of goods in retail centers. In this restriction, according to algorithms 1 and 2, it is determined whether the retailers send the goods to the customers or the customers refer to the retailers to receive the goods. Constraint (20) indicates the minimum demand of each customer. In this constraint, according to algorithms 1 and 2, it is determined whether the retailers should send the goods or the customers should come to receive them. Constraint (21) shows the return percentage of goods from customers. Constraint (22) gives the total percentage of goods returned by customers, which is a maximum of 1. Constraint (23) gives the maximum capacity of goods joining the collection centers by all customers. Constraint (24) shows the number of goods that are shipped from the collection center to the revival centers. Constraint (25) states that the maximum number of revived goods is equal to the number of returned goods. Constraint (26) gives the percentage of goods sent from the total collection to the disposal centers. Constraint (27) shows that the maximum number of goods sent from the collection centers to the disposal centers is equal to the capacity of the disposal centers. Constraint (28) asserts that the maximum number of destroyed goods is equal to the number of returned goods. Constraint (29) presents the balance of goods entering and leaving in all collection centers. Constraint (30) gives the total percentage of goods shipped from the revival centers to the disposal centers. Constraint (31) gives the total percentage of goods shipped from the revival centers to the disposal centers. Constraint (32) presents the total percentage of goods that are shipped from the revival centers to the warehouse centers. Constraint (33) shows the balance of entry and exit of returned goods in revival centers. Constraint (34) gives the maximum standard of carbon dioxide.

3.7. Solution approach

The proposed model, in addition to decreasing costs by choosing the best place for retailers, also reduces the amount of carbon dioxide in retailers and customers by allowing the best place for retailers. In this model, in addition to the fact that retailers can be selected to send services, customers can also refer to

receive services. Due to the probabilistic nature of customers, first of all, the expected distances between customers and retailers are calculated per movement methods performed (Rectangular, Euclidean, Euclidean Square, and Chebyshev). These values are compared with MECD of retailers, which is displayed in algorithm 1 heuristically, and the minimum value is picked. Also, to allocate customers to retailers, considering the customer's movement methods and comparing it with MECT, which is presented in Algorithm 2 heuristically, the minimum value is chosen. At the end, by choosing the minimum cost from the two mentioned methods, the allocation and how to provide the service is determined Algorithm.

1: Allocating retailers to customers

Step 1: Initialization

-Generate the average longitudinal and transverse to the number of probabilistic customers

$$\mu_{11}, \mu_{21}, \dots, \mu_{I1}.$$

$$\mu_{12}, \mu_{22}, \dots, \mu_{I2}.$$

Step 2: Computing expected distance and cost

-Depending on the type of sending the goods from retailers to probabilistic customers (Rectangular, Euclidean, Euclidean Square, Chebyshev) Compute expected distance

-Calculate the cost of sending goods from retailers to potential customers using the second step

Step3:Computing distance coverage radius

-using the second step computes the maximum distance

$$\text{maximum distance} = \max(E[(dicR_{j,i}), (dicED_{j,i}), (dicEDS_{j,i}), (dicCH_{j,i})])$$

$$l_{j,i,r} = rand([1, MaxDistance])_{J \times I \times R}$$

Step4: Computing maximum and the minimum distance coverage radius

-For all retailers to provide services, calculate the minimum and the maximum distance coverage radius separately;

$$\text{Min and Max} = [L_j - \Theta_j \quad L_j + \Theta_j]$$

Step5: assign retailer

if :

$(l_{j,i,r}) \leq [L_j - \Theta_j]$ then calculate $\left\{ \sum_j^J FC_j + \sum_{i=1}^I \sum_{j=1}^J \sum_{r=1}^R x_{j,i,r} \times \text{Cost}_{j,i,r} \times \min(E[dic_{j,i,r}], E[\text{COVER}^1(l_{j,i,r})]) \right\}$ And assign the retailer to the $\max(E[dic_{j,i,r}], E[\text{COVER}^1(l_{j,i,r})])$

$L_j - \Theta_j < (l_{j,i,r}) \leq L_j$, then calculate $\left\{ \sum_j^J FC_j + \sum_{i=1}^I \sum_{j=1}^J \sum_{r=1}^R x_{j,i,r} \times \text{Cost}_{j,i,r} \times \min(E[dic_{j,i,r}], E[\text{COVER}^1(l_{j,i,r})]) \right\}$ And assign the retailer to the $\max(E[dic_{j,i,r}], E[\text{COVER}^1(l_{j,i,r})])$

