



Research Paper

Optimizing The Transportation of Petroleum Products in A Possible Multi-Level Supply Chain

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ABSTRACT

The goal of many supply chain optimization problems is to minimize the costs of the entire supply chain network. However, since environmental protection is one of the main concerns, the green supply chain network has been seriously considered as a solution to this concern in order to minimize its effects on nature. This article refers to the modeling and solution of a green supply chain network for the transportation of petroleum products in order to reduce the annual costs, considering the environmental effects. In this article, the cost elements of the supply chain such as the transportation costs of each petroleum product, operating costs, the cost of purchasing crude oil products and the fixed costs of building oil centers as well as the components of the environmental effects of the supply chain such as the amount of gas emissions and volatile organic particles produced by transportation options in the supply chain, considered green. Considering these two components (cost and environmental impact), we have proposed a multi-objective supply chain model. In this facility model, oil centers have limited capacity and at each level of the chain, there are several types of transportation options with different costs. To solve the problem, we have used two multi-objective particle swarm optimization algorithms and genetic multi-objective optimization algorithm with non-dominant sorting II with a priority-based decoding to encode the chromosome. Finally, we have used TOPSIS method to compare these two algorithms.

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1. Introduction

A green supply chain is often called an environmentally dependent supply chain (ECSC) or an environmental supply chain (ECS), which is rooted in both environmental and supply chain management. Adding greenness to supply chain management involves addressing the impact and relationships between supply chain management and the natural environment. In 1996, the National Science Foundation (NSF) in the United States offered \$400,000 in grants to the Manufacturing Research Consortium (MRC) at Michigan State University to conduct a research project called Environmentally Credible Manufacturing and then proposed a definition of a green supply chain. Since then, many researchers have presented different views on green supply chain management. Walton et al. (1997), stated that green supply chain management refers to the joining of suppliers to environmental management. Sarkis (1998), further emphasizes that supply chain management should include procurement and internal logistics, material management, external logistics, packaging and reverse logistics. Beamon (1999) developed a conceptual model of green supply chain management by adding remanufacturing, recovery and recycling flows to the supply chain. Karlberg (2000) studied the green supply chain of the electronics industry and developed a conceptual model of green supply chain management that added recycling to the chain. Dan and Liu (2000) introduced a green supply chain including suppliers, manufacturers, distributors and consumers, with the aim of minimizing environmental impacts (negative effects) and maximizing resource efficiency throughout the process. The main goal of supply chain management was to protect the environment and use resources effectively. Van Hoek (2002) developed a conceptual model of green supply chain management that made service members own the green supply chain. Ma (2002) introduced the meaning and concept, analyzed the integration of the features of green supply chain management and proposed the structure of green supply chain. Wang et al. (2004) developed a conceptual supply chain model and analyzed the strategic objectives of green supply chain management and divided the green supply chain into four basic systems, i.e., production, consumption, community, and environmental systems, including supplier components, producers, distributors, customers and recyclers paid. Wang and Shen (2004) defined green supply chain management as a modern management model with supply chain design in an ecological way in terms of product life cycle. Srivastava (2007) defined green supply chain management as the integration of environmental thinking into supply chain management, including product design, sourcing and material selection, manufacturing process, delivery of final products to customers, and end of life product management after defining useful life. In general, there are some common features among these meanings and concepts, although there is no agreement on the definition of green supply chain management that focuses on the integration of management strategy, environmental awareness and supply chain management, that is, on the environmental characteristics of the chain and reducing Energy and resource consumption has been emphasized.

Food, electronics, automobile and oil companies are mostly involved in this issue. Some big famous companies, such as; General Motors, Ford, HP, P&G, Nike, etc., have active studies and implementation in the field of green supply chain management. In 2002, Van Hoek (2002) evaluated green efforts and approaches in two case studies of automotive companies, in terms of practices and chain relationships. It has been determined that operations and technological practices in the supply chain have not yet been fully developed to realize the strategic approach of greening. Zeng and Zhou (2006) presented a mixed integer programming model for optimizing the location of facilities and the reverse distribution network of scrap computers. In recent years, some researchers have investigated the green supply chain management on the home appliance industry, for example, Yan (2007) analyzed the obstacles in the green supply chain structure in the electronics industry and proposed some related countermeasures. Ling and Lai (2008) introduced the e-waste laws and regulations of countries while developing, analyzed the situation of e-waste transportation in China, construction of green supply chain in home appliance industry and various recycling methods under the "4R" principle. Xu et al. (2011) conducted some case studies in the home appliance industry, constructed a game model between consumers and firms, and presented a three-player game model for a green supply

chain. Donemz and Turkay (2013) presented a mixed integer linear programming model for reverse supply chain network design. This model included the collection, sorting, recycling, and destruction of battery waste materials in the landfill, and the goal of the model was to minimize the costs of material recycling. Eskanderpour et al. (2013) presented a multi-objective model for the design of the substation network, the proposed model minimized total fixed costs, variable costs, total delay and environmental pollution. Amin and Zhang (2013) presented a multi-objective facility location model for a closed-loop supply chain network in the conditions of product demand and return uncertainty and addressed the effect of demand and return under uncertainty in the network configuration with a probabilistic programming method. Ozceylan et al. (2014), an integrated model for optimizing strategic decisions related to the amount of goods flow in chains.

