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Design of a Green Supply Chain Based on the Kano Model Considering Pricing

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Abstract: Nowadays, the design of supply chain networks should be based on environmental issues as well as the needs of customers since the main driver of a supply chain network is customers. Continuous innovation of products requires understanding the features that are most important to customers, and product pricing should be carried out in a way that includes the satisfaction of both customers and manufacturers. This study uses the Kano model to classify product features into different categories. The design of the green supply chain network based on the Kano model has not been investigated in the literature so far. This study examines a green supply chain network including multiple manufacturers, product types, distributors, and carriers that is designed based on Kano's conceptual model of multiple needs. In the proposed mathematical model of this paper, customer demand is a function of the selling price of the product, transportation pollution is minimized, and a solution based on the Cooperative Game Theory approach is used to solve the mathematical model using the GAMS software. One of the advantages of the proposed mathematical model in this research compared to other supply chain models is that the design needs of the supply chain network based on the Kano model ("must-be", "one-dimensional", "attractive" and "indifferent") can be determined based on customer satisfaction. In addition, the price of the product can be determined according to the satisfaction of both customers and the manufacturers.

Keywords: green supply chain network; game theory; price elasticity of demand; Kano model

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1. Introduction

The popularity of management consulting grew in the late 19th century in the United States. Management consulting is the process of supporting businesses in improving their performance by analyzing existing organizational issues and implementing improvement strategies. Management consultants gather and process the needs of customers so that businesses can remain competitive in the market. The Kano model analysis is a tool that helps developers make informed decisions about product features by anticipating consumer demands. Many companies know that rendering different features or functions in a product can guarantee the success of that product in the market. Innovators consider technology as an enabler for new product development, while marketers tend to see technology as a "means to reach the goal" [1]. Both perspectives demonstrate the significance of technology for developing the product. However, customer appreciation and understanding can be stated as the focal point of marketing operations. The Kano model can help determine what your customers really want from a product or service. This model integrates the driving features for the desired customer and enables the creation of an innovative and pure product or service with all the components needed to delight and surprise customers [2,3]. Firms should meet customer expectations in developing the products and determine which features are most important for their customers. Understanding customers is an element of the study known as Voice of Customers (VOC). VOC is usually performed at the beginning of a novel service, product, or process design and usually involves determining a set of lengthy and comprehensive customer needs and briefing and prioritizing them according to their importance for the customers [4]. Customer requirements usually contain product features that meet different needs. A service or product will be more favorable if it satisfies two or more needs. Customer needs are dynamic. For instance, novel features that today stimulate customers will finally become an expected need for a service or product, and the significance of each feature will vary among customers. As a result, it is vital for firms to revise their comprehension of customer expectations to secure the continued successful features of any modified and/or new product. The primary target of this study is to examine the relationships between product features, customer satisfaction, and product pricing.

Kano et al. proposed the Kano model, which was based on Herzberg's two-factor theory of motivation-health. In this model, the impact of a product or service quality on customer satisfaction is analyzed. It also includes a variety of product and service quality attributes that affect customer satisfaction. Customer satisfaction occurs when customer needs are satisfied. However, a customer becomes frustrated when his/her needs are not met [5].

The Kano model is a two-dimensional, non-linear model that examines the relationship between customer satisfaction and quality. Kano's conceptual model has been widely used in different industries such as aviation, education, and the web [6–8].

Advancing technologies, together with increasing customer needs and product requirements, emphasize the importance of dynamic frameworks such as the Kano model to comprehend the significance of VOC regarding product innovations. Particular quality features and attributes, as well as their effects on customer satisfaction, should be investigated using several methods, such as the Kano surveys [9,10].

The Kano method is commonly used to define new product features. However, analyzing the features that have been recently introduced is also noteworthy for product improvement, i.e., prioritizing each feature from the customer's perspective. This analysis allows technology capabilities to consider features that are most desirable for customers, which requires a deep understanding of the features that are important to customers.

Since customers are the substantial components of a supply chain network, the supply chain network should be designed based on their viewpoint. Moreover, special attention should be paid to pricing because the customer demand is effective in product pricing, which may lead to more network efficiency. The main contribution of the present research is incorporating Kano's four principles into the proposed mathematical programming model for the green supply chain network in order to bring the features of the product as close as possible to the demands of the customers. In addition, pricing is considered in the model to increase the satisfaction of producers and customers.

The structure of this paper is as follows. In Section 2, the relevant studies are reviewed; Section 3 defines the problem at hand and proposes the mixed-integer mathematical programming model for this problem. Section 4 explains the Cooperative Game Theory approach to solving the problem. Moreover, the performance of the Cooperative Game Theory is analyzed using a case study in this section. In addition, the sensitivity analysis is performed to examine how changing supply chain primary factors affect costs and profits. Finally, Section 5 concludes the paper.

2. Literature Review

The Kano model is an approach that is often used to design or improve products and services [11–16]. The various terms "needs", "wants", "features", and "requirements" may be interchangeably used in engineering, marketing, and industrial design literature. Krishnan and Ulrich illustrated that a beneficial representation of a product includes customer requirements, product specifications, and technical performance criteria [17]. Sanders stated that researchers are required to investigate customer's present and ideal usage experiences in order to fully understand customer needs [18]. Furthermore, customer needs can be described as the desirable benefits of customers. Based on a firm's viewpoint, the focus is on novel and advanced product features [4].

The Kano model analyzes the relationship between product quality or attributes and customer satisfaction [8,9,19]. It displays the customer's level of satisfaction based on a particular product feature and attribute that meets the customer's needs. In this model, four different categories of characteristics, including "must-be", "one-dimensional", "attractive", and "indifferent" are proposed [5].

Djekic et al. investigated the relationship between the mechanical features of selected confectionery products and the classification of food processing and sensory characteristics based on the Kano model [20]. In another study, Dace et al. integrated the Kano model with the triple angle (a concept from social cognitive theory) as a tool for changing customer attitudes and behavior by changing the perception of environmental-psychological quality [21]. Moreover, Heidari et al. presented a mathematical programming model considering customer satisfaction [22]. Barrios-Ipenza et al. studied the health quality of the services in two hospitals in Peru using the Kano model [23]. In another study, the classification of students and their education has been discussed using the Kano model [24]. Furthermore, Chen et al. applied the Kano model to the field of education in the COVID-19 pandemic [25]. In addition, Malinka et al. introduced a method for prioritizing the quality features in the field of mobile health [26]. Additionally, Tandiono and Rau proposed a model using the Kano model for establishing quality performance for the environment as well as the Theory of Inventive Problem Solving (TRIZ) with a component-based approach for the systematic design of sustainable and innovative products [27].

