International Journal of Knowledge Processing Studies
(KPS)

Homepage: http://kps.artahub.ir/

ORIGINAL RESEARCH ARTICLE

Smart Model of Green Supply Chain for Pharmaceutical Products with Overlapping Common Customers

Manya Sadat Hashemian[1], Javad Rezaian[2,*], Amir Gholam Abri[3]

[1] Ph.D. Student of Industrial Management, Islamic Azad University, Firuzkoh branch, Firoozkooh, Iran. hashemian.manya@gmail.com, 0009-0009-8553-6026

[2] Associate Professor of Industrial Engineering, Mazandaran University of Science and Technology, Mazandaran, Iran. (Corresponding Author). j.rezaeian@ustmb.ac.ir, 0000-0003-1231-6208

[3] Associate Professor, Department of Mathematics, Firuzkoh Branch, Islamic Azad University, Firoozkooh, Iran. amirgholamabri@gmail.com, 0000-0003-1981-9756

ARTICLE INFO

Article History:
Received: 2023-07-26
Revised: 2023-08-10
Accepted: 2023-10-19
Published Online: 2024-09-01

Keywords:
Intelligent Model, Mathematical Programming, Green Supply Chain, Customer Overlap

Number of Reference: 32
Number of Figures: 0
Number of Tables: 0

DOI: 10.22034/kps.2023.408777.1151

ABSTRACT

The aim of the current research was to provide an intelligent model of the green supply chain of pharmaceutical products with the overlap of common customers. This research applies simulation to the proposed model of a pharmaceutical supply chain with smart and green conditions. The society under investigation is the environment of pharmaceutical companies, with its specific assumptions and goals. This model is simulated in the GAMZ software environment. The problem was examined from two perspectives: simultaneous production (coordination of drugs) and cooperative planning (coordination of suppliers). Additionally, in order to address the issue of vehicle routing under real conditions of limited capacity for delivery vehicles, the expiration date of the drug and time windows in orders were taken into consideration. The objective was to allocate orders to vehicles in a way that minimizes the total delivery time and reduces the amount of carbon dioxide produced. Based on the obtained results, this multi-objective model aims to improve the performance of the pharmaceutical distribution network by addressing three main complexities: economic, environmental, and social. This approach provides a comprehensive and balanced solution for designing the drug distribution network. Its goal is to preserve the environment, improve social conditions, and maximize economic profit. **©authors**

►**Citation:** Hashemian, M., Rezaian, J., & Gholam Abri, A. (2024). Smart Model of Green Supply Chain for Pharmaceutical Products with Overlapping Common Customers. *International Journal of Knowledge Processing Studies (KPS),* 4(3): 168-180. Doi: 10.22034/kps.2023.408777.1151

1. Introduction

Supply chains are highly complex networks that connect suppliers, manufacturers, and customers to ensure the flow of raw materials, intermediate goods, and final products to customers (Cammarano et al., 2023). They can be considered as the fundamental costs associated with creating a product and delivering it to the customer (Azevedo et al., 2021; Shao et al., 2021).

The significant effects that digital and data era technologies and intelligence have had on efficiency and process improvement have made them key drivers of green supply chains. These technologies are useful for optimizing operations, reducing material and energy consumption, and shortening operational processes (Sun et al., 2022). Reducing demand forecasting errors leads to improved inventory control. Custom manufacturing systems offer several advantages, including reduced production costs, increased production flexibility, shorter lead times, improved capacity utilization, minimized supply and time risks, enhanced real-time inventory control, and improved coordination between nodes. The rise of smart technologies in supply chains has contributed to the convergence of environmental efficiency and profitability. However, despite both leading to improved output, they operate within distinct contexts and pursue different ultimate objectives (Pasi et al., 2020). The concept of the smart supply chain aims to achieve the ambitious objective of transforming the global economy for the betterment of all individuals, communities, and the environment. This is accomplished by minimizing the environmental impact of business operations, while also leveraging scientific and technological advancements that are fueled by both basic and applied research. Technology pathways that fuel economic growth. From this perspective, it appears that green supply chains and smart supply chains are propelled by contrasting forces. This is why the present study explores an intelligent model of green supply chain management (De Giovanni et al., 2022; Su et al., 2020).

The supply chain of the pharmaceutical industry is a complex system that encompasses various processes, operations, and organizations. It involves the entire journey of drug discovery, development, and production, ultimately ensuring that pharmaceutical products of the highest quality are delivered to end-users at the right place and time (Fu et al., 2019). Vehicle routing with common customers refers to a group of transport companies that are willing to collaborate with each other in order to minimize distribution costs (Zhu et al., 2008; Wu et al., 2011; Varriale et al., 2021). In this problem, we assume that certain customers are shared by multiple companies, meaning they have a demand from more than one company. A shared customer may refer to a group of individual customers who seek services from different companies but are situated in close proximity, allowing one company to serve them in a single stop on the delivery route. In this context, cooperation between companies means that each company is willing to transfer a portion of their demand to other companies. Customers will switch only if the switch reduces the overall cost of distribution (Oguntegbe et al., 2023). On the other hand, companies exchange or share customer orders or requests. Also, capacity sharing includes scenarios where companies may acquire the capacity of joint partners in order to meet their customers' demands. In this case, the partner companies do not divide the customer demand, and each company delivers its own set of orders. Finally, it can be said that in this issue, a consortium of pharmaceutical companies operating in a densely populated urban area has shown willingness to collaborate in order to lower distribution costs and minimize carbon dioxide emissions. These companies operate in a smart, pharmaceutical green supply chain (Siegel et al., 2022).