$L_j < (l_{j,i,r}) \leq L_j + \Theta_j$, then calculate $\left\{ \sum_j^J FC_j + \sum_{i=1}^I \sum_{j=1}^J \sum_{r=1}^R x_{j,i,r} \times \text{Cost}_{j,i,r} \times \min(E[dic_{j,i,r}], E[\text{COVER}^1(l_{j,i,r})]) \right\}$ And assign the retailer to the $\max(E[dic_{j,i,r}], E[\text{COVER}^1(l_{j,i,r})])$

$(l_{j,i,r}) > L_j + \Theta_j$, then calculate $\left\{ \sum_j^J FC_j + \sum_{i=1}^I \sum_{j=1}^J \sum_{r=1}^R x_{j,i,r} \times \text{Cost}_{j,i,r} \times \min(E[dic_{j,i,r}], E[\text{COVER}^1(l_{j,i,r})]) \right\}$ And assign the retailer to the $\max(E[dic_{j,i,r}], E[\text{COVER}^1(l_{j,i,r})])$

Algorithm 2: Assigning customers to retailers

Step 1: Initialization

Generate the average longitudinal and transverse to the number of probabilistic

customers

$\mu_{11}, \mu_{21}, \dots, \mu_{I1}$.

$\mu_{12}, \mu_{22}, \dots, \mu_{I2}$.

Step 2: Computing expected distance and cost

Depending on the type of sending the goods from retailers to probabilistic customers (Rectangular, Euclidean, Euclidean Square, Chebyshev) Compute expected distance

Calculate the cost of sending goods from retailers to potential customers using the second step

Step3: Computing time coverage radius

using the second step computes the maximum distance

$$MaxTime = \max(E[(dicR_{i,j}), (dicED_{i,j}), (dicEDS_{i,j}), (dicCH_{i,j})])$$

$$t_{i,j,r} = rand([1, MaxTime])_{I \times J \times R}$$

Step4: Computing maximum and the minimum time coverage radius

For all retailers to provide services, calculate the minimum and the maximum time coverage radius separately;

$$Min \text{ and } max = [T_i - \theta_i \quad T_i + \theta_i]$$

Step5: assign customer

if:

$(t_{i,j,r}) \leq [T_i - \theta_i]$ then calculate $\left\{ \sum_j^J FC_j + \sum_{j=1}^J \sum_{i=1}^I \sum_{r=1}^R x'_{i,j,r} \times Cost'_{i,j,r} \times \min([dic_{i,j,r}], E[COVER^2(t_{i,j,r})]) \right\}$ And assign the customer to the max $([dic_{i,j,r}], E[COVER^2(t_{i,j,r})])$

$T_i - \theta_i < (t_{i,j,r}) \leq T_i$ then calculate $\left\{ \sum_j^J FC_j + \sum_{j=1}^J \sum_{i=1}^I \sum_{r=1}^R x'_{i,j,r} \times Cost'_{i,j,r} \times \right.$

$\min([dic_{i,j,r}], E[COVER^2(t_{i,j,r})])\}$ And assign the customer to the
 $\max([dic_{i,j,r}], E[COVER^2(t_{i,j,r})])$

$T_i < (t_{i,j,r}) \leq T_i + \theta_i$, then calculate $\{\sum_j^J FC_j + \sum_{j=1}^J \sum_{i=1}^I \sum_{r=1}^R x'_{i,j,r} \times Cost'_{i,j,r} \times$
 $\min([dic_{i,j,r}], E[COVER^2(t_{i,j,r})])\}$ And assign the customer to the max
 $([dic_{i,j,r}], E[COVER^2(t_{i,j,r})])$

$(t_{i,j,r}) > T_i + \theta_i$ then calculate $\{\sum_j^J FC_j + \sum_{j=1}^J \sum_{i=1}^I \sum_{r=1}^R x'_{i,j,r} \times Cost'_{i,j,r} \times$
 $\min([dic_{i,j,r}], E[COVER^2(t_{i,j,r})])\}$ And assign the customer to the max
 $([dic_{i,j,r}], E[COVER^2(t_{i,j,r})])$

By comparing the outputs of algorithm 1 and algorithm 2, we choose the minimum cost from them. If the lowest output value is related to algorithm number 1, then retailers ship goods to customers. Oppositely, customers will have to move to receive the products.