Forward and reverse and optimization of tactical decisions in production line balance in reverse supply chain. They developed a non-linear mixed integer model with the aim of reducing the costs of transportation, purchasing, refurbishing and disassembly operations. lack of proper integration and redundant processes in organizations; Infrastructure engineering and enterprise architecture is essential and vital for organizations to operate with maximum efficiency (Samadi-Parviznejad et al.,2022). Soleimani et al. (2014) presented a multi-product closed loop supply chain model aimed at cost reduction. They developed a probabilistic mixed integer programming model for this model and considered the parameters of demand, purchase price and return rate as non-deterministic. Rezaee et al. (2015) presented a probabilistic green supply chain model, they considered carbon demand and price as uncertainty parameters and performed a sensitivity analysis on carbon price and demand. Garg et al. (2015) developed a dual-objective model for reverse supply chain network design with the goals of minimizing network costs and maximizing the performance of outsourcing services while also optimizing the flow between facilities. Diabat et al. (2015) also considered a mixed integer nonlinear mathematical programming model for reverse supply chain network design in this article. To solve this single-period and single-product model, the Lagrange release method is used. There is a great deal of information about supply chain processes, and this allows for more insight than ever before (Nahr et al. 2021).

2. Literature Review

Due to the increasing attention to coal mining, industrial transportation in most countries including India is searching for sustainable transportation that leads to environmental protection, maximum delivery speed, minimum transportation cost and increased traffic safety. Gupta et al. (2018) have formulated an integrated multi-objective optimization model for a sustainable transportation problem with expanded capacity in the coal mining industry using Analysis Hierarchy Process (AHP) and Data Envelopment Analysis (DEA) techniques. AHP technique has been used to estimate the weight of different types of vehicles available for transportation based on all three parameters of sustainability i.e. economic, environmental and corporate social responsibility in their research. The DEA technique is used to calculate the efficiency scores of vehicles in different routes of a given transportation network using inputs and outputs that are considered critical in the industrial sector, especially the mining industry. They also reduce dependence on carbon-based fuels for transportation, which results in reduced greenhouse gas emissions. presented a fuzzy interactive optimization approach to obtain preferred compromise green transportation solutions including the optimal number of vehicles used for sustainable transportation.

With the increasing importance of the efficient purchasing function, supplier selection decisions have become more strategic in supply chain management. In the past few years, the closed-loop green supply chain network has faced increasing attention with regard to the environmental regulations, social awareness and customer pressure. In order to cope with these two issues, the research done by Sadeghi and Nahavandi (2018) propose an integrated mathematical programming model for multi-period, multi-product and capacitated closed loop green supply chain in which suppliers offer quantity discounts in order to motivate buyers to purchase more. The model objective functions are the minimization of economic cost and environmental emissions and

maximization of customer satisfaction with determining best suppliers, purchasing amount, location-allocation facilities, transportation mode, technology type, carbon dioxide emissions, inventory levels and flows between facilities. Sensitivity analysis is conducted to validate the model for some test problems. Computational results in their research showed the effectiveness and applicability of the proposed model. Also, results have revealed that supply chain total costs are significantly reduced by considering quantity discount. Whether the upstream and downstream members in a supply chain (considering environmental objectives) simultaneously stabilize economic benefits has become an important problem in the process of green development. However, few quantitative studies on green supply chains have considered environmental and economic benefits to realize multi-objective optimization. To study operation and cooperation strategies with a consideration of the different objective on the level of supply chain, Jian et al. (2019), first establish a green supply chain game model with profit and environment objectives simultaneously considered by the manufacturer. Then, they analyze the multi-objective decisions of the supply chain members under centralized control using a manufacturer-led Stackelberg game and revenue-sharing contract. Using the manufacturer's environmental preference as a variable, the effects of environmental benefits on the supply chain are also investigated. Finally, their study determines that the manufacturer's profit will be reduced after considering the objective of environmental benefits, while the retailer's profit, product greenness, and environmental benefits will be improved. Meanwhile, the total profit of the green supply chain will first increase and then decrease. In particular, a revenue-sharing contract can facilitate the coordination of multiple objectives; in this way, both the manufacturer and the retailer achieve higher profits and environmental benefits compared to a decentralized control condition, which is of great significance in achieving a win-win situation for the economy and the environment. So manufacturing companies are facing major environmental challenges due to energy consumption and related environmental effects. One of the effective strategies to reduce energy consumption is the use of smart scheduling techniques. Since production scheduling can have a significant impact on energy saving in the production system from the point of view of operations management, resource flexibility and complex constraints in the flexible production system turn production scheduling into a complex nonlinear planning problem. Therefore, Dai et al. (2019), formulated a multi-objective optimization model aimed at minimizing energy consumption and construction time for a flexible workshop scheduling problem with transportation constraints. They then presented an advanced genetic algorithm to solve the problem. Finally, they conducted comprehensive experiments to evaluate the performance of the proposed model and algorithm. The experimental results of their research show that the proposed model and algorithm can solve the problem effectively and efficiently. This may provide a basis for decision makers to consider efficient energy planning in the flexible production system.

With the increase in environmental pollution in recent years, researchers have focused on designing closed-loop supply chain networks with environmental issues in mind. In the research conducted by Manojehri et al. (2019), presented a multi-period, multi-product and multi-level uncertain supply chain network. They considered the uncertainty in demand, transportation costs and used a robust optimization approach to deal with this uncertainty. The proposed supply chain network in their research includes four levels of the forward supply chain and four levels of the reverse supply chain. The proposed model is a mixed integer linear programming (MILP) model with the objective of maximizing profit and minimizing pollution generated by product transportation and operational centers. The proposed model is solved with Lingo software, so that the multi-objective model is managed by the tool-based goal programming method. The results of the analysis and comparison of different scenarios show that the objective function has shown the uncertainty parameters and the effect of uncertainty in the parameters simultaneously. Therefore, network modeling based on different scenarios can be a suitable tool for making decisions about facing uncertain and ambiguous parameters.

