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Redesigning and Re-planning of Location, Pricing, Inventory and Marketing Decisions in a Multi-channel Distribution Network: A Case Study

H. Bagheri[a], M. H. Karimi Ghavareshki*[a], H. Fazlollahtabar[b], M. Abbasi[a]

[a] *Department of Industrial Engineering, Faculty of Engineering, Malek Ashtar University of Technology, Tehran, Iran*
[b] *Department of Industrial Engineering, School of Engineering Damghan University, Damghan, Iran*

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ABSTRACT

Discussion of distribution and distribution network design and planning, including location, pricing, optimal selection of distribution channels, as well as marketing decisions, is of great importance in the supply chain. Due to the changes and uncertainty of market demand, the design and planning of the distribution network and static sale have encountered many problems in practice. This article presents a nonlinear mathematical programming model for locating, inventory control, and marketing of manufactured products for a multi-activity organization that includes manufacturing, distribution, retail, and wholesale units. The model includes the localization of distribution centers and the corresponding inventory management, taking into account marketing-related parameters such as multi-channel pricing. A centralized decision support is developed to select the appropriate sales channel, to determine the quantity of products sold in each channel and the discounts granted for each specific channel using real data. In this model, the goal is to maximize profit while increasing customer value by considering competitors' price and choosing the best channel to deliver the product to the customer. Finally, for a small problem instance, the proposed model was solved using the GAMS 28.2.0 x64 optimization software package. Validation study and sensitivity analysis are performed to imply the effectiveness of the formulated mathematical model.

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NOMENCLATURE

Indices		P_K	Product lead time to reach distribution centers
l	Available distribution centers	$M_{m\gamma}$	Variance of product demand in normal distribution
m	The collection of sales channels of the company	CAP_γ	The cost of setting up a new warehouse at point k
k	Set of potential points for creating new distribution centers	$D_{\gamma r}$	The cost of transportation of each product unit from the warehouse of Lam to the sales channel of Mm
r	Areas of demand for the product	C_γ	The cost of transporting each product unit from the warehouse to the sales channel m
Parameters		**Decision variables**	
P	The speed of product production by the domestic manufacturer	φ_m	The selling price of the product in the m channel
$\mathbf{M_{m\gamma}}$	The average price of competitors for the product in the m distribution channel	γ_{mr}	If the product is allocated to the rth region through the mth channel, 1 otherwise 0
$\mathbf{CAP_\gamma}$	Domestic manufacturer's production capacity for the product	ω_{lmr}	The amount of product allocation from the L distribution centers through the m channel for the demand of the r region
$\mathbf{CAP_l}$	The capacity of distribution centers is L	ω'_{kmr}	The amount of product allocation from the kth potential distribution centers through the mth channel for the demand of the rth region
$\mathbf{h_\gamma}$	Cost of maintaining each product unit in distribution centers	α_m	The minimum percentage of net profit considered for the product in m channel
$\mathbf{T_{il\gamma}}$	The cost of transporting each product unit from domestic production to distribution centers is L	Q^*	The amount of the total order of the product by the decision-making system for allocation to the distribution centers

*Corresponding Author Institutional Email: mh_karimi@mut.ac.ir
(H. Karimi Ghavareshk)

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$\mathbf{T'_{jl\gamma}}$	The cost of transporting each product unit from the external manufacturer to the distribution centers is L, because it is delivered to the distributor's warehouse, and the cost of transportation is the responsibility of the supplier.	$EOQ_l = Q_{2l}$	The order amount of the L distribution center of the product
$\mathbf{T''_{lm\gamma}}$	The cost of transporting each product unit from domestic production to distribution centers is k	$EPQ_l = Q_{1l}$	The amount of product production order for L distribution center from the domestic supplier
$\mathbf{A_\gamma}$	The cost of transporting each product unit from the external manufacturer to the distribution centers is L, because it is delivered to the distributor's warehouse, and the cost of transportation is the responsibility of the supplier.	$EPQ_k = Q_{1k}$	The amount of product production order for the kth production center from the domestic supplier
$\mathbf{C'_\gamma}$	The cost of ordering the product from the manufacturer and supplier	$EOQ_k = Q_{2k}$	The order amount of the kth distribution centers of the product by the foreign supplier
$\mathbf{D_\gamma = \sum_r D_{\gamma r}}$	The amount of demand in the rth region of the product (with a normal distribution)	R^*	Reorder point for the product
$\mathbf{P_\gamma = \sum_i P_{i\gamma}}$	The purchase price of the product from a foreign supplier (outsourcing)	Pro_m	The amount of difference in the selling price of the manufactured product in the mth channel compared to competitors and the market
$\mathbf{l_\gamma}$	The set of demand of all regions for the p product	W_k	1 if a new warehouse is established at point k and zero otherwise

1. INTRODUCTION

In recent years, it is required to pay more attention to supply chain management; which has become more and more important. In order to improve and optimize the supply chain, special attention should be paid to the design and planning of distribution and sales. One of the tasks of the distribution and sales system is the transfer of goods from the producer level through the lower levels to the customer level. In addition, the distribution and sales systems can be seen as the eyes of the market observers, who are in direct contact with the customers and can transmit the customers' feedback and opinions to the producers in a timely manner. If producers can incorporate these opinions into their designs and planning, not only will the producers' profits increase, but so will the profits of all components of the supply chain. Distribution systems and sales channels can also collect returned goods and forward them to higher levels in the chain. Other tasks of distribution and sales systems are advertising, market research and competition analysis. A supply chain sales and distribution network typically consists of customers, warehouses, distribution centers, and distribution channels. When planning and designing such networks, decisions are made such as: B. Determining the location of distribution centers, capacity and location of facilities, inventory control policies in distribution center warehouses and determining the final price of the product. Various tools have been used to date to make such decisions, one of the most widespread of which is operations research, which dates back several decades. The design and planning of supply chain networks is one of the most important tasks of supply chain management. Due to the importance of the topic, many articles from different journals have been studied in Scopus and Web of Science databases. The number of reviewed articles was 76, out of which only 13 articles had conducted studies on the problem of joint optimization (location-inventory, location-inventory pricing). Out of 13 articles in the field of joint optimization, almost 61% investigated the problem of integrated optimization of inventory location and only 39% investigated the problem of joint optimization of inventory location and pricing. In this context, a review article has also been studied. The important point is that all these articles are related to the issue of production and distribution, and no article was found about the issue of distribution and sale.

