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A multi-objective optimization model for supply chain network design: A Case Study of Bonny Chow Co.

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Abstract

Today, in the existing competitive market, proper management of the supply chain has attracted a lot of attention to increase profitability and customer satisfaction. Managers and decision-makers may use policies to survive in this situation, but a desirable outcome will only come when a precise and comprehensive model is used. Therefore, a detailed design and systematic planning of the supply chain seems necessary with all levels and units in order to increase the efficiency of the entire supply chain. In this research, two main objectives will be considered using multi-objective optimization methods. The first goal is to minimize the total cost of locating the warehouses in the supply chain, and the second goal is to maximize the level of customer satisfaction and service level of Bonny Chow Company. Computational results show the acceptable performance of the proposed method on a set of real-sized instances and demonstrate its efficiency in solving generated scenarios.

Keywords: Locations; Distribution warehouses; Multi-objective optimization; Transportation cost.

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1. Introduction

The logistics operations in supply chains are part of today's most essential cost-effective actions as they continue to be decisive measures for industries to be competitive. Proficient design of supply chain necessitates methodical considerations of mixed problems in its wide-ranging form. This methodical idea is based on a given network of facilities that supply raw material and transform them into transitional nodes, and finally, distributed between customers. Thus, locating the facilities and routing of the vehicles are interrelated problems. This problem involves selecting the optimal number and locations of facilities, allocating customers to established facilities and constructing delivery routes. This class of decision problems has been studied since the mid-1970s. Maranzana (1964) showed that the location of factories is often affected by transportation costs. Some other researchers believe that the work of Maranzana (1964) is one of the first research on location-routing issues, and in many cases, the emphasis is on finding the shortest path rather than routing the vehicles. In addition, according to the above points, Lambert et al. (1978) stated that many traders are

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aware of the risks of sub-optimality by locating separate depots and vehicle routing. In most of the locating models, the routing problem was ignored. There are three possible reasons for this: (1) When location problems do not account for routing decisions, many practical situations are created, in which case the routing-locating process is clearly not an appropriate in terms of the operational efficiency of the supply chain. (2) Some research objectives for location-based routing are based on the inadequacy of this. Meanwhile, locating is considered as a general strategy, while it regards routing as a tactical problem. The vehicle routes can be calculated at all times (even daily), but deciding the locations of warehouses are usually made for a very long period. So their idea is that the combination of location and routing in the same planning framework is essential. (3) Conceptually, the problem of locating routing is much more difficult than the classic positioning problem. In classical location problems, the distance from the desired unique demand points is being deployed, which makes our problem more manageable, which helps with the advancement of the location problem.

Location-routing models presented in the literature typically minimize some performance metrics. The widely-used measures are cost functions, although some studies consider other metrics, such as the total waiting time of all the customers, the total transportation time, the average traveled length per customer, average recovery time of supply chain against disruption, the maximal waiting time of a customer, the average waiting time per customer, the average response time, and the maximum travel distance of customer.

In the literature of supply chain network design problems, most researchers focused on cost as a criterion to measure supply-chain performances. Nevertheless, another fundamental measure is customer satisfaction. This is explicitly related to the transportation lead-time and responding rapidly to meet marketplace demands. The present study is motivated by the need to optimize the logistics and distribution operations and to determine how to transport products to customers with respect to company and customer's perspectives. Thus, this study integrates decisions made at the strategic level (such as designing the supply chain network) with decisions completed at the tactical level (related to transportation activities).

In the present study, the locating-routing problem is modeled from a mathematical point of view as a complex optimization problem. From the operational point of view, it forms part of distribution management. Most of the realistic locating-routing problems are NP-Hard in nature with a high number of variables and constraints (Park et al., 2007). Thus, exact optimization methods may not be very effective for generating a solution. (Laporte and Nobert, 1981) provided a proof for the NP-Hardness of the locating-routing problems.

In this research, two main objectives will be considered using multi-objective methods. The first goal is to reduce the total cost of locating a warehouse in the supply chain, and the second goal is to maximize the level of customer satisfaction and service level of the company.