The environmental issue is one of the most important issues in the world today. In recent years, a lot of attention has been paid to the management of the closed-loop green supply chain, and the resulting results are considered an important issue for managers. Therefore, in a research, Tadarak et al. (2020) presented a mixed integer programming model for mathematical optimization and design of a closed-loop green supply chain including production and recovery centers, distribution centers, inspection centers, waste centers and customers, which in addition to reducing system costs including The fixed cost of setting up factories and distribution centers, the variable cost of producing products with different technologies, and the cost of transportation, taking into account the carbon tax rate, the amount of carbon resulting from production, transportation, and establishment is minimized. Considering that in real world problems, the parameters have uncertainty, the uncertainty in the production cost parameters, the cost of recovery, distribution, inspection and waste processes, the amount of carbon emissions due to production, transportation and establishment, the capacity of facilities and the amount of demand are investigated in the model. and to deal with the uncertainty of the parameters, the approach of stable probabilistic planning is used. In order to obtain the optimal solution of the problem, Gems software has been used, and at the end, an analysis has been performed on the parameters of the confidence level in the possible state, the weight of the coefficients, and the amount of the penalty of the objective function in the fuzzy model of the problem. Numerical results show that the presented model of their research is able to control uncertainty, for this reason, a stable price has been imposed on the system. Also, the value of the objective function in the possible mode has decreased in price by 5% compared to the stable fuzzy mode.

A research done by Durmaz and Bilgen (2020), addresses the optimal design and planning of the biomass supply chain network that encompasses flow from poultry farms to biogas facilities. A novel multi-stage solution methodology is developed to solve the sustainable biomass supply chain network design problem. Geographical Information Systems, and Analytic Hierarchy Process Techniques are used to determine the candidate location of biogas facilities. The proposed multi-objective mixed integer linear programming model is capable of making strategic decisions (optimal biogas facility locations with capacities) along with the tactical decisions (transportation network flows). The model incorporates the two objective function of maximization of the profit, and minimization of total distance between poultry farms and biogas facilities. The aim is to determine the optimal number, location, and size of the biogas facilities, as well as the network flow, and electricity generated. The applicability of the model and solution methodology is demonstrated through a case study for a poultry supply chain network in Turkey. Additionally, they conducted sensitivity analysis to account for the impact of different parameters on the model. Sensitivity analysis show that both maximum distance parameter, and purchasing prices have major impact on decisions, and financial yield.

Over the past decade, there have always been new paradigms in supply chain design. Green supply chain is a new concept that helps organizations deal with unexpected disruptions and minimize environmental impacts. In this regard, Moussus et al. (2021) developed a suitable mathematical model by presenting a multi-objective optimization model for the green resilient supply chain network in the cement industry. In their research, scenarios were defined in two states of production surplus and non-production surplus. Data analysis in each scenario was done with MATLAB software. CPLEX solver is also used to solve the model. The results of their research showed that the excess production of Dashestan Cement Company has no effect on the resilience of the supply chain. The results of their research showed that if there is excess production, the cost of carbon dioxide emissions is lower than the cost of excess production. Therefore, the company's production plan has little effect on the cost of carbon dioxide emission, and its amount in the designed network is mostly due to the amount of carbon emission in production nodes and arcs.

In a study which has done by Hasani ET AL. (2021), a robust multi-objective optimization model to configure a green global supply chain network structure under disruption has been presented. The proposed model is adapted to a global medical device manufacturing system. Economic and environmental issues are considered

in designing the network, and mitigation strategies are employed to obtain a resilient supply chain network. To deal with the computational tractability of this non-linear and multi-objective optimization problem, a novel hybrid heuristic is developed that incorporates improved strength Pareto evolutionary algorithm 2 (SPEA2). Computational results in their research indicate that the proposed global supply chain network configuration can respond to its global customers' demand in agile as well as green manner. Based on our results, the importance of the SC agility is highlighted by increasing the budget of uncertainty, and some of well-known mitigation strategies are in contradiction to the agile production paradigm.

Due to growing environmental issues and increasing awareness among people and strict environmental laws imposed by the government, companies have forced companies to consider environmental sustainability issues when selecting suppliers. If suppliers have capacity constraints or any other constraints, the complexity of selecting suppliers that meet both demand and company standards increases. In the research conducted by Niranjana et al. (2021) the information obtained from the review of the literature and through the opinion of experts, found the necessary criteria for evaluation and at the same time for choosing a green supplier. Therefore, they presented an integrated decision-making tool, based on fuzzy TOPSIS and fuzzy DEMATEL, to show the best supplier selection method. Due to ambiguity in human judgment, fuzzy concept has been used. They also proposed a MILP (Mixed Integer Linear Programming) that shows how to allocate order in multiple sourcing environments. Modeling a supply chain network for the flow of multiple products in different demand scenarios and problem solving using a new meta-heuristic algorithm such as learner-based optimization (TLBO) is the major contribution of Niranjana's work.