2.1. Competitive Supply Chain

The supply chain includes all activities from raw material procurement to delivery of products. This operation includes supply, production, distribution and sales. The process of managing all these operations is known as supply chain management. Due to the continuous development of technology, market competition and rapid economic expansion, industrial companies must focus on supply chain management. Several factors, such as pricing, affect demand in the supply chain [28].

Recently, several studies have been conducted in the fields of marketing and supply chain. For instance, Mokhlesian and Zegordi developed a nonlinear bi-level programming model for the problem of inventory and pricing coordination in a competitive supply chain [29]. Guillén et al. addressed the impact of financial decisions on the development of an integrated chemical supply chain [30]. Li et al. investigated pricing strategies in centralized and decentralized supply chains [31]. Green et al. examined the links between marketing strategy alignment, supply chain performance, and organizational success [32].

Researchers integrated green marketing and supply chain decisions [33,34]. Several researchers have used the concept of elasticity in supply chain design. Giri and Sharma studied a supply chain with one manufacturer and two retailers based on advertising-dependent demand [35]. Hull proposed a model based on supply and demand elasticity to describe the performance of supply chain networks [36]. Seifbarghy et al. dealt with a two-level supply chain consisting of a manufacturer and a retailer, where the price and quality of the final product affect consumer demand [37]. Kaplan et al. studied the customer's price-oriented behavior using the concept of price elasticity of demand [38]. Li et al. examined pricing, ordering, and coordination of advertising in a supply chain, where retailers face stochastic demand depending on their advertising prices and costs [39]. Ma et al. investigated the two-stage supply chain, considering changes in quality and marketing activities over time [40].

Customer satisfaction is one of the most important factors in the supply chain because it determines how a consumer is satisfied with a company's products, services, or performance [41]. Customer satisfaction directly affects the growth or survival of a product. Therefore, meeting the customer's requirements for the product or service provided ensures the manufacturer's overall quality performance [42]. Aesthetics, brand value, individual requirements, economic feasibility, psychological perception, and other elements that are directly customer-oriented affect the entire product performance, making customer happiness a prioritized checkbox for any new or existing company or product [43]. Kano's technique provides a logical strategy for improving customer satisfaction, even if it is difficult to quantify in other ways [44]. The Kano model helps establish the relationship between consumer preferences and overall satisfaction. By dividing products and services into unsatisfied, satisfactory, and above expectations, the wants and needs of the consumer can be clarified, and they can be compared with the product or service provided [45].

Seyedhosseini et al. examined the effect of the producer's effort on the price sensitivity of customers and presented a mathematical model in which the demand is competitive and dependent on price [46]. Mukhtar and Azhar developed a conceptual model that can help managers develop a competitive value chain using value co-creation and integration to make the entire supply chain competitive [47]. Alabdali and Salam investigated the impact of digitalization on the competitiveness of the supply chain [48]. Moreover, Li et al. studied the impact of blockchain on the competitiveness of the supply chain [49].

2.2. Pricing and Green Coordination

Coordination among the entities of a supply chain is extremely important to win market competition [50,51]. Fundamental trade-offs between important factors such as price, green quality, and buyer choice often create coordination problems. Researchers have proposed different pricing models based on supply chain topologies [52–54]. Other studies addressed more detail about the influence of green factors on price choice [55,56]. Yadav et al. proposed a model for a long-run supply chain in which the selection of products is influenced by the cross-price elasticity of demand. According to their research, combining products with high negative or positive cross-price elasticity is profitable [57]. Ghomi-Avili et al. developed a pricing model for a green closed-loop supply chain that considered interruptions and fuzzy environments [58]. Mondal and Giri investigated pricing techniques and used product portfolios in a closed-loop supply chain. They also hypothesized that price and green choices affect market demand [59]. Jin et al. contributed by coordinating pricing and recycling choices for a reverse supply chain that included both online and offline channels and operated under a variety of power architectures [60]. Jian et al. studied a green closed-loop supply chain coordinated by a profit-sharing agreement [61]. Li et al. recommended investment and promotion options for a closed-loop supply chain [62]. They investigated two advertising agencies and an industrial plant using a two-stage game theory technique. Ranjan and Jha investigated a multi-channel supply chain to distribute products to end users through traditional and online channels [52]. Several studies have considered different assumptions, such as price elasticity and cross-price sensitivity [63,64].

2.3. Supply Chain Coordination Problem

Marketing and supply chains have recently been integrated with different sciences. Chen et al. examined the effect of price regulation and cooperative advertising in a two-channel two-level supply chain [65]. Li et al. studied centralized and decentralized pricing systems in a two-channel competitive green supply chain [31]. Green et al. investigated the relationships between marketing strategy, supply chain performance, and organizational success [32]. Integrating green marketing and supply chain decisions has been challenging [33,34]. Some researchers have exploited the concept of elasticity in forming supply networks. Giri and Sharma considered a supply chain with one manufacturer and two retailers based on advertising-dependent demand [35]. Hull provided a model based on supply and demand elasticity to explain supply chain performance [36]. Seifbarghy et al. examined a two-level supply chain, including a manufacturer and a retailer, in which the price and quality of the final product affect consumer demand [37]. Kaplan et al. studied the customer's price-oriented behavior using the price elasticity of demand [38].

Zheng et al. showed how behavioral theory and non-cooperative and cooperative game theories can be sufficient to promote cooperation at the supply chain level for sustainability [66]. Chhetri et al. presented an integrated theoretical framework that linked all three main constructs of supply chain complexity, including coordination, collaboration and configuration, with product demand and design complexities [67]. Ran and Xu analyzed and designed a coordination contract that is suitable for a low-carbon supply chain under the conditions of carbon tax policy and government subsidies in order to meet the demands of the society's transition to a low-carbon economy [68]. Goodarzian et al. [69] proposed a multi-objective mathematical programming model for dealing with the production-distribution problem. In addition, Mondal et al. [70] modeled green products' distribution. Furthermore, Choi et al. [71] suggested an intelligent two-channel (online-offline) for determining the products' selling prices.

In this research, a three-level supply chain network, including manufacturers, distribution centers, and consumers, is analyzed. The main objective of this research is to determine how the Kano model may help the supply chain network in identifying customer needs. Despite its wide application in the multidisciplinary field of quality management, the Kano model has not been used in optimization. In addition, evaluating customer needs using the Kano model makes supply chain networks customer-oriented and efficient. As a result of more competition, an increasing number of businesses, especially in this sector, focus on their customers instead of profit, which results in customer satisfaction and loyalty to the company.

The main contributions of this study are two-fold: (1) Presenting a mathematical programming model for the supply chain network using Kano's conceptual model, and (2) Using pricing in the design of the customer-oriented supply chain network and solving through a Cooperative Game Theory approach taking transportation pollution into consideration.