In this research, a new model of cooperation in the smart green supply chain for pharmaceutical products has been presented. This model focuses on the collaboration between pharmaceutical companies and aims to optimize the potential benefits of their cooperation, particularly with common customers. In this model, we consider several interconnected pharmaceutical companies operating in the same area. Each company serves its customers from its own warehouse using its fleet of vehicles. One of the unique aspects of the smart green supply chain model for pharmaceutical products, which involves collaboration among pharmaceutical companies and serves common customers, is the utilization of separate warehouses by different pharmaceutical companies. Additionally, not all customers can be shared among these companies. Furthermore, the subsets of companies that can serve a common customer are not fixed, depending on the customer. In general, the objective of implementing a smart green supply chain model for pharmaceutical products, involving joint customers and collaboration among pharmaceutical companies, is to leverage the advantages of companies offering or delivering products to joint customers on behalf of other companies. This model aims to reduce costs in the green pharmaceutical supply chain with joint customers. In this research, several factors are simultaneously considered to bring the problem of vehicle routing closer to real conditions. These factors include limited vehicle capacity, the perishability of certain drugs with a fixed lifespan, and the minimization of carbon dioxide emissions. This combination of factors has not been investigated in similar research before, which increases the complexity of the problem. Therefore, this research aims to answer the question: What is the optimal model for implementing a sustainable and efficient supply chain for pharmaceutical products, specifically focusing on common customers with overlapping needs?

2. Literature Review

The smart green supply chain model refers to a supply chain management system that utilizes intelligent and sustainable technologies to enhance supply chain performance and minimize environmental impacts (Sislian et al., 2022). This model is based on the concepts and principles of the green supply chain, which aims to reduce the consumption of natural resources, the emission of greenhouse gases, and promote sustainability (Hohn et al., 2021). Using smart technologies such as the Internet of Things (IoT), supercomputing, artificial intelligence, and data analysis, this model aims to optimize and enhance processes and performance across the supply chain (Nayal et al., 2022). An intelligent green supply chain model can simultaneously reduce distribution costs and carbon dioxide emissions. Using intelligent algorithms and optimization methods, the model can automatically plan transportation routes (Merminod et al., 2021). This allows supply chain managers to choose routes that can reduce distribution costs and select the most optimal routes for transporting products. By reducing transportation distances, fuel costs and transportation costs are reduced (Gong et al., 2022). In the following, research on the integration of intelligence and green supply chain criteria has been discussed. D'Angelo et al. (2023) conducted a study titled "Green Supply Chains and Digital Supply Chains: Identifying Overlap Areas." They performed a bibliometric analysis of the literature on green supply chain and digital supply chain, using bibliographic data from articles to examine the scientific and theoretical trends in these research areas. Analyzing 131 studies from five different clusters where digital supply chains and green supply chains intersect, our findings revealed varying degrees of overlap within the identified clusters in the operational and environmental domains. Ali et al. (2022), in their research entitled "Mapping in Healthcare Operations and Supply Chain Management," showed that a significant reduction in operational costs and environmental damage can be achieved through the use of smart tools. Ahmad Amouei et al. (2023), in their research entitled "Presenting a Conceptual Model of a Sustainable Supply Chain in a Manufacturing Company," showed that it is possible to save time and money by considering digital and intelligent parameters, as well as reduce noise and air pollution. Zandieh et al. (2018), in their research titled "Sustainable Distribution

Network Design in the Pharmaceutical Supply Chain," demonstrated that companies in the global market must adopt sustainable practices to maintain their supply chain and remain competitive. This research presents a multi-objective model for designing a drug distribution network based on the key principles of sustainability, namely economic, environmental, and social factors. This model helps managers make strategic and technical decisions in the drug distribution network, including determining the capacity of the main and local distribution centers and managing the flow of drugs within the network. Minimizing costs and maximizing community welfare, while also minimizing adverse environmental impacts, is essential for making sustainable decisions. Asamoah et al. (2012) conducted a study on the pharmaceutical industry and proposed a robust methodology for assessing and choosing suppliers within a pharmaceutical company. The mentioned study specifically aimed to use the hierarchical analysis process method to select the most suitable suppliers of raw materials for antimalarial drugs as a case study. Meijboom and Obel (2007) conducted a study on the internal supply chain of an international pharmaceutical company. The company was characterized by a multi-stage and multi-locational operations structure. They examined the issues at three levels: strategic, tactical, and operational. They focused on the tactical level, identifying a model that encompassed both strategic and tactical issues and linked the tactical issues to organizational issues.

By applying intelligent techniques to manufacturing processes, significant improvements in energy and material efficiency can be achieved (Kumar et al., 2023). These improvements can lead to decreased energy consumption, minimized material losses, and reduced production-related carbon dioxide emissions. For example, automation and intelligent control of machinery, optimization of production and energy consumption in heating and lighting systems, and the utilization of intelligent algorithms to optimize production processes are among the potential solutions. Considering the importance of green suppliers and the utilization of renewable resources, the model can be influenced by this factor in the selection of suppliers as well as the appropriate transportation routes. This action can lead to a reduction in carbon dioxide emissions and a commitment to using more environmentally friendly resources. By utilizing sensors and intelligent monitoring systems, supply chain activities and processes can be monitored in real-time. This allows for the collection and analysis of data on energy consumption, costs, and greenhouse gas emissions. This information can help managers identify weaknesses and take appropriate actions to improve supply chain performance, reduce costs, and decrease carbon dioxide emissions. By employing intelligent algorithms, optimizing production and distribution processes, utilizing environmentally-friendly suppliers, and implementing smart monitoring systems, it is possible to simultaneously decrease distribution costs and carbon dioxide emissions in a sustainable green supply chain model. Therefore, it can be said that the smart model of the green supply chain focuses on the utilization of intelligent, optimized, and sustainable technologies across the entire supply chain to attain environmental and economic objectives associated with supply chain sustainability.