Naderi et al. (2022) in a research to design a multi-objective optimization model; The components of cost, customer satisfaction and environmental protection were considered. For the multi-objective optimization of production-inventory-routing in the green supply chain under the conditions of uncertainty, they presented the system dynamics model. They determined the relationships between the selected variables by using the cause and effect model and then by designing the system dynamics model and evaluating and checking It was modeled through tests defined by execution in Vensim software. Finally, three scenarios were developed to determine the strategies influencing the model. The results of their research showed that one of the most effective strategies in achieving the desired situation is maximum customer satisfaction, minimum cost and inventory, and maximum production with the proper implementation of the projects being implemented by the organization in line with green production using appropriate technical knowledge. In a research, Zarei et al.(2022) designed a closed-loop green supply chain network under conditions of uncertainty. In the presented model, they considered four objective functions, including minimization of network costs, minimization of greenhouse gas emissions, minimization of production-technical risk, and minimization of time to send products to customers simultaneously. By using the proposed network, it is possible to manage the flow of raw materials, first-hand products and returned products between facilities, production planning for each of the production centers, how to allocate products to each of the facilities, determine the number of human resources required for hiring and training in Each of the production centers, how to allocate machinery and equipment, as well as time management by determining the minimum acceptable time to send products to customers in such a way that the network has the minimum cost, the minimum amount of greenhouse gas emissions resulting from the operational processes of the facility and transportation and has The lowest production-technical risk and the least time possible, he made strategic decisions. In order to increase the efficiency of the model, Zarei et al considered parameters such as the amount of returned product, recycling rate and destruction in a non-deterministic way and used fuzzy logic to solve the uncertainty. Finally, due to the extensiveness of the model, the validation of the model has been done using the genetic algorithm. The result of the validation indicates the effectiveness of the proposed model in optimizing the closed-loop green supply chain network

3. Model Definition

In this article, a multi-objective and multi-sector green chain network is designed. The network includes two forward and backward flow paths. In the direction of the forward flow, it can be used as a distributor of petroleum raw materials, production centers, distribution centers, and customers, and in the opposite flow, it includes centers such as customers, used product collection centers, centers, and member centers. According to Figure (1) in this network, the raw materials needed for the production centers are purchased from the customer, and after the production of the products, the materials are sent to the distribution centers. Distribution centers send products to customers using appropriate vehicles according to customer consumption. After the products are used by the customers, they are discarded, and these products are collected by the collection center and sent to the repair center for inspection. In post-inspection repair, the repairable products are repaired in the same center as new products and sent to the distribution center for resale, and the usable products are sent to the Andam center as scrap products for disposal.

The network assumptions of the proposed multi-green network include the following:

- *The problem in question is a two-objective model including the objectives of reducing the logistics costs of the oil network and reducing the amount of gas released.*
- *The proposed model includes several different oil products.*
- *Customer demand for any oil product is possible and shortage is not allowed.*
- *The supplier sells the crude oil needed to produce the products with a discount.*
- *The set of potential facility locations are predetermined and specific.*
- *The capacity of all potential oil center facilities is limited and specific*

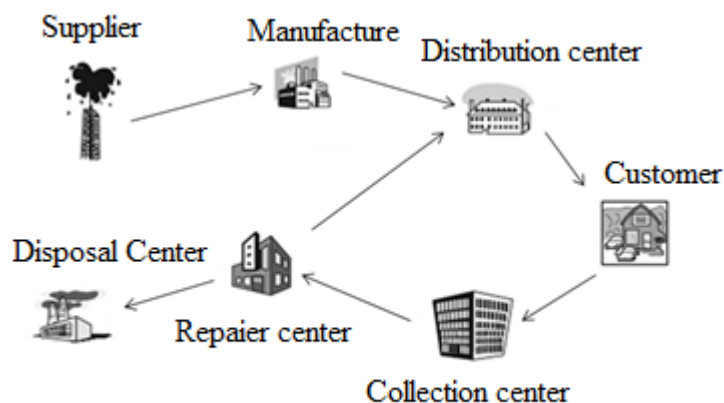


Fig. 1. Proposed green supply chain model

Considering the above assumptions, the most important issue mentioned in this research is the selection and location of crude oil supply centers, production centers, product distribution centers, repair centers and destruction centers, as well as determining the optimal amount of petroleum products flow between the centers and the appropriate level of discount with It is an environmental issue to consider.

Sets

M	set of potential points for annihilation centers
N	sets of potential points for repair centers
P	product set
T	Set of vehicle options
H	set of discount levels
I	Set of potential points for crude oil supply centers
J	set of potential points for production centers
K	set of potential points for product distribution centers
C	set of customer fixed points
L	Set of potential points for product collection centers

Parameters:

Dem_{cp}	(\dots, Var_{Dem})	Customer demand c of product p
R_{cp}	(ar_R)	Amount of consumed products p from customer c
φ_{np}		The percentage of products p that can be repaired at the repair center n
F_i		The fixed cost of building a crude oil supplier i
F_j		The fixed cost of building a production center j
F_k		The fixed cost of building a distribution center k
F_l		The fixed cost of building a collection center l
F_n		The fixed cost of building a repair center n
F_m		The fixed cost of building the destruction center m
TC_{ijpt}		The cost of transporting a unit of product p by vehicle t between centers i and j
TC_{jkpt}		The cost of transporting a unit of product p by vehicle t between centers j and k
TC_{kcpt}		The cost of transporting a unit of product p by vehicle t between centers k and c
TC_{clpt}		The cost of transporting a unit of product p by vehicle t between centers c and l
TC_{nkpt}		The cost of transporting a unit of product p by vehicle t between centers n and k
TC_{nmpt}		The cost of transporting a unit of product p by vehicle t between centers n and m
TC_{lnpt}		The cost of transporting a unit of product p by vehicle t between centers l and n
$Co2_{ijpt}$		The Co_2 emission rate of a unit of product p by vehicle t between centers i and j
$Co2_{jkpt}$		The Co_2 emission rate of one unit of product p by vehicle t between centers j and k
$Co2_{kcpt}$		The Co_2 emission rate of one unit of product p by vehicle t between centers k and c
$Co2_{clpt}$		The Co_2 emission rate of one unit of product p by vehicle t between centers c and l
$Co2_{nkpt}$		The Co_2 emission rate of one unit of product p by vehicle t between centers n and k
$Co2_{nmpt}$		The emission rate of one unit of product p by vehicle t between centers n and m
$Co2_{lnpt}$		The emission rate of one unit of product p by vehicle t between centers l and n
$Co2_{jp}$		The amount of Co_2 emission of a unit of product p in production center i