3. Problem Definition

Today's competitive and dynamic environment has made organizations and companies focus on the customer so that the production of goods and services initiates and ends with the customer. In other words, nowadays, organizations can survive in this competitive environment, whose main focus is to meet the requirements and needs of customers with maximum quality. On the other hand, services have a particular complexity due to their intangible aspects, which makes measurement and design somewhat difficult [72]. Rendering appropriate services to customers is one of the most substantial factors in creating a distinction between businesses in a competitive environment [73].

A quality product meets the needs of customers. Some researchers have introduced quality as something more than compliance with customers' needs and beyond the level of customers' expectations. Accordingly, the number of customer-focused organizations that consider customer satisfaction as the main performance indicator has been increasing [74]. Even according to some experts' opinions, customer-centricity is considered equivalent to good and effective management [75]. There are three very important factors that create satisfaction in customers [76]:

1. Identification of customers;
2. Identification of customers' needs;
3. How to estimate the demands of customers.

For this purpose, the Kano model categorizes the features of a product, which is based on how much the presence or absence of a feature in the product can lead to customer satisfaction or dissatisfaction. The needs of customers are placed in one of these three groups [77]:

1. Basic needs: meeting these needs does not increase customer satisfaction, but not meeting them will cause severe customer dissatisfaction;
2. Functional needs: customer satisfaction related to these types of needs is a linear function of product feature conditions. This means that improving the performance level of the product leads to customer satisfaction, and lowering its level leads to dissatisfaction;
3. Motivational needs: meeting this category of needs causes tremendous customer satisfaction and often attracts customers to the brand of that product, and not meeting them will not cause customer dissatisfaction. For this reason, some researchers have considered the Kano model as a three-dimensional model.

According to the literature review, various models have been presented by several researchers, but none of them have considered the three main aspects of the Kano model in the design of the supply chain network [28–52,52–71]. This study considers the problem of a supply chain network design based on the motivational needs of customers. The proposed model of this research is developed for a green supply chain network consisting of four different stages. The first stage is customers (c) who demand to consume different products (k) with their level of expectations. The second stage is distribution centers (d), which store and distribute products between manufacturers and customers. The third step is the carriers (t) needed to transport products between manufacturers, distribution centers, and customers. The last stage is the manufacturers (m), each of which may have different levels of ability to produce products at different levels of expectations.

In this research, for the relationship between the Kano model and supply chain design, deviation variables are defined to estimate more or less than the level of customer expectations, that is, when the customer requires a specific level of functional needs, but these needs are not fully met, the value of the deviation variable becomes negative. In the case of going beyond the functional needs, the value of the deviation variable becomes positive. Finally, the zero value of the deviation variable indicates the exact fulfillment of the functional needs.

This study seeks to design a green three-level multi-product supply chain network, including manufacturers, distribution centers, carriers, and customers, based on the criteria of the Kano model customer segment (shown in Figure 1). In this supply chain, the products are produced and delivered to the customers according to the customers' needs with the goal of optimizing the entire supply chain network. The manufacturers sell a wide range of products that are suitable for different consumer groups in the first stage. In the second stage, the distribution centers (d) are responsible for storing and transporting goods between the manufacturers and customers (c), in which carriers (t) are used to transfer goods from the manufacturers to the distribution centers and eventually to the customers.

According to Kano's conceptual model, there are four categories of needs, one of which is indifferent and is left out in this research. Three categories of customer needs, including "must-be needs", "one-dimensional needs", and "attractive needs", are examined in the present study.

In this mathematical programming model, the total revenue, market penalty and reward, total cost, and lost sales are considered to evaluate the utility of the entire supply chain network.

The assumptions of the proposed model are as follows:

- All parameters are known and certain.
- Lost sales and selling less than the product demand are allowed but penalized.
- There is no waste.
- Customer demand can be segmented.

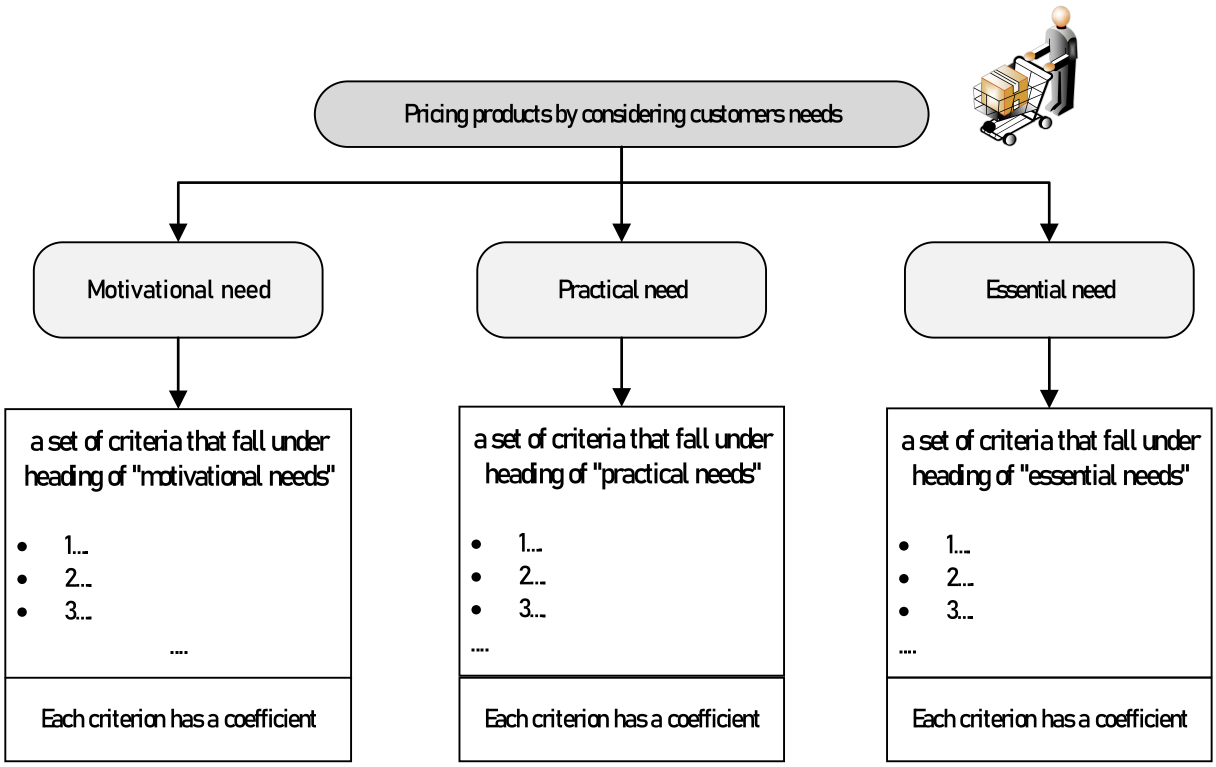

Figure 1. The study framework.