2. Literature review

A comprehensive review of location-routing models, applications and solution methods was also provided by Lopes et al. (2013). In recent studies, new variants of location-routing problems have been put forward, which simultaneously optimize location, routing and other decisions such as inventory decisions. In order to cope with the complexity of location-routing problems, solution methods are mainly limited to heuristics and meta-heuristic algorithms. Tuzun and Burke (1999) proposed a two-step Tabu search meta-heuristic algorithm for joint location routing problem. This two-step solution method makes the search process more efficient, therefore generating good quality solutions without expensive computation. An all-encompassing computational study demonstrates that the proposed two-step Tabu search algorithm attains noteworthy improvement over an existing effective heuristic.

Barreto et al. (2007) proposed a discrete location-routing problem with two levels: a set of potential capacitated distribution centers and a set of ordered customers. They determined the set of installed distribution centers as well as the distribution routes. The problem is also constrained with capacities on the vehicles. Moreover, there is a homogeneous fleet of vehicles, carrying a single product and each customer is visited just once. All the versions obtained using different grouping procedures were tested on a large number of instances (adapted from data in the literature) and the results were compared so as to obtain some guidelines concerning the choice of a suitable clustering technique.

Javid and Azad (2010) proposed an optimization model that simultaneously makes the location, allocation, inventory management, capacity determination, and routing decisions in a supply chain system using a meta-search algorithm. It was assumed that demand is uncertain and follows a normal probability distribution. In addition, each supply point keeps a minimum amount of inventory. The model has been solved successfully using an exact method based on a mixed integer convex formulation for small to medium sized test instances. Moreover, a heuristic method was proposed based on an integration of Tabu Search and Simulated Annealing to tackle large-sized instances of the problem. The outcomes confirm that the designed heuristics are meaningfully efficient for different sizes of the real problems.

Walther et al. (2012) have studied the design of regional generation networks for the second generation of artificial biofuels in Germany. In this research, they provided concepts for plant benefits as well as strategies for installing and building capacity, and ultimately providing advice to policy makers as well as potential investors. Baghalian et al. (2013) developed a randomized mathematical formula for designing a multi-product supply chain network including multi-capacity production facilities, distribution centers, and retailers in uncertain markets. In this study, they are looking for a discrete set of potential pockets of distribution centers and retail outlets, and examine the impact of strategic location decisions on operating inventory and supply chain decision-making.

Rath and Gutjahr (2014) provided an NSGA-II metaheuristic algorithm for the depot location–routing problem in supply chains under disruptions. The model handles the situation faced by international support establishments after the incidence of a catastrophic disruption. The problem has been formulated as a multi-objective optimization model that accounts for economic recovery and humanitarian performance criteria. The problem has been solved using an epsilon constraint method to obtain efficient Pareto frontiers. The experimental results were compared to those obtained from existing efficient exact solution approaches.

Govindan et al. (2014) addressed a sustainable two-echelon location–routing problem with multiple-vehicle routing decisions under time window constraints. The problem involves the optimization of supply chain network of perishable foodstuff. In order to modeling purposes, a multi-objective optimization model was presented by integrating sustainability and cost-effective approaches to distribution decision in a food supply chain network. The problem has been solved using multi-objective particle swarm optimization (MO-PSO) and multi-objective variable neighborhood search (MO-VNS). The outcomes verified the efficiency of the proposed integrated approach achieving near-to-optimal solutions as against the existing solution techniques. Ramezani (2014) provided a supply chain network design model based on queuing theory with uncertain lead time. The model accounts for both tactical and strategic decisions regarding the location of factories and distribution centers. The problem was formulated as a scenario-based two-stage stochastic programming model. At the strategic level, the sourcing policy and the capacity of factories and distribution centers are determined. The effectiveness of the proposed model was tested using numerical examples.Rabbani et al. (2017) proposed a queuing model for location–inventory problem of a supply chain under risk of facility disturbance. The studied supply chain involves multiple delivery centers, one supplier, and multiple vendors. The model was presented to find the optimal location of distribution centers, order assignment and inventory replenishment policy. The problem was formulated as a mixed-integer nonlinear optimization model with the aim of minimizing the summation of expected inventory cost, facility location and transportation costs. The efficiency of the proposed model was tested using test problems via LINGO software.