One of the main areas of supply chain activity involves the distribution and sale of products. Due to the connection of the distribution network with the customer, the redesign and positioning of the network activities as well as the proper and correct planning of the distribution network has a significant impact on the cost, performance and flexibility of the supply chain network. The distribution and distribution network examined in this article reaches the customer through two types of suppliers, including internal manufacturers and external manufacturers, and through distribution and distribution centers to three distribution channels (retail, wholesale and e-commerce). There are several ways to distribute goods from production and supply points to demand points. The problem we are facing is the planning of the intelligent distribution and distribution network, which includes the placement of warehouses in distribution centers and the assignment of retailers to warehouses, as well as the selection of inventory and pricing policies for different distribution and distribution channels. In the studied distribution network, three retail and wholesale and internet channels were considered. The design and planning of the distribution and pricing network should be optimized to optimize the amount of demand allocation to each channel considering the profit from each channel. In the three-channel sales network to be examined, the prices and sales volumes should be determined in such a way that the conflict and competition between the two internal channels of the company, i.e. the retail and wholesale channels, is kept as low as possible and under control. In the considered model, product manufacturers are divided into two categories, which include suppliers within the organization and external manufacturers not connected to the holding company. In addition to the location of the distribution centers, this model also considered the inventory policy and pricing in different channels. It is worth noting that products are sold and delivered to customers through three main distribution channels, including retail, wholesale and internet.

Our goal in the studied model is to maximize the profit from Turnover in all three channels retail, wholesale and internet, which results from the difference between income and expenses and offers the maximum benefit for the customer, taking into account the availability and delivery time of the goods. In fact, the revenue is the revenue from the sale of products in all three retail and wholesale channels and the Internet, and the cost includes the cost of setting up a branch warehouse, inventory costs and transportation costs, including shipping from the main warehouse to the distribution centers, from the distribution centers to retailers and wholesalers. The distribution centers and production units affiliated with the holding company have limited capacities in this regard. Utilizing multiple capacities for distribution center storage has made the problem more practical. Further decisions are the optimal assignment of retailers and wholesalers to the established distribution centers, determining the product price and customer demand online for different sales channels. The pricing policy adopted in this edition attempts to manage the demand leakage in the retail, wholesale and internet channels by including restrictions on wholesale, retail and internet prices. If the demand leakage is not managed, the company's distribution channels will face internal competition (for the company's product), which will eventually lead to multi-priced goods.

Considering that the proposed model is presented for organizations that have different stores and a complete supply and value chain for each product, including delivery, production, distribution and sale, which requires simultaneous and coordinated planning for better and more accurate planning . It is between the variables of these 4 levels that we have attempted to use an integrated planning model for location, pricing, inventory management and marketing decisions. In the location discussion, we need to locate new warehouses or distribution centers during the implementation of the model since the demand for the product is variable and the capacity of the existing warehouses or distribution centers does not respond to it, and we need new locations for distribution centers during the implementation of the model.

2. LITERATURE REVIEW

Location, inventory, pricing and marketing decisions are important issue to address [1]. However, not much attention has been paid to this issue in the existing literature. The objective of classical location-inventory problems is simultaneously to decide on location allocation and to determine the amount of inventory storage in distribution centers [2]. Farahani et al. [3], provided a comprehensive review of the literature on location-inventory decision integration and explained its components and benefits.

Nasiri et al. [4] have presented a hierarchical model to combine production, distribution and inventory problems in a location-allocation problem with multi-capacity warehouses. Two Lagrangian methods and Genetic Algorithm (GA) have been used to achieve optimal solutions. Diabat et al. [5] presented an algorithm to solve a supply chain network that had three levels. They compared the obtained results from the output of the algorithm with the results of other research.

Ahmadi et al. [6] considered a distribution network with seasonal and non-seasonal products that had three levels. In this distribution network, joint decisions are made about location and inventory control, and it is assumed that movement between warehouses is allowed. The presented model has 2 objectives which are used by the fuzzy method. In another study, Puga and Tancrez [7] developed a heuristic algorithm to solve a large-scale inventory-location problem in a multilevel supply chain including retailers, distribution centers, and a central factory with uncertain customer demand. The goal was to minimize inventory, transportation, location, and allocation costs, as well as to provide a certain level of customer service.

Ross et al. [8] have investigated an inventory location problem in a multi-product, multi-level supply chain with uncertain demands under a continuous inventory policy.

A supply chain that has a number of products, several levels where the demand is uncertain and the policy of inventory control is continuous.The goal of this model is to minimize the total cost including allocation, location, transportation, inventory, and lost sales costs. The intended model was non-linear, and a heuristic algorithm was used to solve it. Correia and Melo [9] have developed a mixed integer linear programming model for a multi-period location-allocation-inventory problem where in which customers' treatment for delivery time is considered different. The desired model is presented as a mixed integer. Mousavi et al. [10] studied a multi-period and multi-product inventory location-allocation problem in a two-level buyer-seller supply chain in which shortages are not allowed and the policy of discounting the total unit amount for purchase. They used a particle swarm optimization algorithm to solve their model.

Rafie-Majd et al. [11] also presented a supply chain problem that had a number of products and in a multi-period manner with uncertain demand. Darvish and Coelho [12] investigated a production-distribution system. They showed that the integration of different decisions improves the results. In designing an integrated supply chain, in addition to determine the location of facilities, costs must also be considered. In some articles, decisions related to price and cost are integrated with production planning.