In the mathematical model presented in this research, the following decisions are made:

1. The amount of customer demand that must be satisfied;
2. How to transport the demand to the customer;
3. Number of lost sales;
4. Forecasting customer demand based on price;
5. The final price of the product;
6. Overall customer satisfaction (taking into account the Kano model).

Finally, this model considers decision-making processes for a real-world supply chain network to purchase products in accordance with customer expectations, taking the reduction in emissions into account.

A mathematical programming model is presented in this section. This model maximizes the final profit in a three-level supply chain.

The indices, parameters and variables of this model are defined in Abbreviations.

Objective function

$$Maximize\ \ (TR - PC - HC - TC - EC - ML - LC) \tag{1}$$

The objective Function (1) attempts to maximize the utility of the entire supply chain network. The objective function includes total profit minus costs. There are six sections for the costs (production costs, storage costs, transportation costs, CO_2 emissions, the total market penalty for deficiencies in various parts of expectations, and lost sales costs).

Constraints:

$$TR = \sum_{m \in M} \sum_{d \in D} \sum_{k \in K} \sum_{c \in C} Price_{kd} Dee_{ck} \tag{1a}$$

$$PC = \sum_{m \in M} \sum_{d \in D} \sum_{k \in K} \sum_{t \in T} U1_{kt}^{md} q_{mk} \tag{1b}$$

$$HC = \sum_{m \in M} \sum_{d \in D} \sum_{k \in K} \sum_{t \in T} U1_{kt}^{md} j_d \tag{1c}$$

$$TC = \sum_{m\in M}\sum_{d\in D}\sum_{k\in K}\sum_{t\in T} U1_{kt}^{md} h1_t b_{md} + \sum_{c\in C}\sum_{d\in D}\sum_{k\in K}\sum_{t\in T} U2_{kt}^{dc}\ h2_t a_{dc} \tag{1d}$$

$$EC = \sum_{m\in M}\sum_{d\in D}\sum_{k\in K}\sum_{t\in T} X1_{kt}^{md} \theta1_t b_{dm} + \sum_{c\in C}\sum_{d\in D}\sum_{k\in K}\sum_{t\in T} X2_{kt}^{dc} \theta2_t a_{dc} \tag{1e}$$

$$\begin{aligned} ML = {} & \sum_{c\in C}\sum_{k\in K}\sum_{t\in T}\sum_{d\in D}\sum_{m\in M} \beta_1 \left(\mathrm{npm}_{\mathrm{kt}}^{md-} + \mathrm{npt}_{\mathrm{kt}}^{\mathrm{dc}-} + \mathrm{npd}_{\mathrm{kt}}^{\mathrm{dc}-}\right) \\ & + \sum_{c\in C}\sum_{k\in K}\sum_{t\in T}\sum_{d\in D}\sum_{m\in M} \beta_{\mathrm{r}} \left(\mathrm{nrm}_{\mathrm{ktr}}^{\mathrm{md}-} + \mathrm{nrt}_{\mathrm{ktr}}^{\mathrm{dc}-} + \mathrm{nrd}_{\mathrm{ktr}}^{\mathrm{dc}-}\right) \end{aligned} \tag{1f}$$

$$LC = \sum_{c\in C}\sum_{k\in K} ys_{ck} o_k \tag{1g}$$

$$Dee_{ck} = \left(de_{ck} - \beta'_k Price_{kd}\right) \qquad \forall\ c \in C,\ m \in M,\ k \in K,\ d\ \in D \tag{2}$$

$$\sum_{d\in D}\sum_{t\in T} U2_{kt}^{dc} + ys_{ck} = de_{ck} \qquad \forall c \in C,\ k \in K \tag{3}$$

$$\sum_{m\in M}\sum_{t\in T} U1_{kt}^{md} = \sum_{c\in C}\sum_{t\in T} U2_{kt}^{dc} \qquad \forall\ d \in D,\ k \in K \tag{4}$$

$$U1_{kt}^{md} \le X1_{kt}^{md}\ M \qquad \forall m \in M,\ \ k \in K,\ t \in T,\ d \in D \tag{5}$$

$$U2_{kt}^{dc} \le X2_{kt}^{dc}\ M \qquad \forall c \in C,\ \ k \in K,\ t \in T,\ d \in D \tag{6}$$

$$\sum_{k\in K}\sum_{t\in T}\sum_{d\in D} U1_{kt}^{md} \le y_m \qquad \forall m \in M \tag{7}$$

$$\sum_{k\in K}\sum_{m\in M}\sum_{d\in D} U1_{kt}^{md} \le V1_t \qquad \forall t \in T \tag{8}$$

$$\sum_{k\in K}\sum_{c\in C}\sum_{d\in D} U2_{kt}^{dc} \le V2_t \qquad \forall t \in T \tag{9}$$

$$\sum_{d\in D}\sum_{t\in T} U1_{kt}^{md} - X1_{kt}^{md}\ *\ pm_m\ \ge 0 \qquad \forall k \in K,\ \ m \in M \tag{10}$$

$$\sum_{k\in K}\sum_{m\in M}\sum_{d\in D} U1_{kt}^{md} - X1_{kt}^{md}\ *\ tm_m \ge 0 \qquad \forall t \in T \tag{11}$$

$$\sum_{k\in K}\sum_{c\in C}\sum_{d\in D} U2_{kt}^{dc} - X2_{kt}^{dc}\ *\ tm_t \ge 0 \qquad \forall t \in T \tag{12}$$

$$X2_{kt}^{dc} tl_1^t + npt_{kt}^{dc-} - npt_{kt}^{dc+} = X2_{kt}^{dc} se_k \qquad \forall\ k \in K,\ t \in T,\ d \in D,\ c \in C \tag{13}$$

$$X2_{kt}^{dc} dl_1^d + npd_{kt}^{dc-} - npd_{kt}^{dc+} = X2_{kt}^{dc} se_k \qquad \forall\ k \in K,\ t \in T,\ d \in D\ , c \in C \tag{14}$$

$$X1_{kt}^{md} sl_1^m + npm_{kt}^{md-} - npm_{kt}^{md+} = X1_{kt}^{md} se_k \qquad \forall m \in M,\ k \in K,\ t \in T,\ d \in D \tag{15}$$

$$X2_{kt}^{dc} tl_1^t + nrt_{ktr}^{dc-} - nrt_{ktr}^{dc+} = X2_{kt}^{dc} re_r \qquad \forall c \in C,\ k \in K,\ t \in T,\ d \in D,\ r \in R \tag{16}$$

$$X1_{kt}^{md} sl_{mr} + nrm_{ktr}^{md-} - nrm_{ktr}^{md+} = X1_{kt}^{md} re_r \ \forall m \in M,\ k \in K,\ t \in T,\ d \in D,\ r \in R \quad (17)$$