Toro et al. (2017) proposed a multi-objective optimization model for the sustainable location-routing problem taking into accounts the environmental issues. The problem has been formulated as a novel multi-objective optimization model by minimizing the operational costs as well as the minimization of gas emissions effects. This innovative optimization model considers a set of new constraints motivated on preserving the problem connectivity concern. The result of sensitivity analysis indicates the efficiency of the proposed solution techniques.

Mogale et al. (2018) provided a dynamic multi-objective optimization model for location-allocation of Grain silo in food supply chain network. They account for minimization of total network cost as well as total lead time. The problem has been solved using multi-objective optimization algorithms. Vahdani et al. (2018) proposed a two-stage multi-objective model for the integrated multi-period location-routing-inventory problem in logistics networks under uncertainty. The model decides the optimal location of the distribution centers and warehouses with various levels of capacity, vehicle routing and distribution of goods to the affected areas so as to minimize the total cost and travel time as well as improving the reliability of the solution. The problem has been solved using NSGAII and MOPSO and the results have been reported. Yu et al. (2018) addressed a dual-channel supply chain network design for agri-product under data uncertainty. The aim was to minimize the supply chain operation cost as well as maximizing the degree of satisfaction. A multi-objective optimization method was used to represent the trade-off between supply-chain contributors. The efficiency of the proposed model was confirmed with a real case. Alavidoost et al. (2018) provided a multi-objective nonlinear programming model for a multi-commodity tri-echelon supply chain network design problem. The objective was to determine the optimum service level so that total operating cost is minimized. The problem has been solved using Non-dominated Sorting Genetic Algorithm (NSGA-II), Non-dominated Ranking Genetic Algorithm (NRGA), and Pareto Envelope-based Selection Algorithm (PESA-II). A test experiment was conducted to compare the performance of the proposed solution algorithms.

In the research examined above, we find that most of the methods used do not match the real-world variables, but in the leading research, we try to provide a model with real-world variables, which can be used with the highest returns. The main contributions of this study are:

- A new mathematical model for the multi-level supply chain design is developed based on the indicators such as production rates, storage rates, and distribution efficiency in terms of operating cost.
- The model outputs provide a more comprehensive view of the location of warehouses and distribution centers in the supply chain considering constant fixed costs and annual variables.

3. Problem Statement

The supply chain is an integrated system of interconnected equipment and activities related to process and product transfer and distribution among customers. A supply chain involves all steps that directly or indirectly contribute to fulfilling a customer's request. In a regular supply chain, raw materials are shipped from suppliers to factories, then the products produced in the factories are sent to the middle warehouses and distributor's warehouses, and then they are transferred to retailers and ultimately reach the final customer or the same consumer. So a commodity can reach a different consumer chain.

Supply chain management is a collection of tools designed to increase the efficiency of suppliers, manufacturing plants, warehouses and ultimately product vendors, and aims to allocate them to the right place at the right time to minimize costs. The above definition indicates that there are many components in the supply chain that are interdependent, each of which tries to maximize its target function. In principle, we face a very different problem with a function, and there is a need for the simultaneous satisfaction of all of them.

So far, success criteria for companies have reduced costs, shorter production times, shorter delivery times, fewer inventory holdings, and higher market share increased the reliability of delivery, better customer service, higher quality and effective coordination between Demand, supply, and production. The exchange between the investment cost and the service level may change over time; therefore, in assessing the supply chain performance, there is a need for a continuous chain evaluation, in which case managers can make the right decisions at the right time. As the supply chain management focuses on integrating the work of suppliers, distributors, and end customers, then many of the company's activities range from strategic level to tactical and operational levels.

The main problem with the design of supply chain design is the collection of optimal solutions to the multi-objective problem, so we need an efficient algorithm that can provide the best possible solutions by searching the entire solution space. Previous research shows that mathematical methods work well in this field, and finally, one can provide an appropriate solution to the multi-objective problem (Wang et al., 2011). Therefore, multithreading math programming is used in this research. In this research, two main goals will be considered. The first goal is to reduce the total costs of locating the warehouses in the supply chain, and the second goal is to maximize the level of customer satisfaction and service level. To solve such a problem, multi-objective solution methods should be used. With regard to the two goals defined in this paper, looking for a solution, what are the constraints of locating distribution centers and central warehouses in the supply chain? What are the constraints of the distribution system in a multi-level supply chain?