3. Method

This research applies simulation to the proposed model of a pharmaceutical supply chain with smart and green conditions. The society under investigation is the environment of pharmaceutical companies, with its specific assumptions and goals. This model is simulated in the GAMZ software environment. The problem was examined from two perspectives: simultaneous production (coordination of drugs) and cooperative planning (coordination of suppliers). Additionally, in order to address the issue of vehicle routing under real conditions of limited capacity for delivery vehicles, the expiration date of the drug and time windows in orders were taken into consideration. The objective was to allocate orders to vehicles in a way that minimizes the total delivery time and reduces the amount of carbon dioxide produced. In the continuation of this research, the parameters, variables, and limitations of the proposed problem model have been introduced. The objectives considered in this problem are: minimizing the total transportation amount, maximizing the satisfaction of demand points by meeting the demand for different products or minimizing unmet demand. To combine these two goals into a single objective, they are included in a target function with a specific turnover coefficient. Other objectives include minimizing the amount of carbon dioxide produced and reducing the overall distribution cost, which encompasses the sustainable economic aspect. A new model is presented in this way. After examining various aspects of the model, we explored different methods for solving the mathematical model. Additionally, a case study will be conducted in the pharmaceutical industry to apply the problem-solving approach. For this reason, in this article, we have considered the above problem as having dual objectives. The first objective is to minimize costs (intelligence objective), while the second objective is to reduce pollutants (green objective function).

4. Findings

The vehicle routing network for the distribution of perishable products is defined in a complete graph $G = (N, A)$, where $N = C \cup \{0\}$ and $A = \{(i, j) \mid i, j \in N\}$. The symbol "C" represents a set of customers, while "0" represents a warehouse. Each *arc* $(i,j) \in A$ is two-sided and asymmetric, with a travel time that is determined by both the Euclidean distance and the time it takes to depart from the origin *i*. Typically, there is a limited inventory of similar vehicles available either in stock or at the production site. In addition to meeting vehicle capacity restrictions and customer time windows, it is essential that no delivered goods are damaged at the time of delivery and that all requirements of selected customers are met. Assumptions: Customer demand is somewhat uncertain. Products have a limited lifespan, so after the end of each product's life cycle, it becomes spoiled. The location of customers is already known and fixed. When a vehicle leaves the warehouse, the quality of its cargo deteriorates. However, if the shipping time is within the shelf life of the product, the quality still meets the customer's requirements. For each customer, there is a limited time window within which service must be provided. Different time shifts have been considered for employees who need to serve customers during their designated shifts.

Validity and reliability of the data were based on the four criteria of trustworthiness, transferability, dependence and dependability and verifiability. Also, in simulation techniques, all environmental conditions are predicted with the assumption of uncertainty and relative stability, so validity and reliability are confirmed.

Indexes:

Point index (distribution base and customers, i=0 is the distribution point) $i,j=0,1,2,...,N$

Index of vehicles $k=1,2,...,K$

Index of products $p=1, 2,...,P$

Time shift $m=1, 2,...,M$

Parameters:

Distance between points *i* and *j* D_ij

Fuel consumption of vehicle *k* to deliver product from location *i* to *j* (liters per kilometer) ρ_ijk

Average vehicle consumption while waiting ρ_w

Waiting time of vehicle k at customer *i* W_ik

Customer service time *i* S_i

The cost of using vehicle k to travel between two places *i* and *j* CD_{ijk}

Variable cost for vehicle *k* CF_k

Fixed cost of using vehicle *k* CG_k

Shipping cost per product unit *p* CTp

Emission rate when the vehicle is in motion CER

Emission rate when the vehicle is waiting RES

Emissions when the vehicle is first started CST

Customer i's demand for product *p* DM_{ip}

A very large BN number

The capacity of vehicle k to deliver the consignment to customers CAP_k

Travel time by vehicle *k* from location *i* to *j* T_{ijm}

End of time shift *m* TM_m

The earliest possible time to serve customer *i* in time shift *m* EST_{im}

The latest possible service time for customer *i* in time shift *m* LST_{im}
The latest possible service time for customer *i* in time shift *m* LPp

Variables

Total amount of product p delivered to customer *i* Q_{ip}
Arrival time of vehicle k at location *i* in time shift *m* A_{ikm}
Departure time of vehicle k to location *i* in time shift *m* L_{ikm}
If vehicle k moves from location *i* to location *j* in time shift *m* $X_{ijkm}= \{0,1\}$
If vehicle *k* is used in time shift m, $Z_{km}= \{0,1\}$

The objective function of the problem

The proposed model includes two objective functions. The first objective function is the operating cost due to transportation, servicing and use of the vehicle. The second objective function is the environmental effects caused by fuel consumption for transportation, service and vehicle use. Both objective functions are minimization type. In fact, the first objective function includes the total cost of using the vehicle to move between two points, the cost of waiting for each customer, the cost of unloading, the fixed cost of using the vehicle and the cost of sending the product to customers:

(1)

$$Operation\ Cost = \sum_{i=0}^{N}\sum_{j=0}^{N}\sum_{k=1}^{K}\sum_{m=1}^{M}\left(\left(D_{ij} \times CD_{ijk} + W_{jk} \times CF_k + S_j \times CF_k\right) \times X_{ijkm}\right) + \sum_{k=1}^{K}\sum_{m=1}^{M} Z_{km} \times CG_k + \sum_{i=1}^{N}\sum_{p=1}^{P} Q_{ip} \times CT_p$$

Environmental function The environmental objective function is equal to the sum of pollutant gas emissions from transportation between two locations (from warehouse to customer, from one customer to another customer, from customer to warehouse), pollutant gas emissions from waiting for a customer, pollutant gas emissions from servicing, and fixed emissions from choosing a vehicle. Therefore, the environmental function is defined as the following equation:

(2)

$$Envromental\ impact = \sum_{i=0}^{N}\sum_{j=0}^{N}\sum_{k=1}^{K}\sum_{m=1}^{M}\left(\left(D_{ij} \times \rho_{ijk} \times CER + W_{jk} \times \rho_w \times RES + S_j \times \rho_w \times RES\right) \times X_{ijkm}\right) + \sum_{k=1}^{K}\sum_{m=1}^{M} Z_{km} \times CST$$

Limitations of the problem

The limitations of this problem can also be placed in the following categories for further explanation:

Customer restrictions

Constraints (4) and (5) ensure that each customer is visited only once.

(4)

$$\sum_{j=1}^{N}\sum_{k=1}^{K}\sum_{m=1}^{M} X_{ijkm} = 1 \quad \forall i \in N$$

(5)

$$\sum_{i=1}^{N}\sum_{k=1}^{K}\sum_{m=1}^{M} X_{ijkm} = 1 \quad \forall j \in N$$

Vehicle restrictions

Constraint (6) guarantees that customers are visited by active vehicles. This equation is as follows.

(6)

$$X_{ijkm} \le Z_{km} \qquad \forall i، j، k، m$$

Local visit restrictions

Limitation (7) shows that every vehicle must leave that place after visiting a place.

(7)

$$\sum_{i=1}^{N} X_{ijkm} - \sum_{i=1}^{N} X_{jikm} = 0 \qquad \forall j, k, m$$

Stock restrictions

Constraints (8) and (9) ensure that the number of input and output devices to a warehouse are equal in each time shift. These limits are defined as follows:

(8)
$$\sum_{j=2}^{N} X_{0jkm} \leq Z_{km} \quad \forall k, m$$

(9)
$$\sum_{i=2}^{N} X_{i0km} \leq Z_{km} \quad \forall k, m$$

Demand limit

In this limit, it is ensured that the customer's demand is met.

(10)
$$Q_{ip} \geq DM_{ip} \quad \forall i \text{،} p$$

Vehicle capacity limitations:

Limits (11) and (12) guarantee that the amount of products transported by each vehicle does not exceed the capacity of that vehicle.

(11)
$$Q_{jp} \leq \sum_{i=0}^{N} \sum_{k=1}^{K} \sum_{m=1}^{M} X_{ijkm} \times BN \quad \forall j \text{،} p$$

(12)
$$\sum_{p=1}^{p} Q_{ip} \leq Z_{km} \times CAP_k \quad \forall i \text{،} k \text{،} m$$

Entry time limits

Constraints (13) and (14) calculate the arrival time of vehicles to serve each customer.

(13)
$$A_{jkm} \geq A_{ikm} + T_{ijm} - (1 - X_{ijkm}) \times BN \quad \forall i \text{،} j \text{،} k \text{،} m$$

(14)
$$A_{jkm} \leq A_{ikm} + T_{ijm} - (1 - X_{ijkm}) \times BN \quad \forall i, j, k, m$$

Checkout Time Limits

Constraint (15) calculates the departure time of each vehicle from each customer after entering and delivering the product.

(15)
$$L_{ikm} = A_{ikm} + S_i \quad \forall i \text{،} k \text{،} m$$

Time window limitations

Time window constraints ensure that each customer is served in his own time window

(16)
$$A_{ikm} \geq EST_{im} \quad \forall i \text{،} k \text{،} m$$

(17)
$$L_{ikm} \leq LST_{im} \quad \forall i \text{،} k \text{،} m$$

Time limits for leaving the warehouse

Constraint (18) states that the time each vehicle leaves the warehouse is equal to zero (the start of the time shift).

(18)
$$L_{0km} = 0 \quad \forall k \text{،} m$$

Time shift restrictions

In this restriction, it is stated that the time of entering the warehouse must be before the end of the shift.

(19)
$$A_{0km} \leq TM_m \quad \forall k \text{،} m$$

Product Lifetime Limits

This limitation shows that the products sent to each customer must be delivered before the lifetime of the most critical product sent. This limit is defined as equation:

(20)
$$A_{jkm} + (W_{jk} + S_j) \times X_{ijkm} \leq LP_p \quad \forall i \text{،} j \text{،} k \text{،} m \text{،} p$$

Constraints on the sign of variables

In this limit, the direction and value of the decision making variables are shown.