$Co2_{mp}$	The amount of Co_2 emission of a unit of product p in the destruction center m
C_{jp}	The cost of producing a unit of product p in production center j
C_{kp}	The cost of distributing a unit of product p at the distribution center k
C_{lp}	The cost of collecting a unit of product p at the collection center l
C_{np}	Inspection repair cost of a unit of product p at repair center n
C_{mp}	The cost of destroying a unit of product p in the destruction center m
Cap_{ip}	The supply capacity of crude oil i from product p
Cap_{jp}	The capacity of production center j of product p
Cap_{kp}	Capacity of distribution center k of product p
Cap_{lp}	The capacity of the collection center l of product p
Cap_{np}	Capacity of repair center n of product p
Cap_{mp}	The capacity of the destruction center m of the product p
VA_{ihp}	The lower limit of the discount range of product p from crude oil supplier i at discount level h
P_{ihp}	Purchase price of product p from crude oil supplier i at discount level h

Decision variables:

X_{ijpt}	The amount of product p transported between centers i and j by vehicle t
X_{jkpt}	The amount of product p produced and transported between centers j and k by vehicle t
X_{kcpt}	The amount of product p transported between centers k and c by vehicle t
X_{clpt}	The amount of product p returned and transported between centers c and l by vehicle t
X_{lnpt}	The amount of product p transported between centers l and n by vehicle t
X_{nmpt}	Amount of scrap product p transported between centers n and m by vehicle t
X_{nkpt}^r	The amount of product p repaired and transported between centers n and k by vehicle t
X_{kcpt}^r	The amount of product p repaired and transported between centers k and c by vehicle t
Q_{ip}	Total purchase amount of product p from crude oil supplier i
Z_i	If crude oil supplier i is established, one and zero otherwise
Z_j	If production center j is built, one and zero otherwise
Z_k	If the center of the k distribution is constructed, one and zero otherwise
Z_l	If collection center l is built, one and zero otherwise
Z_n	If repair center n is built, one and zero otherwise
Z_m	If m destruction center is built, one and zero otherwise
A_{ihp}	One if crude oil supplier i is selected at discount level h for product p and zero otherwise

According to the stated sets, parameters and decision variables, the multi-objective green supply chain network design problem is modeled as a mixed integer non-linear mathematical programming probabilistic model as follows:

$$\text{Min } E[W_1] = \sum_{i=1}^I F_i Z_i + \sum_{j=1}^J F_j Z_j + \sum_{k=1}^K F_k Z_k + \sum_{l=1}^L F_l Z_l + \sum_{n=1}^N F_n Z_n + \sum_{m=1}^M F_m Z_m + \quad (1)$$

$$\begin{aligned} & \sum_{i=1}^I \sum_{j=1}^J \sum_{p=1}^P \sum_{t=1}^T E[Tc]_{ijpt} X_{ijpt} + \sum_{j=1}^J \sum_{k=1}^K \sum_{p=1}^P \sum_{t=1}^T E[Tc]_{jkpt} X_{jkpt} + \sum_{k=1}^K \sum_{c=1}^C \sum_{p=1}^P \sum_{t=1}^T E[Tc]_{kcpt} (X_{kcpt} + X_{kcpt}^r) \\ & + \sum_{c=1}^C \sum_{l=1}^L \sum_{p=1}^P \sum_{t=1}^T E[Tc]_{clpt} X_{clpt} + \sum_{l=1}^L \sum_{n=1}^N \sum_{p=1}^P \sum_{t=1}^T E[Fc]_{lnpt} X_{lnpt} + \sum_{n=1}^N \sum_{k=1}^K \sum_{p=1}^P \sum_{t=1}^T E[Fc]_{nkpt} X_{nkpt}^r + \\ & \sum_{n=1}^N \sum_{m=1}^M \sum_{p=1}^P \sum_{t=1}^T E[Fc]_{nmpt} X_{nmpt} + \sum_{j=1}^J \sum_{k=1}^K \sum_{p=1}^P \sum_{t=1}^T E[C]_{jkpt} X_{jkpt} + \sum_{k=1}^K \sum_{c=1}^C \sum_{p=1}^P \sum_{t=1}^T E[C]_{kp} (X_{kcpt} + X_{kcpt}^r) \\ & + \sum_{c=1}^C \sum_{l=1}^L \sum_{p=1}^P \sum_{t=1}^T E[C]_{lp} X_{clpt} + \sum_{l=1}^L \sum_{n=1}^N \sum_{p=1}^P \sum_{t=1}^T E[C]_{np} X_{lnpt} + \sum_{n=1}^N \sum_{m=1}^M \sum_{p=1}^P \sum_{t=1}^T E[C]_{mp} X_{nmpt} + \\ & \sum_{i=1}^I \sum_{j=1}^J \sum_{p=1}^P \sum_{t=1}^T \sum_{h=1}^H E[P]_{ihp} A_{ihp} X_{ijpt} \end{aligned}$$

$$\text{Min } E[W_2] = \sum_{i=1}^I \sum_{j=1}^J \sum_{p=1}^P \sum_{t=1}^T E[Co2]_{ijpt} X_{ijpt} + \sum_{j=1}^J \sum_{k=1}^K \sum_{p=1}^P \sum_{t=1}^T E[Co2]_{jkpt} X_{jkpt} + \quad (2)$$