3.7.1. Non-Sorting-Genetic Algorithm II

General problem solving: The use of meta-heuristic algorithms will have highly profitable results in solving complex, difficult problems (X. Chen et al., 2018). Therefore, the use of the NSGA-II in solving unrestricted multi-objective problems is expanding swiftly (Pasandideh et al., 2015) (Forouzanfar et al., 2018). In this paper, due to the double-objective nature and multiplicity of constraints, this algorithm is employed to solve the general model of the SC. Figure 2 gives the flowchart of this type of algorithm. (Garg et al., 2012)

Figure2. Flow chart of the NSGA II

In addition, a Taguchi method is used to set the parameters of these algorithms to enhance their performance.

Table 2 shows proposed values for NSGA II algorithm parameters

Table 2: Proposed values for NSGA II algorithm parameters

mutation	Cross over	Pop number	Max number
0.2	0.4	80	200

See algorithm NSGA II calculations in the supplemental file part B

3.8. Numerical example

In this paper, to understand the problem model, a numerical example for the CLSC model presented in Figure 1. Is solved using MATLAB 16Ra coding. See numerical example data in the supplemental file part C.

4. Computational result

The GCLSC issue, as a multi-objective issue, is one of the most prominent branches in SC issues. Due to the entry of pollutants into the environment, much attention is paid to this issue nowadays. One of the primary measures in such issues is to decrease the service distance of retailers or lessen the time for customers to reach the service centers. In this study, which is a special case of CLSC issues, the problem is addressed by presenting heuristic allocation algorithms and focusing on retailers with known coordinates and the level of their coverage distance to send services. Moreover, customers have probabilistic coordinates and the coverage time of visiting the retail centers. In this model, for the first time, the optimal allocation is done by simultaneously comparing the distances and expected coverage of retailers and probabilistic customers. Also, using the NSGA-II algorithm, the best places of retailers are discovered. The distance coverage radius between retailers and the time coverage radius of the customers considering the amount of standard radius, upper and lower bounds of each of the retailers and customers is calculated. To block further dispersal in solving this example, we held the potential location search range for probabilistic customers within [1000, 10000] and the optimal search location for retail centers within [1000, 11000] spans. Thus, the optimal coordinates of retailers are calculated in the same span.

Figure3. Initial coordinates of retailers and probabilistic customers and standard, lower and upper coverage radius

Figure 4 shows the Random points of total cost and Oxygen emissions until reaching the optimal point.

Figure4. The Random point's chart

Figure5. The Pareto front chart of Numerical Sample

Regarding Figure 5, the results of problem-solving before and after solving with the NSGA-II algorithm are presented in Table 3. The results show that customers should turn to retailers for services.

Table3. Total system cost and O₂ emissions

	Results check	Cost and emission of O ₂ gas calculated by allocating the proposed algorithm		Cost and emission of O ₂ gas calculated by NSGA-II	
		CLGSC Total Cost	O ₂ (m ³)	CLGSC Total Cost	O ₂ (m ³)
1	The total cost of the system, if retailers provide services to probabilistic customers	11465231	1931	7253329	719.82
2	The total cost of the system, if probabilistic customers go to retailers for service	7484935	839	7030848	703.66
Conclusion		Customers go to retailers for services		Customers go to retailers for services	

In Figure 6, in addition to the initial coordinates of retailers and probabilistic customers, using the results of Table 3, the calculated optimal coordinates that retailers can offer to these customers are also depicted.

Figure6. Optimal coordinates of retailers

Table4. Retailer coordinates before and after solving by NSGA-II.