(21)
$$Q_{ip} \text{،}\ A_{jkm} \text{،} L_{ikm} \geq 0\ ; X_{ijkm} \text{،}\ Z_{km} = \{0 \text{،} 1\}$$

The final model. In this model, the demand is considered uncertain. That is, either there is no accurate information available for the desired parameters, or the available information is insufficient to predict the future situation. For example, a new drug has been developed. There is no historical data available on the level of demand, and even the information on the actual and potential number of patients is insufficient to accurately predict the demand. In this research, the proposed model is developed based on the theory of belief uncertainty. Based on this theory, the demand parameter is represented as ξ_(DM_ip). To confirm the proposed model, it is necessary to convert the non-deterministic model into a deterministic model in order to solve it. In this article, we simultaneously consider two methods, expected values and critical values (EV-CCM), to transform the model into a deterministic state. The demand equation is non-deterministic, and it is defined using the expected method and critical value as follows:

(1)
$$M\left\{Q_{ip} \geq \xi_{DM_{ip}}\right\} \geq \gamma^1_{i،p} \quad \forall i،p$$

Now, using the following theorem and inference, equation (1) becomes a definite equation. the case; Since the parameter $\xi_{DM_{ip}}$ is independent of other parameters of the model, then the parameter $\xi_{DM_{ip}}$ has a regular distribution $\emptyset_{DM_{ip}}$. In this case, equation (1) is rewritten as follows:

(2)
$$Q_{ip} \geq \varphi^{-1}_{\xi_{DM_{ip}}}\left(\gamma^1_{i،p}\right) \quad \forall i،p$$

Argument; Based on the above theorem, the demand limit, i.e. equation (45), is rewritten as follows:

$$M\left\{Q_{ip} \geq \xi_{DM_{ip}}\right\} \geq \gamma^1_{i،p} \Leftrightarrow M\left\{Q_{ip} - \xi_{DM_{ip}} \geq 0\right\} \geq \gamma^1_{i،p} \Leftrightarrow Q_{ip} \geq \varphi^{-1}_{\xi_{DM_{ip}}}\left(\gamma^1_{i,p}\right)$$

Therefore, the above theorem is deduced based on the mentioned proof. The first result; As stated, since the parameter $\xi_{DM_{ip}}$ is independent, the demand parameter has a regular zigzag distribution Z(a,b,c). In this case, the possible limit for confidence value $\gamma^1_{i،p}$ less than 0.5 is rewritten as follows:

$$Q_{ip} \geq \left(1 - 2\gamma^1_{i،p}\right)a_{DM_{ip}} + 2\gamma^1_{i،p}\, b_{DM_{ip}} \quad \forall i،p$$

The second result; As stated in the above theorem, since the parameter $\xi_{DM_{ip}}$ is independent, the demand parameter has a regular zigzag distribution Z(a,b,c). In this case, the possible limit for the confidence value $\gamma^1_{i،p}$ equal to and greater than 0.5 is rewritten as follows:

$$Q_{ip} \geq \left(2 - 2\gamma^1_{i،p،t}\right)b_{DM_{ip}} + \left(2\gamma^1_{i،p} - 1\right)c_{DM_{ip}} \quad \forall i،p$$

As stated, the uncertain demand equation (based on confidence values less than 50% and more than 50%) has been rewritten in the above form. Since this thesis is designed to respond to the distribution of pharmaceutical products.

$$Min\, Z^1 = Operation\ Cost = \sum_{i=0}^{N}\sum_{j=0}^{N}\sum_{k=1}^{K}\sum_{m=1}^{M}\left(\left(D_{ij} \times CD_{ijk} + W_{jk} \times CF_k + S_j \times CF_k\right) \times X_{ijkm}\right) + \sum_{k=1}^{K}\sum_{m=1}^{M} Z_{km} \times CG_k + \sum_{i=1}^{N}\sum_{p=1}^{P} Q_{ip} \times CT_p$$

$$Min\, Z^2 = Envromental\ impact = \sum_{i=0}^{N}\sum_{j=0}^{N}\sum_{k=1}^{K}\sum_{m=1}^{M}\left(\left(D_{ij} \times \rho_{ijk} \times CER + W_{jk} \times \rho_w \times RES + S_j \times \rho_w \times RES\right) \times X_{ijkm}\right) + \sum_{k=1}^{K}\sum_{m=1}^{M} Z_{km} \times CST$$

ST:

$$\sum_{j=1}^{N}\sum_{k=1}^{K}\sum_{m=1}^{M} X_{ijkm} = 1 \quad \forall i \in N$$

$$\sum_{i=1}^{N}\sum_{k=1}^{K}\sum_{m=1}^{M} X_{ijkm} = 1 \quad \forall j \in N$$

$$X_{ijkm} \leq Z_{km} \quad \forall i،j،k،m$$

$$\sum_{j=2}^{N} X_{0jkm} \leq Z_{km} \quad \forall k,m \qquad \sum_{i=1}^{N} X_{ijkm} - \sum_{i=1}^{N} X_{jikm} = 0 \quad \forall j،k،m$$

$$\sum_{i=2}^{N} X_{i0km} \leq Z_{km} \quad \forall k،m$$

$$Q_{ip} \geq \left(1 - 2\gamma^1_{i،p}\right)a_{DM_{ip}} + 2\gamma^1_{i،p}\, b_{DM_{ip}} \quad \forall i،p$$

$$Q_{jp} \leq \sum_{i=0}^{N}\sum_{k=1}^{K}\sum_{m=1}^{M} X_{ijkm} \times BN \quad \forall j،p$$

$$\sum_{p=1}^{p} Q_{ip} \leq Z_{km} \times CAP_k \quad \forall i،k،m$$

$$A_{jkm} \geq A_{ikm} + T_{ijm} - \left(1 - X_{ijkm}\right) \times BN \quad \forall i،j،k،m$$

$$A_{jkm} \leq A_{ikm} + T_{ijm} - \left(1 - X_{ijkm}\right) \times BN \quad \forall i،j،k،m$$

$$L_{ikm} \leq LST_{im} \quad \forall i،k،m$$

$$L_{0km} = 0 \quad \forall k،m$$

$$A_{0km} \leq TM_m \quad \forall k،m$$

$$A_{jkm} + \left(W_{jk} + S_j\right) \times X_{ijkm} \leq LP_p \quad \forall i،j،k،m،p$$

$$Q_{ip}،A_{jkm}،L_{ikm} \geq 0\,; X_{ijkm}،Z_{km} = \{0،1\}$$

Data simulation to test the effectiveness of the proposed model

Indices and sets

Index of distribution base and customers 1 and 2 = *i*

Vehicle index 1 = *k*

Index of products 1 = *p*

Time shift 1 = *m*

Parameters:

Distance between points i and j = D_{ij}

	1	2
1	150	250
2	450	200

Waiting time of vehicle *k* at customer *j* = *wjk*

	1
1	30
2	45

Fuel consumption of vehicle 1 to deliver product from location *i* to location *j*= up_{ijk}

	1
1.1	1700
1.2	1500
2.1	1400
2.2	1800

Si = Customer service time *i*

S (i)=40 S(2)=50

The cost of using vehicle k to travel between location *i* and *j* CD (k, j, & i)

	1
1.1	20
1.2	15
2.1	10

Fixed cost of using = *CG(k)*

vehicle k 800 = *CG (1)*

Variable cost for vehicle k = *CFK*

1100 = CF (1) = *CFK*

Shipping cost per product unit *CTP=1*

2800 = *CT (1)*

Customer i's demand for product *p* = DM_{ip} which has a middle bound, an upper bound and a lower bound, because the demand of customers in different periods of time is not a constant value.

LDM (p, i) Lower bound

	1
1	100
2	150

gamma = MDM = Middle bound

$D_{(i,j)}$ =

	1
1	200
2	250

uDM = upper bound

	1
1	300
2	250

Travel time by vehicle *k* from location *i* to location *j* in time shift *m*

$T_{(i,j,m)}$

	1
1.1	1000
1.2	500
2.1	400
2.2	800

Capacity of vehicle 1 for delivery to customers *Cap(k)*

Cap(1) =200

TM(m)= TM(1) end of time shift *m* = 2300

The earliest possible service time for EST_{im} customers *EST*

	1
1	750
2	600

The latest possible service time for an EST_{im} customer *i* in time advance *m* EST_{im}

	1
1	2000
2	2500

*The latest possible time to serve customer *i* in time shift *M* LP_p

LP(1)=1500

The emission rate of polluting gases when the vehicle is moving = *CER*

CER=0.5

*BN=900000**

Positive variables

Departure time of vehicle k to place

m = $L_{(i,k,m)}$

Arrival time of vehicle k to place *i* in

m = $A_{(I,k,m)}$

The total amount of product P delivered to customer

i = $Q_{(i,p)}$

The emission rate when the vehicle first starts CST = 3.0. *CST*

Emission rate of polluting gases = *RES* When the vehicle is waiting 4.0 = *RES*

UPW=10 maximum vehicle fuel consumption = *UPW*

Binary variables: $x_{(i,j,k,m)}$
If vehicle K moves from location *i* to location *j* in time shift *m*.
Operating cost objective function = Z_1
Environmental function = Z_2
Total objective function = *ZT*
If vehicle k is used in time shift m = Z_{km}

After placing the given hypothetical numbers in the designed model and solving the problem with the help of GAMZ software, the optimal values of the transportation model are obtained, which are specified below.
Total amount of product *P* delivered to customer *i*

Variable *Q*

	1
1	180
2	230

Departure time of vehicle *k* to location *i* in time shift *m*
Variable *L*

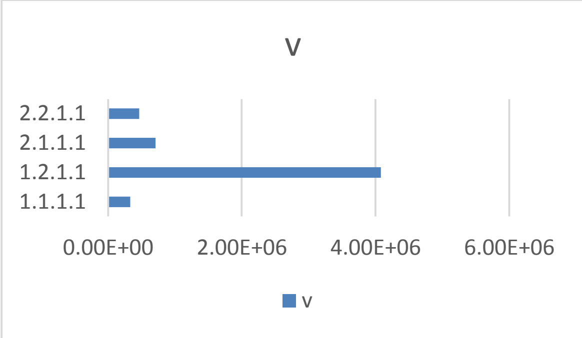
	1
101	790
102	1455

The arrival time of vehicle *k* at location *i* in shift *m*
Variable *A*

	1
101	750
102	1405

If vehicle *k* moves from location *i* to location *j* in time shift *m*
Variable *X*

1.1.1.1	0	3.3378E+5
1.2.1.1	1	40.8175E+5
2.1.1.1	1	7.0953E+5
2.2.1.1	0	4.6738E+5



If vehicle *k* is used in time shift *m*, Z_{km}
Variable *Z*

101	1	800

The objective function value of operating cost obtained from the linear model of transportation
Z_1 =2335300.00 total COS1

The environmental function value obtained from the linear transport model
Z_2=4785.300 environmental impact

The value of the exponential objective function obtained from the linear transport model
Z_t=2340085.300