Fattahi et al. [13] stated that pricing decisions are important from two perspectives in the supply chain. First, they determine the revenue from the sale of a product unit to customers and affect the demand for the product and thus the total sales and revenue. Second, due to the non-uniformity of customer demand, regions depends on pricing decisions, they affect the number and capacity of facilities and the overall structure of the supply chain to adequately respond to demands. Ahmadzadeh and Vahdani [14], designed a three-level closed-loop supply chain in a correlated demand environment. The periodic review method has been used to control the buffer in the warehouse and in this model, the shortage has been allowed. 3 meta-heuristic algorithms have been used to solve the presented model. Fattahi et al. [15] considered a multi-period supply chain redesign problem for simultaneous pricing and supply chain redesign decisions where customers have stochastic price-dependent demand for products. They provided a model and then solved it using the Decom Benders method. The obtained results showed that the proposed algorithm has a good performance. Rabbani et al. [16] presented a combined location-inventory-routing model with pricing in the design of a distribution network that determines the number of trucks for each established distribution center and they also assigned customers to routes. Two meta-heuristic algorithms have been used to solve the proposed model. Nasiri et al. [17] presented a multi-layer distribution network design problem with pricing strategy in a stochastic environment, where location, inventory, and pricing decisions in retail and wholesale channels were made simultaneously. They considered network consists of a central warehouse, a set of distribution centers and a set of retailers and wholesalers. Nasiri et al. [18] presented a mixed integer nonlinear programming model to determine the optimal pricing of products in different sales and distribution channels. Decisions related to inventory location and control have been made in a unified and uncertaintly manner, distribution channels while integrating location allocation and inventory control decisions of distribution centers in a nondeterministic environment. A memetic algorithm has been used to solve the mixed integer nonlinear programming model. Shafaghizadeh et al. [19] addressed the allocation of inventory distribution for a distribution network, including a factory, a number of potential locations for distribution centers and a number of retailers. Customers demand is assumed to be certain and deterministic for all periods but time varying in the limited planning horizon. A meta-heuristic method is used to solve it. Moosavi and Seifbarghy [20] presented a new mathematical model for a green closed-loop supply chain (GCLSC) network with the objectives of maximizing profits, maximizing the number of jobs created, and maximizing reliability. Due to the uncertainty on some parameters such as demand and transportation costs, the new method of robust fuzzy programming model was utilized. Multi-objective Grey Wolf Optimizer (MOGWO) and Non-dominated Sorting Genetic Algorithm II (NSGA II) were used to tackle the problems for larger sizes. A number of instances of the problem in larger sizes were solved. Soleimani et al. [21] addressed the design of a sustainable closed-loop supply chain including suppliers, manufacturers, distribution centers, customer zones, and disposal centers considering the consumption of energy. In addition, the distribution centers play the roles of warehouse and collection centers. The problem involves three choices of remanufacturing, recycling, and disposing the returned items.

The general innovation of the article is that all the articles worked in this field include production-distribution planning, while in the proposed article decision-making and production-distribution-sale planning are presented. The general innovation of this article is divided into two parts, the first part includes supply: considering that this model is presented for organizations that have a complete value chain from supply to sales. In the proposed article, the product supply planning has been done in a combined way, that is, in the supply planning, both the economic order quantity EOQ and the economic production quantity EPQ have been presented in the model in a combined manne. The reason for this type of supply planning is because it is low and responsive. The lack of product production capacity inside the organization is why we sometimes need simultaneous planning from outside the organization. In the second part, innovation includes distribution and sales: in all the articles worked in this field, the amount of product demand in each sales channel is already known, while in the proposed article, the amount of demand in each channel is not known, only the amount of demand in each region. For the product, it is clear that decisions are made regarding the selection of distribution channels for each region, product pricing in each channel and the amount of demand coverage by each channel so that it has the most benefit for the organization and the most benefit for the customer. In short, the variables of marketing decisions are fully considered in this model.

3. PROPOSED PROBLEM AND MODELLING

The distribution and sales network investigated in this research is a forward distribution network, single period and single product, whose components include two types of producers inside and outside the organization, distributors, wholesalers and retailers, and internet sales, and the product is sold through three retail channels, wholesale and internet sales can reach the end customer. The investigated distribution network has a divergent structure, in the sense that we are facing a divergent structure during the process in which the goods are transported from the manufacturer to the distribution centers and from there to the wholesalers and retailers and even the final customer. In this network, the amount of total demand in a region has been uncertain, that the total demand of each region is supplied by three channels, that the amount of demand in each channel is not known, that after solving the model, the amount of demand met by each channel is determined, that is, the amount The fulfilled demand in each channel is a variable that is determined after solving the model.

The investigated supply chain is used for durable goods, which is multi-level, and the entities of this chain include internal and external production centers, distribution centers, and retailers and wholesalers. One of the assumptions of the model is that the investigated supply chain with its distribution centers in the country can cover all the desired areas of the country with three different channels and respond to all demands as soon as possible. After production in the factory, the product is transferred to the warehouse of the distribution centers and based on the optimal quantities and the optimal price, it is sent to wholesalers, retailers or even to the final customer in different regions. Investigated distribution network is shown in Figure 1. Figure 1 shows the sales distribution network of the proposed model. As can be seen, the proposed network has two types of internal production, external production (production outsourcing). The reason for outsourcing the production in some cases is due to the low production capacity of the product in relation to the demand, and in some cases the production is not able to meet the market demand due to the limited capacity, and to avoid lost sales, some of the production needs are forced to be outsourced. During the execution of the work, due to the limited capacity of the warehouses of the distribution centers, we need to locate and create new distribution centers, which is shown in Figure 1 with a red pentagon. According to Figure 1, the proposed sales network has 3 authorized sales channels (wholesale, retail and online sales) and also the total demand of each region is shown as the potential power for the total demand of the region.

3. 1. Proposed Optimization Model

As stated in the problem definition section, the problem in this article is that a multi-activity organization has production centers that have a wide market, which based on the market demand produces some of its demand in its centers and it prepares the rest of the demand in the form of supply (production outsourcing) from outside the organization. It sends its required production and supply products to the distribution centers for distribution. Based on the demand of each region, the relevant centers sell the most optimal quantity, channel and price through three channels of retail, wholesale and internet sales to the final customer. The amount of demand for each product in each region is specified as the input parameter of the model, but the amount of demand for the product, the price of the product and the amount of demand fulfilled by each channel are model variables in the field of distribution and sales. In this model, in the sales distribution department, we are looking for what product, at what price, in what volume, in which channel will be sold, which will be the most profitable for the organization and also the most favorable for the customer. In short, in this model, choosing the optimal channel is one of the main decision variables. Delivery, in this model, the variables of the problem are in what volume, at what price, in what channel, so that the demand of each region is covered in such a way that it has the most profit for the organization and also the best service to the customer. In terms of delivery time and price, it means that the desired model has two goals, the first goal of the model is to maximize the profit of the organization and the second goal is to maximize the customer's benefit from the two dimensions of the sales price in each channel and the service delivery time. In the presented model, the amount of demand of each region in a probabilistic manner (normal distribution) obtained through real online data should be covered by the three