$$X2_{kt}^{dc} dl_r^d + nrd_{ktr}^{dc-} - nrd_{ktr}^{dc+} = X2_{kt}^{dc} re_r \qquad \forall c \in C,\ k \in K,\ t \in T,\ d \in D,\ r \in R \quad (18)$$

$$\begin{gathered} X1_{kt}^{md}, X2_{kt}^{dc} \in [0,1],\ U1_{kt}^{md}, U2_{kt}^{dc}\ ,\ Price_{kd},\ Dee_{ck},\ Ad_{dk}, \\ Ada_{mk}, npm_{kt}^{md-}, npm_{kt}^{md+},\ nrm_{ktr}^{md-}, nrm_{ktr}^{md+},\ npt_{kt}^{dc-}, npt_{kt}^{dc+},\ nrt_{ktr}^{dc-},\ nrt_{ktr}^{dc+} \\ , npd_{kt}^{dc-},\ npd_{kt}^{dc+}, nrd_{ktr}^{dc-}, nrd_{ktr}^{dc+} \geq 0 \end{gathered} \quad (19)$$

In the above model, Constraint (2) shows the final demand for the product k by the customer c.

Constraint (3) states that the amount of product shipped from the distribution center to the customer must meet the customer's demand (the shortage is also computed).

Constraint (4) states that the amount of product shipped from the manufacturer to the distribution center is equal to the amount of product shipped from the distribution center to the customer.

Constraints (5) and (6) indicate that if there is a demand, the product will move along the path.

Constraint (7) dictates that the amount of product that is sent from the manufacturer must be equal to the production capacity of the manufacturer.

Constraints (8) and (9) mandate that the amount of product transferred from the manufacturer to the distribution center and from the distribution center to the customer does not exceed the capacity of the vehicle.

Constraints (10)–(12) indicate that the product flow is always positive.

Constraint (13) shows the equality and balance between the motivational level of the set of customer's needs regarding the product and the score of the carrier's first (motivational) criterion.

Constraint (14) is similar to the previous constraint, but the slack variables related to the distribution centers exist in the equation, and the motivational level of the product from the customers' viewpoint and the motivational evaluation score of the distribution centers are considered.

Constraint (15) is also similar to the previous two constraints. In this constraint, the score of satisfying the producer's motivational needs is considered, and the slack variables of this constraint are related to the manufacturer.

Three constraints (13)–(15) considered the customers' viewpoint and only considered the motivational level of the set of needs of the product.

Constraint (16) also deals with the balance and equation between the final customer's need level for the criteria r and the carrier's evaluation score t for the criteria r. Moreover, the slack variables of shortage and surplus related to the carriers are used.

Constraint (17) is similar to Constraint (16), except that the manufacturer is considered in this constraint.

Constraint (18) is also similar to Constraint (16), but this constraint considers the distribution centers.

The price of the product is determined according to the customers' needs, as shown in Figure 1. In the Kano model, three essential needs are presented (basic need, functional need, and motivational need). Each need has a set of criteria, and each criterion has a value assigned to it. Therefore, the price of the product is distinguished after taking into account all of the criteria in order to increase customer satisfaction.

4. Solution Approach

In this section, we consider the Cooperative Game Theory in which the supply chain members make decisions in cooperation with each other. In this case, the supply chain members seek to maximize the profit of the entire system. The proposed optimization model is implemented in a case study and solved using the Cooperative Game Theory to obtain the optimal solution; finally, the results are analyzed. It should be noted that several research works have considered case studies and numerical examples to validate their proposed models and solution approaches [78–81].

4.1. Case Study

Considering that data collection is extremely important, the required information to solve the proposed mathematical programming model was taken from the study of Tontini and Picolo, 2013 [82]. A sample problem including two manufacturers, three distribution centers, ten customers, five carriers and three types of products is provided to validate the proposed model and the solution approach. The problem data is presented as follows.

As can be seen in Figure 2, product 1 is sent from factory 2 to distribution center 1 by trucks 1, 2 and 3. Then, according to the estimated customers' demand, product 1 is shipped to customers 1, 4, and 5 by vehicles 3, 4, and 5, and product 3 is delivered to customer 2 by vehicle 1.

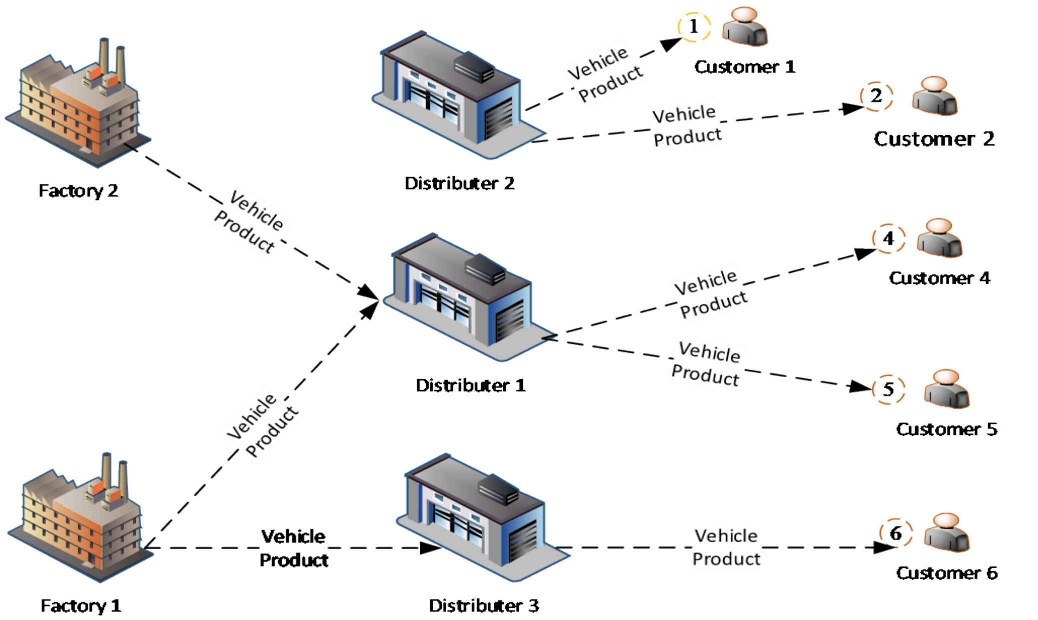

Figure 2. The schematic supply chain network for the case study.

The level of needs of consumer segments for products is shown in Table 1.

Table 1. The levels of the needs of consumer segments for products.

se_4	se_3	se_2	se_1	Segments
		10		Motivational
6			6	Practical
	4			Essential

The levels of customer expectations from the criteria are taken from the study of Tontini and Picolo [82].

Tables 2–8 provide the other necessary information for solving the research problem in the GAMS software version 24.1.2.