4. Mathematical model

In this section, we will examine the design of the mathematical model for the problem. In what follows, we introduce the variables and parameters used in this model. The nomenclature for the variables and parameters of the proposed model is summarized next.

e	Sources of production (equipment, manpower, urban services, etc.)
i	The products
j	Factories
k	Possible distribution centers
l	Customer zones
m	Possible warehouses
s	Product demand scenario
t	Time

4.1. sets

K^{ss}	Set of distribution centers to be supplied by a warehouse.
L^{ss}	Set of client zones to be provided by a single distribution center

4.2. parameters

C_{im}^{WH}	Cost per unit of storage for the product in stock
C_{ik}^{DH}	Cost per storage unit for the product at distribution centers
C_{m}^{W}	An annual fee on the location of the warehouse
C_{k}^{D}	The annual fee by the establishment of distribution centers at the place
C_{ij}^{P}	Cost of production per unit of product at the factory
C_{ijm}^{RT}	Cost of transportation or transportation of each product unit from the factory to the warehouse
C_{imk}^{TR}	The cost of transportation of each unit of the product from the warehouse to the distribution center
C_{ikl}^{TR}	The cost of transportation or transportation of each product unit from the distribution center to the customer's area
C_{ijt}^{l}	Cost per unit of inventory control at the factory at the time
C_{imt}^{l}	The cost of each inventory control unit in stock at the time
C_{ikt}^{l}	Cost per unit of inventory control at the distribution center at the time
$\widetilde{D}_{k}^{\max}$	Maximum capacity of distribution centers
$\widetilde{D}_{k}^{\min}$	The minimum capacity of distribution centers
$\widetilde{D}_{ilt}^{[s]}$	Demand for the product from the customer area at the time frame for the scenario
$\widetilde{I}_{ijt}^{[s],\min}$	Minimum inventory available at the factory at the end of the time for the scenario
$\widetilde{I}_{imt}^{[s],\min}$	At least the inventory available at the end of the time for the scenario
$\widetilde{I}_{ikt}^{[s],\min}$	Minimum inventory available at the distribution center at the end of the time for the scenario
n^{DC}	Minimum inventory available at distribution centers
n^{W}	Minimum inventory available in stock
n^{P}	Minimum inventory available at the factories
NS	Number of product demand scenarios
$\widetilde{P}_{ijt}^{[s],\max}$	Maximum factory production capacity for the product at the end of the time for the scenario
$\widetilde{P}_{ijt}^{[s],\min}$	Minimum factory production capacity for the product at the end of the time for the scenario

$\tilde{Q}_{mk}^{\min}$	The minimum flow rate of material flow from warehouse to a distribution center
$\tilde{Q}_{kl}^{\min}$	The minimum flow rate of the material from the distribution center to the customer's area
$\tilde{Q}_{ijm}^{[s],\max}$	The maximum flow rate of product transfer from factory to warehouse based on the scenario
$\tilde{Q}_{imk}^{[s],\max}$	The maximum flow rate of product transfer from warehouse to distribution center based on the scenario
$\tilde{Q}_{ikl}^{[s],\max}$	The maximum flow rate of the product from the distribution center to the client based on the scenario
$\tilde{R}_{je}$	Resource availability rate at the factory
$\tilde{W}_{m}^{\max}$	Maximum storage capacity
$\tilde{W}_{m}^{\min}$	Minimum storage capacity
ΔT_t	Period of the time period
α	Service level

4.3. Continues varaibles

$\tilde{D}_k$	Distribution Center Capacity
$\tilde{I}_{ijt}^{[s]}$	Available inventory level at the factory at the end of the period based on the scenario
$\tilde{I}_{imt}^{[s]}$	Available product inventory level at the end of the period based on the scenario
$\tilde{I}_{ikt}^{[s]}$	Available inventory level at the distribution center at the end of the period based on the scenario
$\tilde{P}_{ijt}^{[s]}$	The rate of production at the factory in the period based on the scenario
$\tilde{Q}_{ijmt}^{[s]}$	The flow rate of product transfer from factory to a warehouse in a period based on the scenario
$\tilde{Q}_{imkt}^{[s]}$	The flow rate of product transfer from warehouse to a distribution center in a period based on the scenario
$\tilde{Q}_{iklt}^{[s]}$	The flow rate of the product from the distribution center to the customer in the period based on the scenario
$\tilde{W}_m$	Storage capacity