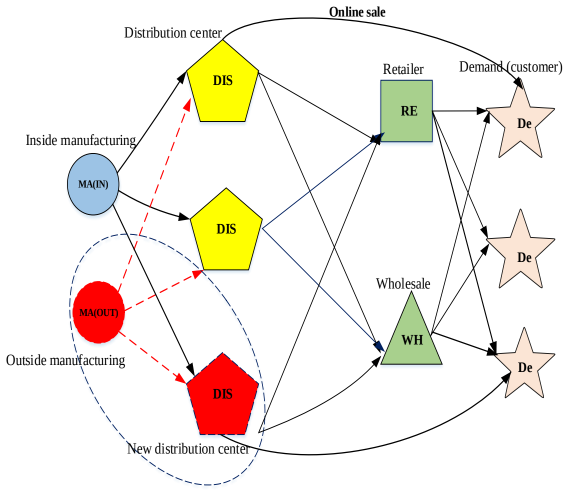


Figure 1. General shape of the investigated distribution network

desired channels. In the previous models presented, the amount of demand in different channels is known, but in the model under review, the amount of demand in the region is possibly determined through online data, and this demand must be met by distribution centers, but in the model under review, the most optimal selection is made. The channel for the product, the amount of sales volume and the sales price in each channel are among the outputs of the model. In the mathematical model under investigation, the inventory policy is also considered, which product should be produced or supplied in what volume so that the costs of inventory control and ordering are minimal and increase the profit of the organization. The desired mathematical model is modeled in the scenario of unauthorized shortage, which will be explained below.

3. 2. Calculation of the Optimal Order Amount with Two Types of Suppliers in a Non-deterministic (Probable) State Inventory chart in the mode $D > P$ considering the definite demand is shown in Figure 2, in this case, the optimal amount of ordering is equal to the relationship $Q^* = EOQ + EPQ$ and because$D > P$, the amount of production is equal to the production capacity, that is, $EPQ = P$. In order to optimize the amount of production and the optimal order to satisfy the amount of demand, the relationship $Q^* = EOQ + P$ should be optimized. In the above relationship, considering that the amount of P is constant and some of the demand is met by production, the amount of the remaining demand, i.e. $D - P$, should be calculated by the order will be supplied.

$\frac{h}{2}QT + A + QC$	Total costs of a course
$K(Q) = \frac{h}{2}QTn + An + QCn$	Total annual costs
$K(Q) = \frac{h}{2}Q + A\frac{D-P}{Q} + CD$	To optimize the total annual cost, we derive K(Q) with respect to Q
$Q^* = \sqrt[2]{\frac{2(D-P)A}{h}}$	Optimal order quantity

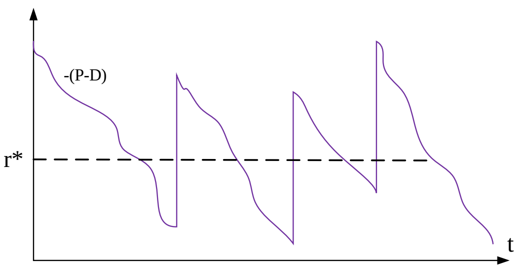


Figure 2. Inventory chart in the state $D > P$ considering the definite demand

Equation Q^*shows the amount of the desired order of the desired product from external producers

3. 3. The Proposed Mathematical Model The objective function of the model consists of two parts. The first is to minimize the completion time and the second is to minimize the average cost of maintenance and repairs per unit of time. Considering that in most of the previous mathematical models integrated planning has been worked in the field of production-distribution, but in the proposed model, due to the special conditions of some organizations, an integrated planning model of production-distribution-sales has been proposed, which according to the new discussion of sales, In the integrated planning model, marketing decision variables have been added to the mathematical model, and these decisions include what product with what volume $\omega'_{kmr} + \omega_{lmr}$ at what price φ_m in which channel γ_{mr} should be sold in the model. Also, the discussion of the new location variable of W_k distribution centers during the execution of the model is one of the topics and new variables of the proposed model. We hope the honorable reviewer will be convinced. The model is formulated as follows:

$$Q^* = EOQ^* + (fix)P \quad \rightarrow \quad Q^* = EOQ^* \tag{1}$$

$$R^* = DL + Z_{1-\alpha} \sqrt[2]{L\,V} \;\rightarrow\; R^* = L\,(D-P) + Z_{1-\alpha} \sqrt[2]{L\,V} \tag{2}$$

$$D_{max} = DL + ss \;\rightarrow\; D_{max} = DL + ss \tag{3}$$

$$D \approx N(\mu, \sigma^2) \;\rightarrow\; Z_{1-\alpha} = \frac{(D-P)L + ss - (\mu - PL)}{\sqrt{var(D-P)L}} \tag{4}$$

3. 4. Calculation of the Order Point with Two Suppliers in Non-Deterministic (Probable) Mode Equation (5) shows the reorder point to supply the desired product from external suppliers.

$$ss = Z_{1-\alpha}\sqrt{var(D-P)L} \;\rightarrow ss = Z_{1-\alpha}\sqrt{L\,V} \tag{5}$$

$$R^* = (D-P)L + Z_{1-\alpha} \sqrt[2]{L\,V} \tag{6}$$

3. 5. Distribution and Sales Model

$$Max\ f_1 = \sum_l \sum_m \sum_r \varphi_m\ \gamma_{mr}\ \omega_{lmr} + \sum_k \sum_m \sum_r \varphi_m\, \gamma_{mr}\, \omega'_{kmr} - \left(\sum_l C\, Q_{1\,l} + \sum_k C\ Q_{1\,k}\right) - (C'Q^*) - \left(\frac{h}{2} \times \frac{Q^*}{T} + A\,\frac{D-P}{\frac{Q^*}{T}}\right) - \left(\sum_l T_{1\,l}\, Q_{1\,l} - \sum_l Q_{1\,k}\, T'_{1\,k} - \sum_l \sum_m \sum_r \omega_{lmr}\ T_{lm} - \sum_l \sum_m \sum_r \omega'_{kmr}\ T''_{km}\right) - \sum_i \sum_l p_k\, W_k \tag{7}$$

$$Max\ f_2 = \sum_m \left(\left(\frac{Pro_m}{M_m}\right) \sum_l \sum_r \boldsymbol{\omega_{lmr}}\right) + \sum_m \left(\left(\frac{Pro_m}{M_m}\right) \sum_k \sum_r \boldsymbol{\omega'_{kmr}}\right) \tag{8}$$