Table 2. The distribution center criteria and their expected needs from suppliers [82].

r	Criteria Name	re_r
1	Battery charge life	4
2	Lightweight	5
3	"Doubling up" as a universal remote control for TV appliances	4
4	Resolution of the camera (megapixels)	4
5	Taking pictures in dark environments (flash)	5
6	Photo quality (in general)	4
7	Easy on-screen viewing (big screen)	4
8	Resilience (e.g., when dropped on the floor)	4
9	GPS (location, route maps and satellite)	4
10	Universal battery charger (can be used for multiple devices)	4
11	Digital photo camera	6
12	Touchscreen	4
13	Video call in dark environments	5
14	MP3 player	5
15	Sensitivity to signal tower (good coverage)	6
16	Headset with wireless microphone	6
17	Front camera for video calls	6
18	Integrated video camcorder	6
19	Connectivity (Bluetooth, Wi-Fi, USB, etc.)	6
20	Small size of the device	9
21	Ease in terms of typing messages	4
22	Internet browsing access	4
23	Access to Twitter, Orkut and Facebook	8

Table 3. Evaluation scores of suppliers for criteria.

r	sl_{1r}	sl_{2r}	sl_{3r}	sl_{4r}	tl_{1r}	tl_{2r}	tl_{3r}	tl_{4r}	dl_{1r}	dl_{2r}	dl_{3r}	dl_{4r}
1	5	6	6	4	2	5	3	6	5	7	6	6
2	5	5	6	3	4	3	3	3	6	5	6	5
3	4	5	4	5	4	4	3	4	5	7	5	4
4	4	4	3	4	4	4	5	5	4	5	5	3
5	3	3	5	3	2	4	3	5	4	6	4	6
6	6	5	5	5	5	5	3	3	5	5	4	5
7	4	5	5	6	6	5	3	4	5	6	4	4
8	5	5	6	5	5	5	3	4	5	6	5	3
9	3	4	5	4	5	6	4	5	5	5	5	5
10	5	3	4	5	6	6	4	5	4	5	5	5
11	4	3	5	6	6	5	4	4	4	5	6	6
12	4	5	5	5	4	5	5	4	4	4	6	6
13	5	5	4	4	5	5	4	6	5	4	6	5
14	6	4	5	5	5	6	5	6	4	4	5	5
15	2	3	6	4	5	6	4	5	5	6	5	4
16	3	4	6	6	4	6	5	5	4	6	5	4
17	4	5	4	5	4	5	4	4	4	5	4	3
18	5	5	4	5	6	5	4	4	4	5	4	3
19	6	4	5	4	6	4	4	4	5	4	4	5
20	4	3	6	4	5	5	4	5	5	4	5	5
21	3	3	6	5	5	6	5	5	4	3	5	4
22	3	3	4	5	5	6	5	5	4	3	5	4
23	2	5	4	6	6	5	5	6	4	4	6	4

Table 4. Values of market bonus α_k and determination β_r multipliers.

Multipliers	α_1	α_2	α_3	α_4
Values	5	2	2	5

Multipliers	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}	β_{12}	β_{13}	β_{14}	β_{15}	β_{16}	β_{17}	β_{18}	β_{19}	β_{20}	β_{21}	β_{22}	β_{23}
Values	4	5	4	4	5	4	4	4	4	4	6	4	5	5	6	6	6	6	6	9	4	4	8

Table 5. Data related to products.

k	de_{1k}	de_{2k}	de_{3k}	de_{4k}	o_k
1	75	20	30	50	200
2	41	44	41	41	150
3	30	41	35	41	200
4	50	41	41	36	180

Table 6. Data related to manufacturers.

S	q_{m1}	q_{m2}	q_{m3}	q_{m4}	y_m	pm_m
1	100	600	400	130	1000	50
2	120	100	400	150	400	50
3	80	60	400	100	200	50
4	130	30	808	200	700	50

Table 7. Data related to carriers.

t	$h1_t$	$h2_t$	$V1_t$	$V2_t$	tm_t
1	500	300	500	500	200
2	200	100	1500	1500	200
3	800	600	500	500	50
4	500	300	500	500	100

Table 8. Data related to distribution centers.

d	b_{1d}	b_{2d}	b_{3d}	b_{4d}	a_{d1}	a_{d2}	a_{d3}	a_{d4}	j_d
1	476	66	101	626	173	503	314	158	0.2
2	222	358	382	514	287	332	257	449	0.5
3	210	200	350	400	300	310	210	300	0.4
4	190	250	410	350	310	320	250	350	0.3

The mathematical model was solved using the GAMS software. Figure 2 depicts the obtained results. As shown in this figure, the demands of customers 1, 2, 4, and 6 are met. Furthermore, factories 1 and 2 as well as distribution centers 1 and 2, are operating. However, distribution center 2 is off.

According to Figure 2, the results of solving the proposed model show that the total estimated demand in this supply chain is 48,676 units of type 1, 2 and 3 products. The total number of products sent from the factories to the distribution centers is 16,407 units, and the distribution centers transfer the same amount to the customers. Considering that the shortage is allowed in the proposed mathematical programming model, the total number of shortages is equal to 32,269 units, which is equal to the difference between the total number of demands and the total number of products sent to customers. Other outputs of solving the case study with the GAMS software are presented in Table 9.

Table 9. Outputs of solving the case study with the GAMS software.

PC (Production cost) = 140,070,752 HC (Total inventory cost in the distribution center) = 3,521,415 TC (Total transportation cost) = 14,489,370 EC (Total cost of producing emissions) = 11,719 ML (Profit gained from the reward of meeting the motivational needs) = 2404 LC (Lost sale cost) = 6.453935 × 10[8]	$\boldsymbol{\sum_{c\in C}\sum_{k\in K} Dee_{ck} = 48{,}676}$
	$\sum_{m\in M}\sum_{d\in D}\sum_{k\in K}\sum_{t\in T} U1_{kt}^{md} = 16,407$
	$\sum_{d\in D}\sum_{c\in C}\sum_{k\in K}\sum_{t\in T} U2_{kt}^{dc} = 16,407$
	$\sum_{c\in C}\sum_{k\in K} ys_{ck} = 32,269$
	$\sum_{d\in D}\sum_{c\in C}\sum_{k\in K}\sum_{t\in T} U2_{kt}^{dc} + \sum_{c\in C}\sum_{k\in K} ys_{ck} = 48,676$

4.2. The Sensitivity Analysis of the Model

The main goal of this study was to investigate the motivational needs in the design of the supply chain network. Consequently, a series of scenarios with different levels of motivational needs are examined; for example, coefficient β_1 is considered to examine how the determination of customers' motivational needs affects the network. In fact, this analysis is like simulating a real observation where customers may have different determination levels in their motivation needs for buying decisions. In order to analyze the effect of changing the β_1 coefficient (the motivational needs) on the output, its value presented in Table 4 was changed by 10, 20, and 30 percent higher and lower than the initial value.