$$\begin{aligned} & \sum_{k=1}^K \sum_{c=1}^C \sum_{p=1}^P \sum_{t=1}^T E[Co2]_{kcpt} (X_{kcpt} + X_{kcpt}^r) + \sum_{c=1}^C \sum_{l=1}^L \sum_{p=1}^P \sum_{t=1}^T E[Co2]_{clpt} X_{clpt} + \\ & \sum_{l=1}^L \sum_{n=1}^N \sum_{p=1}^P \sum_{t=1}^T E[Co2]_{lnpt} X_{lnpt} + \sum_{n=1}^N \sum_{k=1}^K \sum_{p=1}^P \sum_{t=1}^T E[Co2]_{nkpt} X_{nkpt}^r + \sum_{n=1}^N \sum_{m=1}^M \sum_{p=1}^P \sum_{t=1}^T E[Co2]_{nmpt} X_{nmpt} \\ & + \sum_{j=1}^J \sum_{k=1}^K \sum_{p=1}^P \sum_{t=1}^T E[Co2]_{jkpt} X_{jkpt} + \sum_{n=1}^N \sum_{m=1}^M \sum_{p=1}^P \sum_{t=1}^T E[Co2]_{mp} X_{nmpt} \end{aligned}$$

S.t.

$$P\left\{\sum_{k=1}^K \sum_{t=1}^T X_{kcpt} + \sum_{k=1}^K \sum_{t=1}^T X_{kcpt}^r \geq Dem_{cp}\right\} \geq 1 - \alpha \quad \forall c, p \quad (3)$$

$$P\left\{\sum_{l=1}^L \sum_{t=1}^T X_{clpt} \geq R_{cp}\right\} \geq 1 - \alpha \quad \forall c, p \quad (4)$$

$$\sum_{c=1}^C \sum_{t=1}^T X_{clpt} = \sum_{n=1}^N \sum_{t=1}^T X_{lnpt} \quad \forall l, p \quad (5)$$

$$\varphi_{np} \sum_{l=1}^L \sum_{t=1}^T X_{lnpt} = \sum_{k=1}^K \sum_{t=1}^T X_{nkpt}^r \quad \forall n, p \quad (6)$$

$$(1 - \varphi_{np}) \sum_{l=1}^L \sum_{t=1}^T X_{lnpt} = \sum_{m=1}^M \sum_{t=1}^T X_{nmpt} \quad \forall n, p \quad (7)$$

$$\sum_{c=1}^C \sum_{t=1}^T X_{kcpt}^r = \sum_{n=1}^N \sum_{t=1}^T X_{nkpt}^r \quad \forall k, p \quad (8)$$

$$\sum_{c=1}^C \sum_{t=1}^T X_{kcpt} = \sum_{k=1}^K \sum_{t=1}^T X_{jkpt} \quad \forall j, p \quad (9)$$

$$\sum_{i=1}^J \sum_{t=1}^T X_{ijpt} = \sum_{k=1}^K \sum_{t=1}^T X_{jkpt} \quad \forall j, p \quad (10)$$

$$A_{ihp} VA_{ihp} \leq Q_{ip} \quad \forall i, p, h \quad (11)$$

$$\sum_{h=1}^H A_{ihp} = Z_i \quad \forall i, p \quad (12)$$

$$Q_{ip} = \sum_{j=1}^J \sum_{t=1}^T X_{ijpt} \quad \forall i, p \quad (13)$$

$$\sum_{j=1}^J \sum_{t=1}^T X_{ijpt} \leq Cap_{ip} Z_i \quad \forall i, p \quad (14)$$

$$\sum_{k=1}^K \sum_{t=1}^T X_{jkpt} \leq Cap_{jp} Z_j \quad \forall j, p \quad (15)$$

$$\sum_{c=1}^C \sum_{t=1}^T X_{kcpt} + \sum_{c=1}^C \sum_{t=1}^T X_{kcpt}^r \leq Cap_{kp} Z_k \quad \forall k, p \quad (16)$$

$$\sum_{c=1}^C \sum_{t=1}^T X_{clpt} \leq Cap_{lp} Z_l \quad \forall l, p \quad (17)$$

$$\sum_{l=1}^L \sum_{t=1}^T X_{lnpt}^r \leq Cap_{np} Z_n \quad \forall n, p \quad (18)$$

$$\sum_{n=1}^N \sum_{t=1}^T X_{nmpt} \leq Cap_{mp} Z_m \quad \forall m, p \quad (19)$$

$$X_{ijpt}, X_{jkpt}, X_{kcpt}, X_{clpt}, X_{lnpt}, X_{nmpt}, X_{nkpt}^r, X_{kcpt}^r, Q_{ip} \geq 0 \quad (20)$$

$$A_{ihp}, Z_i, Z_j, Z_k, Z_l, Z_n, Z_m \in [0, 1] \quad (21)$$

The first objective function minimizes the expected value of the costs of the entire proposed supply chain network. These costs include the fixed cost of building centers and facilities, product transportation costs, product purchase costs, and operating costs in each of the centers, respectively. The second objective function minimizes the total gas emissions emitted by vehicles.