ST:

$$\sum_m \sum_r \omega_{lmr} = Q_{1\,l} + Q_{2\,l} \quad \forall \quad l \tag{9}$$

$$\sum_m \sum_r W_k \omega'_{kmr} = Q_{1k} + Q_{2k} \quad \forall \quad k \tag{10}$$

$$\sum_m \gamma_{mr} \leq 2 \quad \forall \quad r \tag{11}$$

$$\sum_l \sum_m \gamma_{mr}\, \omega_{lmr} + \sum_k \sum_m \gamma_{mr}\, \omega'_{kmr} \leq D_r \quad \forall \quad r \tag{12}$$

$$Q^* \leq \sum_l Q_{2l} + \sum_k Q_{2k} \quad \forall \quad l \tag{13}$$

$$\varphi_m \geq \left(\frac{(\sum_l Q_{1l} + \sum_k Q_{1k}) \times C + \left(\frac{Q^*}{T} \times C'\right)}{\sum_l Q_{1l} + \sum_k Q_{1k} + \frac{Q^*}{T}}\right) \ \forall\,, m \tag{14}$$

$$\varphi_m \leq (1+\alpha_m)\left(\frac{(\sum_l Q_{1l} + \sum_k Q_{1k}) \times C + \left(\frac{Q^*}{T} \times C'\right)}{\sum_l Q_{1l} + \sum_k Q_{1k} + \frac{Q^*}{T}}\right) \forall m \tag{15}$$

$$Q_{1l} + Q_{2l} \leq CAP_l \quad \forall \ l \tag{16}$$

$$\sum_l Q_{1l} = CAP \tag{17}$$

$$Pro_m = (M_m - \varphi_m) \quad \forall \ p \quad m \tag{18}$$

$$\varphi_m \ , \omega_{lmr} \ , \omega'_{kmr}, Q^*, R^*, Q_{1l} \ , Q_{2l}, Q_{2k}, Q_{1k}, Pro_m \geq 0 \quad Integer \tag{19}$$

$$\gamma_{mr} \ , W_k \quad 1\ , 0 \qquad 0 \leq \alpha_m \leq 0.5 \tag{20}$$

The function of relation (7) seeks to maximize the net profit from the sale of the product; Equation (8) seeks to maximize the utility (price compared to competitors) for the customer. Equations (9) and (10) state that the amount of the product that entered the distribution center (existing distribution center and establishing new distribution centers) is equal to the amount of the product that left the distribution center and reached the customer through the sales channels. Equation (11) states that for better management and to prevent underselling, the sales channels for the product can be at most 2 channels. Equation (12) shows the amount of product allocated to customer through distribution centers and different channels. Equation (13) shows the method of allocating the product ordered from the supplier to the distribution centers. Equations (14) and (15) show the pricing range as well as the net profit of each product unit based on the cost price of the manufactured and purchased product. Equation (16) shows the capacity of distribution centers. Equation (17) shows the production capacity of production units for the desired product. Equation (18) shows the price difference of the desired product in sales channels compared to competitors. Equations (19) and (20) show the decision making variables of the model.

4. NUMERICAL EXAMPLES ANDDISCUSSIONS (ETKA ORGANIZATION)

The proposed model is presented for the Etka organization because it has a complete supply chain in the field of production, distribution and sales channels. In the next, 5 regions of Tehran province with data extracted from the Etka organization are given in Table 1. Each region will be solved using the GAMS software in the desired model and the results of each region have been analyzed and reviewed. In this case study, there are *l= 3* existing distribution centers in the west, east and center of tehran, *m=3* sales channels consist of wholesale,

TABLE 1. A summary of the literature review

Study	Joint Optimization	Marketing Decisions			Multiple Product	Demand Uncertainly	Multiple Channel	Solving Approach
		Product	Channel	Price				
Kaya and Urek [1]	Location- Inventory- pricing	-	-	✓	Yes	No	No	Meta -Heuristic
Zhang and Unnikrishnan [2]	Location - Inventory	-	-	-	No	Yes	Yes	Exact
Farahani et al. [3]	Location-inventory	-	-	-	No	No	Yes	Heuristic and meta-heuristic
Rafie-Majd et al. [11]	Location-inventory	-	-	-	No	Yes	No	Heuristic
Rabbani et al. [16]	Location-inventory- pricing	-	-	✓	No	No	No	Meta -Heuristic
Nasiri et al. [17]	Location- Allocation- Inventory-replenishment policy, Retail and wholesale prices			✓	No	Yes	Yes	Exact-Approximate Meta-heuristic
Nasiri et al. [18]	Location-Inventory-pricing			✓	Yes	Yes	Yes	Exact-Approximate Meta-heuristic
This work	Relocation- Inventory-Pricing- Marketing Decision	✓	✓	✓	Yes	Yes	Yes	Exact

retailing, online sale, *k=3* potential centers (k=1 Southeast, k=2 Northweast, k=3 Southwest) for establishing new distribution centers in , *r=5* demand areas for the product.

5. COMPUTATIONAL RESULTS

In Table 1 the parameters of the model for the case study of the ETKA organization are given. The case study is related to 5 demand centers (regions 9, 10, 14, 16, 17) and 3 existing distribution centers related to Tehran province. The amount of customer demand follows a normal probability distribution. Due to the capacity limitations, the existing distribution centers are not able to meet the demand.To solve the problem, we have to redesign the distribution centers as well as replining the distribution network, which is used in the model presented in this article. Table 2 summarizes the optimal values of inventory management variables as well as the optimal location of new distribution centers the optimal locations of new distribution centers are southeast and southwest. In Table 3, the optimal values of variables related to product pricing in different channels, the amount of product allocation from distribution centers to demand points are given. For more visibility and easier understanding of the model and the results obtained for the case study, the results of solving the model are briefly shown in Figure 3. Figure 3 shows all the variables related to inventory management in distribution centers as well as the optimal location of new distribution centers. Also, the variables of goods allocation from distribution centers to demand centers for areas 9 and 16 (to avoid crowding the figure) are shown as examples. As stated, there are 2 suppliers, including an internal supplier and an external supplier in Tehran province, for Etka organization. As mentioned, according to Table 2, the production capacity in the target network is limited, and sometimes the production capacity does not meet the demand of the regions, which is forced to outsource some of the demand to production units outside the organization, which are shown in the table of these two types of production units per unit. Production (internal and external) is given.