5. Discussion

This research discusses a multi-objective model for designing a pharmaceutical distribution network based on the main principles of sustainability, including economic, environmental, and social factors. The primary objective function was cost-related, aiming to minimize transportation costs for products from production centers to distribution centers and from distribution centers to customers. The second goal was to reduce CO_2 emissions from the distribution network. The third objective function was to maximize social welfare, specifically by increasing the employment rate, in the performance of the pharmaceutical distribution network. This research presents a multi-objective model for designing the pharmaceutical distribution network based on the three main concepts of sustainability: economic, environmental, and social (Mak et al., 2021). The primary objective of this research is to enhance the stability of the pharmaceutical distribution network. In the first objective, the aim is to reduce product transportation costs in the pharmaceutical distribution network. By minimizing transportation costs (Yu et al., 2010; Vishwakarma et al., 2016), it is possible to facilitate and improve the process of drug distribution. This performance can lead to a reduction in the final costs of products for customers. In the second objective, the reduction of CO_2 emissions from the pharmaceutical distribution network (Shah, 2004) has been considered as a goal. According to global developments and environmental requirements, it is possible to reduce greenhouse gas emissions, such as CO_2, by improving transportation methods and reducing fossil fuel consumption. This will help improve the quality of the environment and preserve natural resources. The third goal of this research is to maximize social welfare in the pharmaceutical distribution network's performance (Ahmadi et al., 2018; Holmström et al., 2019). By increasing the employment rate and creating job opportunities in the field of drug distribution, it is possible to have a positive effect on society and increase the level of social welfare. With its multi-objective model, this research aims to enhance the performance of the pharmaceutical distribution network by addressing three main complexities: economic, environmental, and social. This approach provides a comprehensive and balanced solution for designing the drug distribution network. Its goal is to preserve the environment, improve social conditions, and maximize economic profit. The intelligent model of the pharmaceutical green supply chain is a comprehensive and balanced solution for designing a pharmaceutical distribution network that prioritizes economic, environmental, and social sustainability. By utilizing the intelligent model of the pharmaceutical green supply chain, this study examines the potential to enhance the performance of the pharmaceutical distribution network across three key areas. First, by optimizing costs, it is possible to reduce the expenses associated with transporting products from production centers to distribution centers and subsequently from distribution centers to customers. This issue leads to a reduction in the final costs of products for customers. By implementing strategies and enhancing transportation processes, the emission of greenhouse gases, such as CO_2, from the distribution network can be optimized. This work is accomplished by improving transportation methods, reducing the consumption of fossil fuels, and increasing the utilization of green and sustainable methods in the pharmaceutical distribution network.

6.Conclusion

The smart model of the pharmaceutical green supply chain maximizes efficiency and job opportunities in the field of drug distribution by emphasizing the improvement of social welfare. This helps to increase the employment rate and improve the social conditions of society. The intelligent model of the pharmaceutical green supply chain is a comprehensive and well-balanced solution that enhances the performance and sustainability of the pharmaceutical distribution network. It achieves this by optimizing costs, reducing CO_2 emissions, and improving social welfare. This approach focuses on maximizing economic profit while also preserving the environment and creating social value at the same time. Based on the obtained results, the following practical suggestions are presented:

- The intelligent model of pharmaceutical green supply chain can be used as a tool to improve the efficiency and plan the performance of the pharmaceutical distribution network. By optimizing processes, allocating resources and improving transportation methods, it is possible to reduce costs and increase the productivity of processes. - This model can promote the improvement of transportation methods and the use of green and sustainable methods in the pharmaceutical distribution network. By applying energy management strategies and reducing the consumption of fossil fuels, the emission of greenhouse gases such as CO_2 will be significantly reduced.

- This model can help to maximize social welfare in the operation of pharmaceutical distribution network. By creating job opportunities and increasing the employment rate in the field of drug distribution, a positive impact on the society and increasing the level of social welfare is created.
- By improving distribution processes and reducing shipping time, the intelligent green pharmaceutical supply chain model can provide improved quality and access to medicines. By optimizing routes and distributing medicines more effectively, it is possible to improve customer service and maintain the health of the community.
- This model has the ability to evaluate and compare different scenarios. Using it, it is possible to analyze the advantages and disadvantages of different scenarios in terms of costs, CO2 emissions, and social welfare, and make the necessary improvements.

Funding

For example: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
If there is any fund, please mention.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Ahmad Amouei, M., Valmohammadi, C. & Fathi, K. (2023). Proposing a conceptual model of the sustainable digital supply chain in manufacturing companies: a qualitative approach, *Journal of Enterprise Information Management*, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/JEIM-08-2022-0269

Ahmadi, A., Mousazadeh, M., Torabi, S. A., & Pishvaee, M. S. (2018). Or applications in pharmaceutical supply chain management. *Operations research applications in health care management*, 461-491.

Ali, I., & Kannan, D. (2022). Mapping research on healthcare operations and supply chain management: a topic modelling-based literature review. *Annals of Operations Research*, *315*(1), 29-55. https://doi.org/10.1007/s10479-022-04596-5

Asamoah, D., Annan, J., & Nyarko, S. (2012). AHP approach for supplier evaluation and selection in a pharmaceutical manufacturing firm in Ghana. *International Journal of Business and Management*, 7 (10), 49-62.

Azevedo, S. G., Pimentel, C. M., Alves, A. C., & Matias, J. C. (2021). Support of advanced technologies in supply chain processes and sustainability impact. *Applied Sciences*, *11*(7), 3026.

Cammarano, A., Varriale, V., Michelino, F., & Caputo, M. (2023). A Framework for Investigating the Adoption of Key Technologies: Presentation of the Methodology and Explorative Analysis of Emerging Practices. *IEEE Transactions on Engineering Management*.

D'Angelo, V., & Belvedere, V. (2023). Green Supply Chains and Digital Supply Chains: Identifying Overlapping Areas. *Sustainability*, *15*(12), 9828. doi.org/10.3390/su15129828

De Giovanni, P., Belvedere, V., & Grando, A. (2022). The selection of industry 4.0 technologies through Bayesian networks: an operational perspective. *IEEE Transactions on Engineering Management*.