Number Retailer	Coordinates of the retailers before solving with NSGA-II	Coordinates of the retailers after solving with NSGA-II
1	[1700, 2000]	[6973.9 , 6352.9]
2	[5000 ,700]	[4955.3 , 6822.8]
3	[8500 ,7500]	[4280.1 , 5821.5]

Table5. Probabilistic customers assigned to Retailers

		Before solving by Nsga2			After solving by Nsga2		
		j=1	j=2	j=3	j=1	j=2	j=3
i=1	r=1		✓			✓	
	r=2			✓		✓	
i=2	r=1			✓			✓
	r=2		✓				✓
i=3	r=1		✓		✓		
	r=2	✓			✓		
i=4	r=1		✓			✓	
	r=2	✓					✓
i=5	r=1		✓		✓	✓	
	r=2	✓			✓		
i=6	r=1			✓		✓	
	r=2			✓			✓
i=7	r=1			✓	✓		
	r=2			✓	✓		
i=8	r=1	✓				✓	
	r=2	✓				✓	
i=9	r=1			✓		✓	
	r=2			✓		✓	
i=10	r=1	✓					✓
	r=2		✓				✓

Regarding to the results of this problem before and after solving NSGA-II and the allocation of retailers to customers Table 5 shows customers should for receiving desired goods Refer to retailers

Table 6 presents the decision of the customers regarding the type of motion or the use of coverage before and after the solution by the algorithm NSGA-II.

Table6. Deciding on the type of movement or coverage

		Before solving by Nsga2			After solving by Nsga2		
		j=1	j=2	j=3	j=1	j=2	j=3
i=1	r=1	COVER ²	COVER ²	COVER ²	COVER ²	dicED	COVER ²
	r=2	COVER ²	COVER ²	COVER ²	COVER ²	dicED	COVER ²
i=2	r=1	COVER ²	COVER ²	COVER ²	COVER ²	COVER ²	COVER ²
	r=2	COVER ²	COVER ²	COVER ²	COVER ²	COVER ²	dicCH
i=3	r=1	COVER ²	COVER ²	COVER ²	dicED	COVER ²	COVER ²
	r=2	COVER ²	COVER ²	COVER ²	dicED	COVER ²	COVER ²
i=4	r=1	COVER ²	COVER ²	COVER ²	COVER ²	COVER ²	COVER ²
	r=2	COVER ²	COVER ²	COVER ²	COVER ²	COVER ²	COVER ²
i=5	r=1	COVER ²	COVER ²	COVER ²	dicED	COVER ²	COVER ²
	r=2	COVER ²	COVER ²	COVER ²	dicED	COVER ²	COVER ²
i=6	r=1	COVER ²	COVER ²	COVER ²	COVER ²	dicED	COVER ²
	r=2	COVER ²	COVER ²	COVER ²	COVER ²	COVER ²	COVER ²
i=7	r=1	COVER ²	COVER ²	COVER ²	COVER ²	COVER ²	COVER ²
	r=2	COVER ²	COVER ²	COVER ²	COVER ²	COVER ²	COVER ²
i=8	r=1	COVER ²	COVER ²	COVER ²	COVER ²	dicED	COVER ²
	r=2	COVER ²	COVER ²	COVER ²	COVER ²	dicED	COVER ²
i=9	r=1	COVER ²	COVER ²	COVER ²	COVER ²	dicCH	COVER ²
	r=2	COVER ²	COVER ²	COVER ²	COVER ²	dicCH	COVER ²
i=10	r=1	COVER ²	COVER ²	COVER ²	COVER ²	COVER ²	dicED
	r=2	COVER ²	COVER ²	COVER ²	COVER ²	COVER ²	dicED

5. Conclusion

In this study, the structure of which is GCLSC, in the first stage, considering the probabilistic place of customers and the fixed location of retailers, the expected distance is calculated at the first step according to the type of movement (Rectangular, Euclidean, Ecclesiastical Square, Chebyshev). At the second step, based on the coverage radius, the distance between retailers and the time of probabilistic customers is calculated probabilistically by integral calculations. Additionally, how to allocate customers to retailers or vice versa is achieved by presenting algorithms 1 and 2. In the second stage, which is the general solution to the problem, the NSGA-

II algorithm is applied. The results of applying the model to the studied example indicate that concerning costs and O2 emissions, customers should move to retailers for receiving services. Moreover, considering the calculated expected coverage time, the type of motion is also hinted at. Furthermore, new coordinates are calculated for retailers, which come with the lowest cost for customers and enable the optimal allocation of retailers to customers. Using various scenarios in a time window, probabilistic demand and relocating time can be possible themes for future research

Declarations

Conflict of interest the author declares that have no conflict of interest

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