Constraint (3) guarantees that the demand of all customers is satisfied from all requested products. Constraint (4) shows the return rate of consumed products to the collection center. Constraint (5) indicates that the collection center sends all collected products to the repair center. Constraints (6) and (7) specify the percentage of repairable and scrap products, respectively. Constraint (8) shows that all products repaired by the distribution center are sent to the customer for sale. Constraint (9) shows the amount of production of products to satisfy the demand. Constraint (10) shows the amount of sending products from the supplier to the production center that these products are sent to the distribution center without deficit. Constraints (11) to (13) show the limitations of discount application by the supplier. So that constraint (11) shows the total amount of product purchase from each supplier and only in one discount period. Constraint (12) guarantees that if a supplier is selected, crude oil can be purchased from only one discount level. Constraint (13) shows the amount of transfer of products to each production center. Constraints (14) to (19) also show the capacity limitations of centers and facilities and guarantee that until a facility is selected, its equivalent capacity cannot be used. Constraints (20) and (21) also show the type of decision variables. To confirm the limitations of (3) and (4), their equivalents are expressed as follows:

$$\sum_{k=1}^K \sum_{t=1}^T X_{kcpt} + \sum_{k=1}^K \sum_{t=1}^T X_{kcpt}^r \geq Z_{1-\alpha} \sqrt{Var_{Dem}} + \mu_{Dem} \quad , \quad \sum_{l=1}^L \sum_{t=1}^T X_{clpt} \geq Z_{1-\alpha} \sqrt{Var_R} + \mu_R$$

As a result, the mixed integer nonlinear programming model becomes as follows:

$$(2)-(1) \tag{22}$$

S.t.

$$\sum_{k=1}^K \sum_{t=1}^T X_{kcpt} + \sum_{k=1}^K \sum_{t=1}^T X_{kcpt}^r \geq Z_{1-\alpha} \sqrt{Var_{Dem}} + \mu_{Dem} \quad \forall c, p, t \tag{23}$$

$$\sum_{l=1}^L \sum_{t=1}^T X_{clpt} \geq Z_{1-\alpha} \sqrt{Var_R} + \mu_R \quad \forall c, p, t \tag{24}$$

$$(21)-(5) \tag{25}$$

The proposed model is a non-linear mixed integer programming model with continuous variable and zero and one variable. The proposed model of this article is also a hard NP model, so solving this problem in a large size in an accurate way is very time-consuming; Therefore, many heuristic and meta-heuristic algorithms have been developed for this type of problem to provide a solution close to the optimal solution in less time. In this method, the solution based on arrays with the size and position of all cells determined the number of resources and depots, which were arranged based on priority. In each iteration, the node (source or depot) with the highest priority is selected and connected to another node (depot or source) with the lowest transportation cost. Then, after that, the lowest value (resource capacity or depot demand) is assigned as the transfer value. This continues until all demand from the depots has been met, then the resources connected to the depots are selected as actual facilities.

Thus, the general form of the initial solution used for decoding is in the form of a matrix in the figure 2.

	Part1	Part2	Part3	Part4	Part5	Part6	Part7
P	K + C	C + L	L + N	N + K	K + J	I + J	N + M

Fig. 2. Example of the initial answer used for priority-based decoding

In setting the parameters of meta-heuristic algorithms according to Taguchi method, 3 levels are considered for each factor. For each algorithm, according to the number of factors and the number of their levels, the test design and their implementation have been determined. It is worth mentioning that each of the experiments was repeated 5 times on average and the average values obtained were considered for the final analysis. Table (1) shows the results of parameter setting of meta-heuristic algorithms by Taguchi method.

Table 1. Setting the parameters of meta-heuristic algorithms by Gauchi method

NSGA2		MOPSO	
120	The number of repetitions	120	The number of repetitions
80	Initial population size	80	The number of repetitions
0.6	Mutation rate	2	Speed coefficient 1
0.5	Composition rate	1.5	Speed coefficient 2

Suppose the model is solved by the mentioned two algorithms and the number of N effective solutions is obtained by the model. To compare which algorithm is more useful than the other, the most widely used indices (MSI, number of efficient or Pareto solutions (NPF), computing time (CPU-time), distance index (SI), metric distance index (SM) have been used.

4. Computational results

In this section, calculation results are presented to check the performance of the proposed model. Since there are no standard examples in this field, examples with random data have been used. Therefore, 12 problems in 10 sizes with different problem combinations according to uniform distribution according to tables (2) and (3) have been created randomly.

Table 2. The size of the generated problems

(I , J , K , C , L , M , N , P , T , H)					
1	(3*3*3*6*2*2*2*2*2)	5	(9*8*5*11*5*3*5*5*4*4)	9	(13*12*11*19*8*8*8*7*6*5)
2	(3*3*3*6*2*2*4*2*2)	6	(10*8*5*11*5*3*5*5*4*4)	10	(14*12*12*19*9*8*8*8*7*5)
3	(5*4*4*7*4*2*4*3*2*3)	7	(12*10*7*15*8*6*8*7*6*4)	11	(13*13*12*24*9*8*9*9*8*5)
4	(6*4*5*8*5*2*5*4*2*3)	8	(12*10*9*18*8*7*8*7*6*4)	12	(14*14*15*25*9*9*9*9*8*5)

Table 3. Parameters and limits of nominal data used in modeling

Dem_{cp}	N(150,200),(30*40)	Cap_{ip}	(3600*4500)	TC_{ijpt}	(10*20)
R_{cp}	N(15,20),(3*4)	Cap_{jp}	(3600*4500)	TC_{jkpt}	(10*20)
φ_{np}	(0*0.5)	Cap_{kp}	(3600*4500)	TC_{kcpt}	(10*20)
F_i	(1000000*1200000)	Cap_{lp}	(360*450)	TC_{clpt}	(10*20)
F_i	(1000000*1200000)	Cap_{mp}	(360*450)	TC_{nkpt}	(10*20)
F_k	(1000000*1200000)	C_{np}	(5*8)	TC_{nmpt}	(10*20)
F_l	(1000000*1200000)	C_{mp}	(5*8)	TC_{lnpt}	(10*20)
F_n	(1000000*1200000)	Cap_{np}	(360*450)	C_{jp}	(5*8)
F_m	(1000000*1200000)	P_{ihp}	(h/9*h/8)	C_{kp}	(5*8)
C_{lp}	(5*8)				

The data of each example problem is created ten times according to the uniform distribution of Table 3 and solved by meta-heuristic algorithms. Figure (3) shows the results obtained from the proposed algorithms for problem 9.