According to Figure 3, increasing the β_1 coefficient leads to linearly increasing ML (profit gained from the reward of meeting the motivational needs). By increasing the level of the motivational needs, the mathematical model tries to meet the demand of customers whose needs are at the motivational level to increase the profit from receiving the bonus, which will also result in a significant financial burden. In other words, increasing β_1 leads to the model sensitivity to the market penalty costs that are caused by responding to the demand through the suppliers (manufacturers, distribution centers and carriers) less than the expected motivational needs. In other words, when β_1 increases, the costs increase due to increasing the costs of the lost sales and transportation costs to meet the expected motivational needs of the product from the customers' viewpoint. Similar to the carriers with a higher motivational evaluation score, we also have manufacturers and distribution centers with a higher evaluation score. As a result, the model used more facilities with a higher motivational evaluation score by increasing the sensitivity towards the motivational features of the product. With the percentage change of similar coefficients for the capacity of manufacturers, we have: when we reduce the base amount by known percentages, we actually reduce the amount of production, and considering the amount of demand, this issue will lead to more lost sales, and as a result, the transportation costs will be reduced. However, this reduction is much less than the increase in lost sales, which ultimately leads to an increase in the total costs of the entire supply chain. Moreover, increasing the production capacity leads to meeting the demands of customers and gaining higher profits. This change in other costs may also result in small changes.

Similar to the previous analysis, a sensitivity analysis was performed on the capacity of the distribution centers, shown in Figure 4.

As seen in Figure 4, increasing the capacity of distribution centers has no significant impact on the value of the objective function because the optimal value of the objective function was obtained, and this increase does not have much effect on the model. However, reducing the capacity leads to increasing the cost by up to 20% (decreasing the profit), which is caused by lost sales. On the other hand, reducing the capacity by 30% (and more) increases the cost more than usual, which is not economical. Hence, the strategy for reducing the capacity of distribution centers up to 20% would be reasonable.

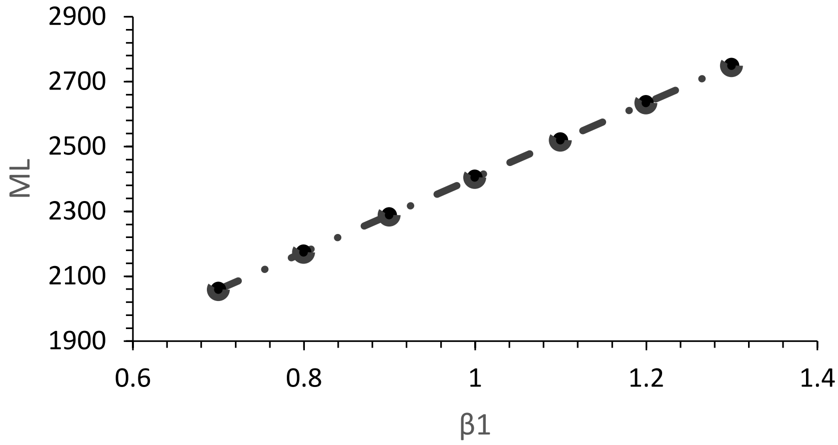

Figure 3. The effect of changing β_1 on the output.

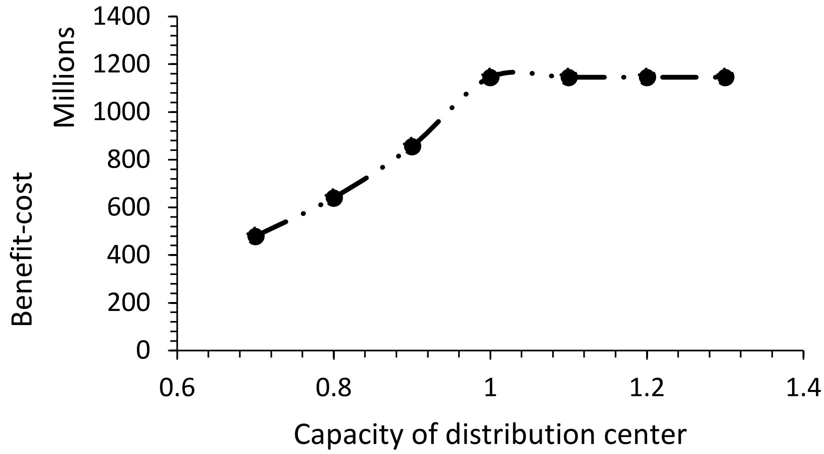

Figure 4. The effect of changing z^d on the output.

Transportation cost is the last parameter to which the sensitivity of the model is analyzed. As shown in Figure 5, to analyze the transportation costs, seven scenarios were considered. First, the amount of 0.7% was added to the cost of the carriers, then this amount increased to 80% and finally rose to 130%, and the results demonstrate that with the increase in the carriers' costs, the amount of TC increases linearly. It is obvious that increasing the transportation cost linearly only raises the total costs.

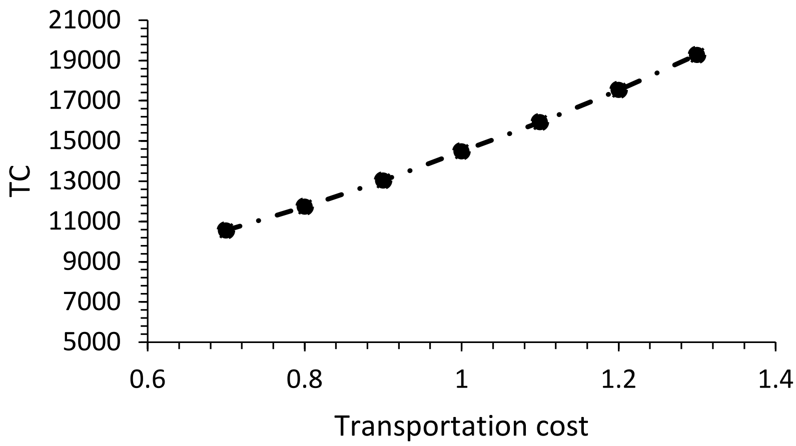

Figure 5. The effect of changing h^t on the output.

5. Discussion and Conclusions

The Kano model is a dynamic tool for developing new products and investigating customer satisfaction regarding the product features at different phases of the product life cycle. The Kano model is intrinsically customer-centric; that is, it focuses exclusively on addressing customer concerns to meet customer needs. The Kano method is intelligently used to determine the needs of customers. In other words, in product development, the Kano model ignores the main concern of companies to the capabilities and/or cost constraints.