4.4. Binary variables

Y_m	If the stock is available, it is equal to 1, otherwise zero
Y_k	If the distribution center is available, it is equal to 1, otherwise zero
X_{mk}	If the material is transferred from the warehouse to the distribution center, it is equal to 1, otherwise zero
X_{kl}	If the material is transferred from the distribution center to the customer, it is equal to 1, otherwise zero

$X_{mkt}^{[s]}$	If the material is transferred from the warehouse to the distribution center in the period according to the scenario, it is equal to 1, otherwise zero
$X_{klt}^{[s]}$	If the material is transferred from the distribution center to the customer in a period based on the scenario, then it is equal to 1, otherwise zero

γ_{im}	The capacity of the warehouse center available at inventory
γ_{ik}	The capacity of the distribution center is available on inventory
ρ_{ije}	The factor of resource utilization rate at the factory for product production
ψ_s	Demand probability based on product scenario over network life

4.5.Objective function

$$
\begin{aligned}
Min \quad Z_1 = & \sum \Delta T_t \left(\sum_m C_m^W Y_m + \sum_k C_k^D Y_k \right) \\
& + \sum_{s=1}^{NS} \psi_s \left(\sum_t \Delta T_t \left(\sum_{i,j} C_{ij}^P P_{ijt}^{[s]} + \sum_{i,m} C_{im}^{WH} \left(\sum_j Q_{ijmt}^{[S]} \right) \right. \right. \\
& + \sum_{i,k} C_{i,k}^{DH} \left(\sum_m Q_{imkt}^{[s]} \right) + \sum_{i,j,m} C_{ijm}^{TK} . Q_{ijmt}^{[s]} + \sum_{i,m,k} C_{imk}^{TR} . Q_{imkt}^{[s]} \\
& + \sum_{i,k,l} C_{ikl}^{TR} . Q_{iklt}^{[s]} + \sum_{i,j,t} C_{ijt}^{I} \frac{I_{ijt}^{[s]} + I_{ij,t-1}^{[s]}}{2} \\
& \left. \left. + \sum_{i,j,t} C_{imt}^{I} \frac{I_{imt}^{[s]} + I_{im,t-1}^{[s]}}{2} + \sum_{i,j,t} C_{ikt}^{I} \frac{I_{ikt}^{[s]} + I_{ik,t-1}^{[s]}}{2} \right) \right) \\
Max \quad Z_2 = & \sum_s NS \left[\alpha \left(\sum_i \sum_m \sum_k \sum_t Q_{imkt}^{[s]} \right) + (1-\alpha) \left(\sum_i \sum_k \sum_l \sum_t Q_{iklt}^{[s]} \right) \right]
\end{aligned}
$$

The above objective function (objective 1) comprises of fixed infrastructure costs such as distribution centers and warehouses, production costs, material handling costs in warehouses and distribution centers, inventory costs at different stages, and transportation costs. The second objective function represents the maximum satisfaction achieved in locating in the multi-level supply chain.

4.6. Constraints

4.6.1. Network structure constraint

$$\sum_{s=1}^{NS} \psi_s = 1 \tag{1}$$

$$X_{mk} \leq Y_m \qquad \forall m,k \tag{2}$$

$$\sum_m X_{mk} = Y_k \qquad \forall k \in K^{ss} \tag{3}$$

$$X_{mk} \leq Y_k \qquad \forall k \notin K^{ss} \tag{4}$$

$$X_{kl} \leq Y_k \qquad \forall k,l \tag{5}$$

$$\sum_k X_{kl} = 1 \qquad \forall l \in L^{ss} \tag{6}$$

The constraint (1) represents the probability of the overall objective of the problem (to the minimum amount of expectation in the distribution network) with respect to minimizing costs in this cycle. Constraint (2) indicates the opening of the warehouse with the distribution center if the warehouse is established.