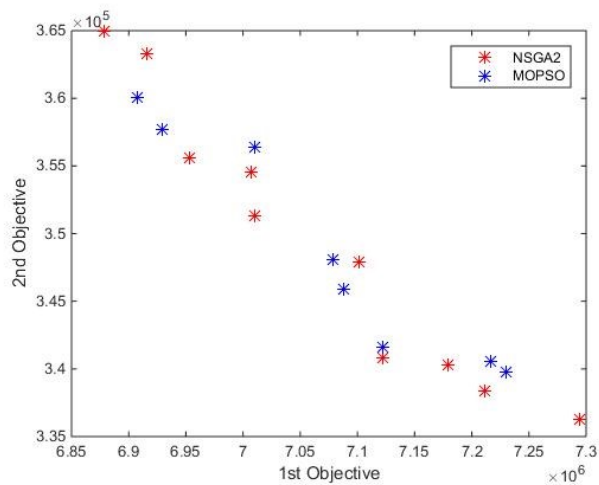


Fig. 3. The results obtained from the proposed multi-objective algorithms for problem 9

As shown in Figure (3), the number of Pareto solutions obtained and the dispersion of efficient solutions of the NSGA2 algorithm are better than the MOPSO algorithm. According to the mentioned comparison indicators, the results of 12 sample problems after solving are obtained as shown in table (4). According to this table, the indicators of the number of Pareto solutions, the index of the most expansion, the distance index and the metric distance index and the calculation time are shown.

Table 4. Results obtained from sample problems designed by multi-objective algorithms

Algorithm	Problem	NPF	MSI	SI	SM	CPU time
NSGA II	1	4	128428.05	11358.81	0.4	40.8
	2	15	315629.28	3123.12	0.41	42.15
	3	11	346172.08	16069.1	0.68	51.73
	4	11	216643.36	9679.56	0.48	57.021
	5	7	364045.69	68366.19	0.61	61.68
	6	15	204342.88	2878.35	0.49	64.63
	7	3	197699.28	47364.8	0.32	85.61
	8	19	325217.56	14894.99	0.44	86.6
	9	10	341205.53	22197.58	0.3	110.93
	10	13	561969.99	85189.2	0.64	145.93
	11	11	207948.77	14340.44	0.55	202.41
	12	3	144186.37	80848.2	0.87	229.96
MOPSO	1	3	68041.05	25760.22	0.83	41.26
	2	14	315629.28	14422.59	0.76	46.42
	3	13	248608.26	12947.01	0.64	60.21
	4	11	187103.74	5645.5	0.23	78.39
	5	12	555560.89	20963.02	0.48	108.66
	6	13	179966.62	26402.36	0.17	103.71
	7	6	125261.84	25348.91	0.64	156.78
	8	11	472839.46	37623.9	0.29	171.85
	9	8	461142.82	30854.12	0.35	243.3
	10	12	297475.78	50813.6	0.66	316.35
	11	8	384947.24	33731.44	0.44	453.07
	12	8	297740.85	15439.04	0.28	480.25

According to table (4) and the obtained results, it can be seen that the average number of Pareto solutions obtained from NSGA2 algorithm is more. On the average, the metric distance index is lower in the MOPSO algorithm. Table (5) shows other calculation results.

Table 5. Average results obtained from sample problems designed by multi-objective algorithms

Algorithm	NPF	MSI	SM	CPU time
NSGA II	10.16	279457.4	0.51	98.28
MOPSO	9.91	299526.5	0.48	188.35

Therefore, to determine the best algorithm in each size, the TOPSIS method has been used to compare algorithms. In this method, 4 indicators of the number of Pareto solutions, more expansion index, metric distance index and computing time are selected. If the first and second index have a larger value and the third and fourth index have a smaller value, it is more suitable. Table (6) shows the results obtained from the comparison of algorithms using the TOPSIS method.

Table 6. The results obtained from TOPSIS method

Criteria weight (entropy method)				Algorithm
w1	w2	w3	w4	
0.001	0.011	0.008	0.978	NSGA II > MOPSO

According to the results obtained from the TOPSIS method, it can be seen that the NSGA2 algorithm has a better performance than the MOPSO algorithm.

5. Conclusion and future suggestions

In this paper, a multi-objective probabilistic green supply chain model was modeled for the transportation of petroleum products with the objectives of reducing logistics costs while considering the environmental objective. To solve the problem, the meta-heuristic multi-objective optimization algorithm of particle swarm and the genetic multi-objective optimization algorithm with non-defeat sorting 2 with decoding based on priority have been used. The results obtained by this type of decoding are better than the size of the existing methods in the literature review. Finally, 12 sample problems were used to evaluate the model, and with the results obtained and the defined indicators, it was determined that the NSGA2 algorithm has a higher efficiency than the MOPSO algorithm for solving this model. For future researches, it is suggested to use newer meta-heuristic algorithms with new decoding to solve the problem. Also, using fuzzy or robust modeling for the model can also help the novelty aspects of the problem.

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