Table 3 shows the available distribution centers. In the continuation of Table 3, the potential locations for the creation of new distribution centers are also given. By solving the proposed model, any of them may be selected to create a distribution center. Table 3 consists of two parts, the first part shows the number of existing distribution centers and the second part shows the potential centers for creating new distribution centers during the execution of the model. In both sections, the exact location of existing distribution centers and the potential location for establishing distribution centers are given.

TABLE 2. The Information of Supplier

Supplier (Manufacuer)	Supplier Type	Location of Suplier
1	Intrnal of Etka	Tehran
2	External of Etka (Outsource)	Tehran

TABLE 3. Existing Distribution Centers and Potential Locations for establishing new Distribution Center

Indicator number (l)	Existing Distribution Center Location
L=1	West of Tehran
L=2	East of Tehran
L=3	South of Tehran
Indicator number (K)	Potential Location for Establishing new Distribution Centers
K=1	Southeast of Tehran
K=2	Northweast of Tehran
K=3	Southwest of Tehran

Table 4 shows the number and region name for customer j. For each region according to the table, it follows the normal distribution N(μ,δ). In Table 4, the total customer demands for 5 regions of Tehran, which had a normal distribution, are given according to the regions of Tehran.

Table 5, shows all the parameter values of the mathematical model in full detail for the case study. Table 6 shows the optimal values of the first and second objective functions. Table 7 shows the optimal values of the model variables resulting from the model solution in full detail. For example, the variable line related to $\boldsymbol{Q_{1k}}$ represents the amount of product allocation from the domestic production unit to the distribution centers, the variable line related to $\boldsymbol{\varphi_m}$ is the optimal price of the product in different channels, and the variable line related to $\boldsymbol{\omega_{lmr}}$ is the amount of optimal allocation of the product from the existing distribution centers to the regions It shows the demand.

TABLE 4. Indicator number and Region name for customer j

Customer indicator number r	Customer in regions	Demand Customer in region D_r
r=1	Region 9 of Tehran	N(80,4)
r=2	Region 10 of Tehran	N(95,5)
r=3	Region 14 of Tehran	N(75,5)
r=4	Region 16 of Tehran	N(120,6)
r=5	Region 17 of Tehran	N(80,3)

TABLE 5. Parameters of the model for ETKA case study

Parameters	Sets	l			k			m			r				
		1	2	3	1	2	3	1	2	3	1	2	3	4	5
$h = 0.5$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$A = 0.7$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$p = 40$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$C = 6$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C'=7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CAP $= 240$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LT	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P_k	-	-	-	-	315	402	391	-	-	-	-	-	-	-	-
V_{va}	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
$D_r(hours)$	-	-	-	-	-	-	-	-	-	-	N(80,4)	N(95,5)	N(75,5)	N(120,6)	N(80,3)
CAP_l	-	100	100	100	-	-	-	-	-	-	-	-	-	-	-
M_m	-	-	-	-	-	-	-	9.2	9.7	9.9	-	-	-	-	-
T_{1l}	-	0.4	0.4	0.2	-	-	-	-	-	-	-	-	-	-	-
T_{2k}	-	-	-	-	0.6	0.4	0.4	-	-	-	-	-	-	-	-
T_{lm}	$l = 1$	-	-	-	-	-	-	0.4	0.6	0.4	-	-	-	-	-
	$l = 2$	-	-	-	-	-	-	0.2	0.4	0.4	-	-	-	-	-
	$l = 3$	-	-	-	-	-	-	0.6	0.2	0.4	-	-	-	-	-
T''_{km}	$k = 1$	-	-	-	-	-	-	0.4	0.4	0.4	-	-	-	-	-
	$k = 2$	-	-	-	-	-	-	0.4	0.4	0.8	-	-	-	-	-
	$k = 3$	-	-	-	-	-	-	0.4	0.2	0.6	-	-	-	-	-

TABLE 6. The results of solving the model

Objective Optimal	Optimal amount
Profit	138.2
Service desirability	84.23

By solving the proposed model with real data, the amount of profit and efficiency is obtained in Table 6.

The results of solving the proposed model are given in Table 7. For example, different values of 1 include (Q_{12}=61, Q_{11}=78, Q_{13}=50). These results are given for all variables and for all indices.

Figure 3 shows the results of solving the model shown in Table 7 on the proposed supply chain network. The results of solving the model are based on the parameters of Table 5. As can be seen from the network in Figure 3, we have two production methods (ETKA and Out source) in the proposed network. Production centers are shown as circles, distribution centers are shown as pentagons, and demand centers are shown as quadrilaterals in the figure. The values of variables $Q_{1k} Q_{2l}$ show the values of goods allocation from internal and external producers to distribution centers, the numbers on the vectors are the optimal values after solving the model. The values of the variables ω_{lmr} and ω'_{kmr} show the optimal values for the allocation of goods from existing and new distribution centers to the demand areas, for example, for two regions r=10 and r=16, which are given on the vectors, as well as 2 to pentagons that are shown inside a dashed ellipse are the optimal points selected for locating new distribution centers. In short, Figure 3 is given for a better understanding of the model solution and its results on the proposed network.

6. SENSITIVITY ANALYSIS

In this section, changes in the cost of transporting parameter have been investigated on the objective function where $W_1 = 0.9$, $W_2 = 0.1$.These changes are given in Table 8 and Figure 4. By reducing the cost of transportation, the amount of profit increases, the value of the second objective function does not change, but the value of the total objective function also decreases.