Constraint (3) indicates the service of a special warehouse to special distribution centers according to the type of requests available. Constraint (4) shows that if there is no distribution center then its connection with the warehouse cannot exist. This relationship is only written for distribution centers that do not source. For the rest of the distribution centers, the constraint (3) is used. Constraint (5) indicates the presence of the distribution center with the customer locations if the distribution center is established. Constraint (6) reflects the fact that some customer locations may be fed by only one distribution center under a supply constraint.

4.6.2. Logical constraints for shipping flows

$$Q_{ijmt}^{[s]} \leq Q_{ijm}^{[s],\max} Y_m \qquad \forall i,j,m,t,s = 1,\ldots,NS \tag{7}$$

$$Q_{imkt}^{[s]} \leq Q_{ijk}^{[s],\max} X_{mk} \qquad \forall i,m,k,t,s = 1,\ldots,NS \tag{8}$$

$$Q_{iklt}^{[s]} \leq Q_{ikl}^{[s],\max} X_{kl} \qquad \forall i,k,l,t,s = 1,\ldots,NS \tag{9}$$

$$\sum_i Q_{imkt}^{[s]} \geq Q_{mk}^{[s],\min} X_{mk} \qquad \forall m,k,t,s = 1,\ldots,NS \tag{10}$$

$$\sum_i Q_{iklt}^{[s]} \geq Q_{kl}^{[s],\min} X_{kl} \qquad \forall k,l,t,s = 1,\ldots,NS \tag{11}$$

Constraint (7) indicates the flow of material from the factory to the warehouse in the event of a connection between the warehouse and the factory. This constraint applies to all scenarios and time periods. Constraint (8) indicates the flow of materials from the distribution center to the customer locations in the event of a connection between the distribution center and the customer. Constraints (10) and (11) indicate the relationship between the warehouse and the distribution center and the distribution center and the customer to send the product or product, respectively.

4.6.3. Material balance constraints

$$I_{ijt}^{[s]} = I_{ij,t-1}^{[s]} + (P_{ijt}^{[s]} - \sum_m Q_{ijmt}^{[s]})\Delta T_t \qquad \forall i,j,t,s = 1,\ldots,NS \tag{12}$$

$$I_{imt}^{[s]} = I_{im,t-1}^{[s]} + (\sum_j Q_{ijmt}^{[s]} - \sum_k Q_{imkt}^{[s]})\Delta T_t \qquad \forall i,m,t,s = 1,\ldots,NS \tag{13}$$

$$I_{ikt}^{[s]} = I_{ik,t-1}^{[s]} + (\sum_m Q_{imkt}^{[s]} - \sum_l Q_{iklt}^{[s]})\Delta T_t \qquad \forall i,k,t,s = 1,\ldots,NS \tag{14}$$

$$\sum_l Q_{iklt}^{[s]} = D_{ilt}^{[s]} \qquad \forall i,l,t,s = 1,\ldots,NS \tag{15}$$

Constraint (12) states that the product at the end of the period, plus the product of the previous period in the period plus the production of the plant during the same period of time from the factory to the warehouse to be supplied to the needs of customers. Constraints (13) and (14) are similar for transferring products from warehouse to distribution centers as well as from distribution centers to the customer.

Normally, customer centers do not hold the normal amount of the product. Accordingly, the constraint (15) indicates the total flow of the product by each customer area from the distribution center, which is assumed to be equal to the market demand in that area.

4.6.4. Production resource constraints

The production rate of each product in each plant cannot exceed a certain level; therefore, there is always a minimum production capacity per product. In addition, production is often the minimum that must be maintained. To maintain production rates and capacity in each plant, we use the following two constraints in all scenarios and at all timescales.

$$P_{ijt}^{[s],\min} \le P_{ijt}^{[s]} \le P_{ijt}^{[s],\max} \qquad \forall i, j, t, s = 1,\dots, NS \tag{16}$$

$$\sum_i P_{ijt}^{[s]} \le R_{je} \qquad \forall j, e, t, s = 1,\dots, NS \tag{17}$$