It is very important to investigate the effect of any new feature on customer satisfaction. This paper examined that the endeavors for product feature development should focus not only on what a product (technology) can do but also on features that are important to customers. In addition, this research exploited the Kano method in categorizing different features of a product into "one-dimensional", "attractive" and "indifferent" categories and examined the effect of these features on customer satisfaction, taking the product pricing into account. These classifications are useful for prioritizing the features that are most important to customers and are extremely important for high-tech products where the features of the new products are being continuously developed. To achieve competitive advantage through differentiation strategies, greater improvement endeavors and efforts should be directed based on "attractive" features.

In this study, three categories of needs were defined based on the customer buying behavior and needs. Moreover, a mathematical programming model was proposed for the supply chain network optimization based on the Kano model, considering multiple products, manufacturers, carriers, distribution centers, and customers. In addition, the emission of greenhouse gases and the dependence of demand on the selling price of products has been investigated. The findings of the research demonstrated that the needs of customers could be divided into the main needs ("one-dimensional", "attractive" and "indifferent"). Furthermore, the needs of customers should be designed according to the understanding of customer needs (voice of customers) to enhance the actual efficiency of green supply chain networks. The profit of the entire supply chain and the profit of each member of the supply chain under the conditions of cooperation were investigated. With the increase in the variety of products and the increase in the number of customers, the profit of the whole supply chain and its members increases. The proposed model of this study as an appropriate pattern can be used by the researchers and planners of the green supply chain. From a practical point of view, this research can assist firms with their decision-making on the design and management of their whole business processes. As an example, when a retailer realizes that the customers' needs, based on specific market research, regarding the segment of the attractive feature have increased, the members of the supply chain should cooperate with each other to improve this segment. For future studies, demand, production, and transportation costs can be considered uncertain and nondeterministic parameters or exponential price elasticities can be used. In addition, the ISO 14000 standards can be taken into account in order to reduce waste. Furthermore, the reverse route can be incorporated into the proposed model to avoid waste. Moreover, different meta-heuristic algorithms may be exploited to solve the mathematical model for large-sized problems, and the results may be compared. Furthermore, the concept of resilience and backup suppliers should be taken into account to reduce shortages.

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Abbreviations

Sets and indices	
$\boldsymbol{k \in K}$	Products' set
$\boldsymbol{m \in M}$	Manufacturers' set
$\boldsymbol{d \in D}$	Distribution centers' set
$\boldsymbol{c \in C}$	Customers' set
$\boldsymbol{t \in T}$	Carriers' set
$\boldsymbol{r \in R}$	Criteria's set
Parameters	
$\boldsymbol{h1_t}$	Cost of transportation with carrier *t* from manufacture *m* to distribution center *d*
$\boldsymbol{h2_t}$	Cost of transportation with carrier *t* from distribution center *d* to customer c
$\boldsymbol{V1_t}$	Capacity of transportation with carrier *t* from manufacture *m* to distribution center *d*
$\boldsymbol{V2_t}$	Capacity of transportation with carrier *t* from distribution center *d* to customer *c*
$\boldsymbol{q_{mk}}$	Production cost per unit of product *k* in the manufacture *m*
$\boldsymbol{o_k}$	Cost of lost sales for product *k*
$\boldsymbol{j_d}$	Cost of warehousing each product unit in the distribution center *d*
$\boldsymbol{se_k}$	Product level required by customers
$\boldsymbol{re_r}$	Customer expectation level for the criterion *r*
$\boldsymbol{sl_{mr}}$	Assessment score of manufacturer s for criteria *r*
$\boldsymbol{tl_{tr}}$	Assessment score of carrier t for criteria *r*
$\boldsymbol{dl_{dr}}$	Assessment score of distribution center *d* for criteria *r*
$\boldsymbol{y_m}$	Production capacity of manufacturer *m*
$\boldsymbol{a_{dc}}$	Distance between customer *c* and distribution center *d*
$\boldsymbol{b_{md}}$	Distance between distribution center *d* and manufacturer *m*
$\boldsymbol{de_{ck}}$	Demand of customer *c* for product *k*
$\boldsymbol{\beta'_k}$	Customer sensitivity to product price
$\boldsymbol{pm_m}$	Minimum production amount of manufacturer *m*
$\boldsymbol{tm_t}$	Minimum transportation amount of carrier *t*
$\boldsymbol{\beta_r}$	Market bonus multiplier for product *k*
$\boldsymbol{\theta 1_t}$	The amount of CO_2 emitted by carrier *t* to go from manufacture *m* to distribution center *d*
$\boldsymbol{\theta 2_t}$	The amount of CO_2 emitted by carrier *t* to go from distribution center *d* to customer c
Decision variables	
$\boldsymbol{U1_{kt}^{md}}$	The amount of demand for distribution center *d* of product *k*, which is met by carrier *t* by manufacturer *m*.
$\boldsymbol{U2_{kt}^{dc}}$	The amount of customer demand *c* of product *k* that is met by carrier *t* by the distribution center *d*.
$\boldsymbol{X1_{kt}^{md}}$	If product *k* is transported by carrier *t* from the manufacturer *m* to the distribution center *d*: 1; otherwise: 0.
$\boldsymbol{X2_{kt}^{dc}}$	If product *k* is transported by carrier t from distribution center *d* to customer *c* 1, otherwise 0.
$\boldsymbol{ys_{ck}}$	The number of lost sales to customer demand *c* of product *k*.
$\boldsymbol{Price_{kd}}$	Final price of product *k* by distribution center *d*
$\boldsymbol{Dee_{ck}}$	Final demand for product *k* by customer *c*
$\boldsymbol{npm_{kt}^{md-}}$	Deviational variable related to manufacturers for being under the expectations of customers
$\boldsymbol{npm_{kt}^{md+}}$	Deviational variable related to manufacturers for going beyond the expectations of customers
$\boldsymbol{nrm_{ktr}^{md-}}$	Deviational variable related to manufacturers for being under the expectations of customers
$\boldsymbol{nrm_{ktr}^{md+}}$	Deviational variable related to manufacturers for going beyond the expectations of customers

Decision variables

npt_{kt}^{dc-}	Deviational variable related to carriers for being under the expectations of customers
npt_{kt}^{dc+}	Deviational variable related to carriers for going beyond the expectations of customers
nrt_{ktr}^{dc-}	Deviational variable related to carriers for being under the expectations of customers
nrt_{ktr}^{dc+}	Deviational variable related to carriers for going beyond the expectations of customers
npd_{kt}^{dc-}	Deviational variable related to distribution centers for being under the expectations of customers
npd_{kt}^{dc+}	Deviational variable related to distribution centers for going beyond the expectations of customers
nrd_{ktr}^{dc-}	Deviational variable related to distribution centers for being under the expectations of customers
nrd_{ktr}^{dc+}	Deviational variable related to distribution centers for going beyond the expectations of customers

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