TABLE 7. The results of solving the model fo ETKA case study

Variables	Sets	l			k			$m=1$					$m=2$					$m=3$				
		1	2	3	1	1	2	r=1	r=2	r=3	r=4	r=5	r=1	r=2	r=3	r=4	r=5	r=1	r=2	r=3	r=4	r=5
Q_{1l}	-	61	78	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Q_{2l}	-	23	17	35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Q_{1k}	-	-	-	-	36	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Q_{2k}	-	-	-	-	54	0	96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
W_k	-	-	-	-	1	0	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
γ_{mr}	-	-	-	-	-	-	-	0	1	1	1	0	1	1	0	1	1	1	0	0	0	1
	l = 1	-	-	-	-	-	-	0	9	19	8	0	7	9	0	6	9	7	0	0	0	10
ω_{lmr}	l = 2	-	-	-	-	-	-	0	10	19	25	0	6	8	0	21	0	6	0	0	0	0
	l = 3	-	-	-	-	-	-	0	13	13	8	0	7	9	0	6	7	10	0	0	0	12
	k = 1	-	-	-	-	-	-	0	10	12	9	0	9	8	0	11	7	9	0	0	0	15
ω'_{kmr}	k = 2	-	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	k = 3	-	-	-	-	-	-	0	10	12	12	0	8	9	0	14	10	11	0	0	0	10
Variables	Sets	l			k			$m=1$					$m=2$					$m=3$				
φ_m	-	-	-	-	-	-	-	9.1					9.5					9.8				
α_m	-	-	-	-	-	-	-	0.23					0.25					0.26				
Pro_m	-	-	-	-	-	-	-	0.9					0.5					0.2				

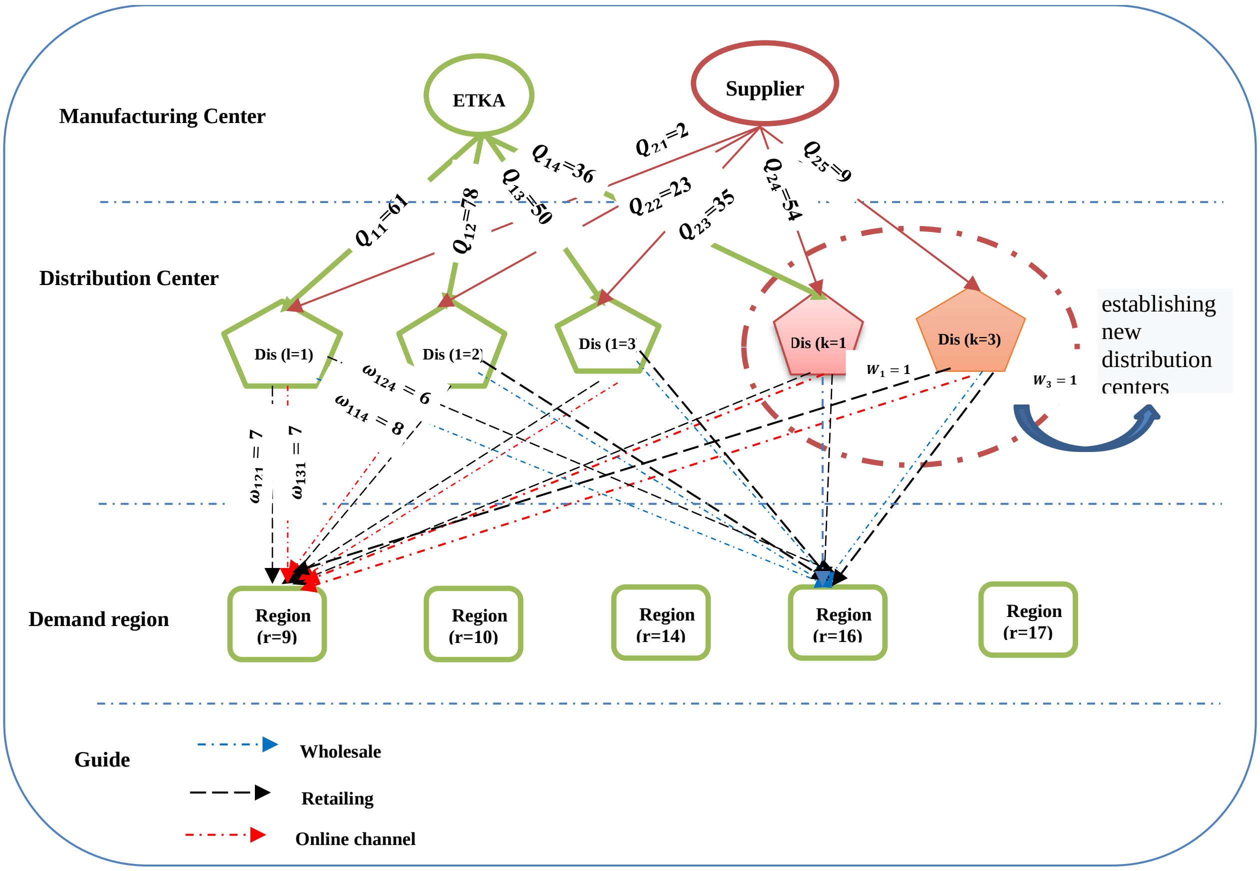


Figure 3. Solving the model using the real data of the Atka organization

TABLE 8. Variation of objective function with changes in cost of transporting

Cost of transporting	Profit objective functions (f_1)	Service desirability objective functions (f_2)	Objective function LP Metric model
50% increase	120/12	11/2	0/25
40% increase	118/01	11/2	0/24
30% increase	112/2	11/2	0/22
20% increase	108/8	11/2	0/21
10% increase	99/4	11/2	0/19
Normal	123/3	11/2	0/18
10% reduction	127/9	11/2	0/1
20% reduction	131/3	11/2	0/12
30% reduction	135/7	11/2	0/13
40% reduction	138	11/2	0/15
50% reduction	140/5	11/2	0/17

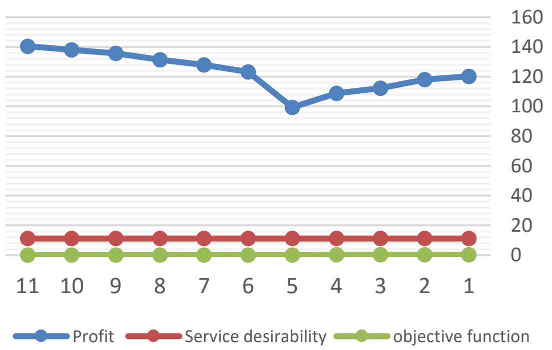
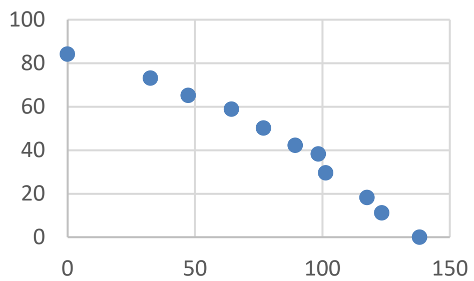


Figure 4. Variation of objective function with changes in cost of transporting

The proposed model is solved using the LP metric method and the results are shown in Table 7 and Figure 5. Considering that the objective function seeks to minimize, according to Table 9, the best situation is situation 1, where $W_1 = 0.9$, $W_2 = 0.1$.