Fu, H. P., Chang, T. S., Yeh, H. P., & Chen, Y. X. (2019). Analysis of factors influencing hospitals' implementation of a green e-procurement system using a cloud model. *International journal of environmental research and public health*, *16*(24), 5137.

Gong, Y., Wang, Y., Frei, R., Wang, B., & Zhao, C. (2022). Blockchain application in circular marine plastic debris management. *Industrial Marketing Management*, *102*, 164-176. doi: 10.1016/j.indmarman.2022.01.010.

Hohn, M. M., & Durach, C. F. (2021). Additive manufacturing in the apparel supply chain—impact on supply chain governance and social sustainability. *International Journal of Operations & Production Management*, *41*(7), 1035-1059. doi: 10.1108/IJOPM-09-2020-0654.

Holmström, J., Holweg, M., Lawson, B., Pil, F. K., & Wagner, S. M. (2019). The digitalization of operations and supply chain management: Theoretical and methodological implications. *Journal of Operations Management*, *65*(8), 728-734. doi: 10.1002/joom.1073.

Kumar, P., Sharma, D., & Pandey, P. (2023). Coordination mechanisms for digital and sustainable textile supply chain. *International Journal of Productivity and Performance*

Management, *72*(6), 1533-1559. https://doi.org/10.1108/IJPPM-11-2020-0615

Mak, H. Y., & Max Shen, Z. J. (2021). When triple-A supply chains meet digitalization: The case of JD. com's C2M model. *Production and Operations Management*, *30*(3), 656-665. doi: 10.1111/poms.13307.

Merminod, V., Le Dain, M. A., & Frank, A. G. (2022). Managing glitches in collaborative product development with suppliers. *Supply Chain Management: An International Journal*, *27*(3), 348-368. doi: 10.1108/SCM-01-2020-0042.

Meijboom, B., & Obel, B. (2007). Tactical coordination in a multi-location and multi-stage operations structure: A model and a pharmaceutical company case. *Omega*, *35*(3), 258-273.

Nayal, K., Raut, R. D., Yadav, V. S., Priyadarshinee, P., & Narkhede, B. E. (2022). The impact of sustainable development strategy on sustainable supply chain firm performance in the digital transformation era. *Business Strategy and the Environment*, *31*(3), 845-859.

Oguntegbe, K. F., Di Paola, N., & Vona, R. (2023). Communicating responsible management and the role of blockchain technology: social media analytics for the luxury fashion supply chain. *The TQM Journal*, *35*(2), 446-469. https://doi.org/10.1108/TQM-10-2021-0296

Pasi, B. N., Mahajan, S. K., & Rane, S. B. (2020). Smart supply chain management: a perspective of industry 4.0. *Supply Chain Management*, *29*(5), 3016-3030.

Shah, N. (2004). Pharmaceutical supply chains: key issues and strategies for optimisation. *Computers & chemical engineering*, *28*(6-7), 929-941.

Shao, X. F., Liu, W., Li, Y., Chaudhry, H. R., & Yue, X. G. (2021). Multistage implementation framework for smart supply chain management under industry 4.0. *Technological Forecasting and Social Change*, *162*, 120354. doi: 10.1016/j.techfore.2020.120354.

Siegel, R., Antony, J., Govindan, K., Garza-Reyes, J. A., Lameijer, B., & Samadhiya, A. (2022). A framework for the systematic implementation of Green-Lean and sustainability in SMEs. *Production Planning & Control*, 1-19.

Sislian, L., & Jaegler, A. (2022). Linkage of blockchain to enterprise resource planning systems for improving sustainable performance. *Business Strategy and the Environment*, *31*(3), 737-750.

Su, Y., Yu, Y., & Zhang, N. (2020). Carbon emissions and environmental management based on Big Data and Streaming Data: A bibliometric analysis. *Science of The Total Environment*, *733*, 138984.

Sun, X., Yu, H., Solvang, W. D., Wang, Y., & Wang, K. (2021). The application of Industry 4.0 technologies in sustainable logistics: A systematic literature review (2012–2020) to explore future research opportunities. *Environmental Science and Pollution Research*, 1-32.

Varriale, V., Cammarano, A., Michelino, F., & Caputo, M. (2021). Sustainable supply chains with blockchain, IoT and RFID: A simulation on order management. *Sustainability*, *13*(11), 6372.

Vishwakarma, V., Prakash, C., & Barua, M. K. (2016). A fuzzy-based multi criteria decision making approach for supply chain risk assessment in Indian pharmaceutical industry. *International Journal of Logistics Systems and Management*, *25*(2), 245-265.

Wu, Z., & Pagell, M. (2011). Balancing priorities: Decision-making in sustainable supply chain management. *Journal of operations management*, *29*(6), 577-590. doi: 10.1016/j.jom.2010.10.001.

Yu, X., Li, C., Shi, Y., & Yu, M. (2010). Pharmaceutical supply chain in China: current issues and implications for health system reform. *Health policy*, *97*(1), 8-15.

Zandieh, M., Janatyan, N., Alem-Tabriz, A., & Rabieh, M. (2018). Designing sustainable distribution network in pharmaceutical supply chain: A case study. *International journal of supply and operations management*, *5*(2), 122-133. doi: 10.22034/2018.2.2

Zhu, Q., Sarkis, J., & Lai, K. H. (2008). Confirmation of a measurement model for green supply chain management practices implementation. *International journal of production economics*, *111*(2), 261-273. doi: 10.1016/j.ijpe.2006.11.029.