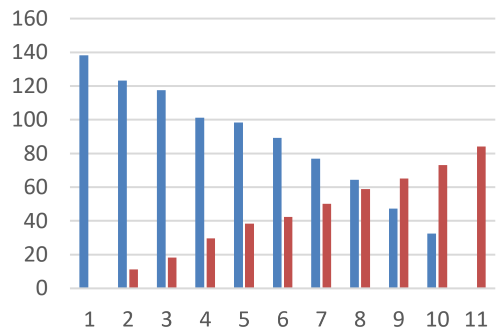


Figure 5. Pareto chart of results for different weights

TABLE 9. Weighing the objective functions and objective function of the LP metrice model

Status	Weight of objective functions	Profit objective functions (f_1)	Service desirability objective functions (f_2)	Objective function LP Metrice model
1	W_1=0.9 W_2=0.1	123.3	11.2	0.18
2	W_1=0.8 W_2=0.2	117.5	18.3	0.27
3	W_1=0.7 W_2=0.3	101.3	29.6	0.38
4	W_1=0.6 W_2=0.4	98.4	38.4	0.39
5	W_1=0.5 W_2=0.5	89.3	42.3	0.42
6	W_1=0.4 W_2=0.6	76.9	50.2	0.41
7	W_1=0.3 W_2=0.7	64.3	58.9	0.37
8	W_1=0.2 W_2=0.8	47.3	65.2	0.31
9	W_1=0.1 W_2=0.9	32.5	73.2	0.19

In addition to the above, Due to the fact that the solution method of the proposed model is exact, the solution time increases for problems with a large number of data. For future studies, it is suggested that in addition to exact solution algorithms, heuristic and meta-heuristic solution algorithms, for example, the algorithms used by Zhao and Zhang [22], where a learning-based algorithm is proposed with the aim of increasing generalization ability. The algorithm used by Dulebenets [23] is a new Adaptive Polyploid Memetic Algorithm (APMA); also similar algorithm were used by Pasha et al. [24], Kavoosi et al. [25] and Rabbani et al. [26].

7. CONCLUSIONS AND FUTURE RESEARCH

In this research, a non-linear planning model was presented to optimize economic goals, including the profit from product sales in the entire chain, as well as the desirability of providing services compared to competitors, which include maximizing product sales in sales channels, minimizing costs. Transportation, warehouse construction, inventory management and control, and finally choosing the most optimal sales channel based on the demand of the regions. The presented two-objective model was solved using the LP-Metrice technique and GAMS software. In the following, the sensitivity analysis on the importance and weight of the objective functions and the final impact on the objective function have been measured. Finally, each of the target functions was measured according to the real data as well as the importance of economic considerations, and the results and sensitivity analysis were presented in the form of tables and graphs. Computational results based on real data analysis for a furnicutre product are reported for Etka organization. The sample used includes two suppliers (1 internal, 2 external), three existing distribution centers and 3 potential locations for creating new distribution centers, and 5 demand areas (areas 9, 10, 14, 16, 17) for Tehran province.The solution of the proposed model leads to the selection of the most optimal distribution channel of the desired product in different areas of Tehran, as well as the creation of new distribution centers by optimizing the costs of creation, transportation and inventory management costs. The consequences of solving the model are as follows.

- Due to the fact that the existing distribution centers are not able to meet the demand of demand centers in terms of capacity, new distribution centers have been established in the southeast and southwest areas of Tehran.
- The most optimal channel for the distribution of goods in region 9 is retail and internet channels, for region 10 wholesale and retail, for region 14 only wholesale channels, for region 17 wholesale and retail channels and for region 18 retail and online sales is.
- The main motivation of Atta to use this model is to reduce system costs and provide better services than competitors. Distribution costs are reduced when the product reaches the customer through the best channel from the supplier.

In future works, modeling based on online data can be a good and accurate work. Considering the emergence of the 4th generation industry and the use of new technologies to collect data in real time and analyze them and use them in supply chain modeling can be a valuable work.

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Persian Abstract

چکیده

امروزه بحث طراحی و برنامه ریزی شبکه توزیع و فروش اعم از مکان‌یابی، قیمت‌گذاری، انتخاب بهینه ترین کانال فروش و همچنین تصمیمات بازاریابی از اهمیت بسزایی در زنجیره‌تامین می باشد باتوجه به تغییرات و عدم قطعیت مقدار تقاضا در بازار طراحی و برنامه‌ریزی شبکه توزیع و فروش ایستا در عمل با مشکلات زیادی مواجه گردیده است در این مقاله یک مدل برنامه‌ریزی ریاضی غیرخطی برای مکان‌یابی، کنترل موجودی و بازاریابی محصول تولیدی برای یک سازمان چند فعالیتی (سازمان که دارای واحد تولیدی، توزیع و خرده فروشی و عمده فروشی می باشد) با داده‌های آنلاین در زمان واقعی ارائه می‌گردد که در این مدل به دنبال ایجاد و مکان‌یابی مراکز توزیع جدید در حین فعالیت شبکه در صورت افزایش تقاضا، مدیریت موجودی در مراکز توزیع و همچنین تصمیمات بازاریابی اعم از قیمت‌گذاری محصولات در کانال‌ها (عمده فروشی، خرده فروشی، اینترنتی)، انتخاب بهینه‌ترین مقدار و کانال برای فروش محصول، میزان فروش در هر کانال و در نهایت قیمت‌گذاری برای محصول در کانال‌های مختلف با در نظر گرفتن داده‌های واقعی و سیستم پشتبان تصمیم‌گیر به صورت متمرکز می‌باشد. در این مدل هدف حداکثر کردن سود و همچنین افزایش مطلوبیت برای مشتری با در نظر گرفتن قیمت رقبا و انتخاب بهترین کانال برای ارائه محصول به مشتری می‌باشد. در نهایت مدل مورد نظر در حجم پایین‌تر با نرم افزار گمز حل گردیده و تحلیل حساسیت روی پارامترهای مختلف صورت گرفته است.