4.6.5. Warehouse capacity and distribution centers

One of the important issues in designing and longevity of the network is the capacity of warehouses and distribution centers. The relationships below represent the number of products that can be stored temporarily before they are placed on the market.

$$W_m^{\min} Y_m \le W_m \le W_m^{\max} Y_m \qquad \forall m \tag{18}$$

$$D_k^{\min} Y_k \le D_k \le D_k^{\max} Y_k \qquad \forall m \tag{19}$$

$$W_m \ge \sum_i \gamma_{im} I_{imt}^{[s]} \qquad \forall m, t, s = 1,\dots, NS \tag{20}$$

$$D_k \ge \sum_i \gamma_{ik} I_{ikt}^{[s]} \qquad \forall k, t, s = 1,\dots, NS \tag{21}$$

Constraints (18) and (19) are the maximum and minimum capacity of each warehouse and distribution center, if any, of the warehouse or distribution center. The constraints (20) and (21) are coefficients indicate the amount of capacity to hold each product unit in the warehouses and distribution centers.

4.6.6. Confidence level constraints

$$I_{ijt}^{[s]} \ge I_{ijt}^{[s],\min} \qquad \forall i, j, t, s = 1,\dots, NS \tag{22}$$

$$I_{imt}^{[s]} \ge I_{imt}^{[s],\min} Y_m \qquad \forall i, m, t, s = 1,\dots, NS \tag{23}$$

$$I_{ikt}^{[s]} \ge I_{ikt}^{[s],\min} Y_k \qquad \forall i, k, t, s = 1,\dots, NS \tag{24}$$

$$I_{ijt}^{[s],\min} = \frac{n^p}{7} \sum_m Q_{ijmt}^{[s]} \qquad \forall i, j, t, s = 1,\dots, NS \tag{25}$$

$$I_{imt}^{[s],\min} = \frac{n^W}{7}\sum_k Q_{imkt}^{[s]} \qquad \forall i,m,t,s=1,\dots,NS \tag{26}$$

$$I_{ikt}^{[s],\min} = \frac{n^{DC}}{7}\sum_l Q_{iklt}^{[s]} \qquad \forall i,l,t,s=1,\dots,NS \tag{27}$$

$$P_{ijt}^{[s]} \geq 0 \qquad \forall i,\, jt,s=1,\dots,NS \tag{28}$$

$$I_{ijt}^{[s]} \geq 0 \qquad \forall i,\, j,t,s=1,\dots,NS \tag{29}$$

$$I_{imt}^{[s]} \geq 0 \qquad \forall i,m,t,s=1,\dots,NS \tag{30}$$

$$I_{ikt}^{[s]} \geq 0 \qquad \forall i,k,t,s=1,\dots,NS \tag{31}$$

$$Q_{ijmt}^{[s]} \geq 0 \qquad \forall i,\, j,m,t,s=1,\dots,NS \tag{32}$$

$$Q_{imkt}^{[s]} \geq 0 \qquad \forall i,m,k,t,s=1,\dots,NS \tag{33}$$

$$Q_{iklt}^{[s]} \geq 0 \qquad \forall i,k,l,t,s=1,\dots,NS \tag{34}$$

5. Case study

A case study of this study is related to the Iranian Bonny Chow Company, which is evaluated in this section using the model presented in Section IV. This case is motivated by the global procurement center of a world-class company in Iran. In this case, we are required to offer some strategic management on the supply chain network design if the operating cost and customer satisfaction are of concern. This company is a complete production unit that produces 50 different product types. For these products, they need a warehouse of manufactured goods and distribution centers for these goods to various cities. Customers of this company are considered in each of the 31 provinces of the country. For this purpose, there are 7 locations for warehousing and 10 locations for the establishment of distribution centers. By solving the model, we are looking to determine the best places to build warehouses and distribution centers, to determine the production and delivery schedule between the factory and the warehouses and distribution centers of this company. In the following, input values for the parameters defined in the mathematical model are expressed.

Table 1. Input data of used indices

Row	Parameter	Value	Measurement unit
1	i	5	Products
2	j	1	Factory
3	k	10	Potential distribution centers
4	l	31	Place of customers
5	m	7	Warehouse
6	s	3	Scenario
7	t	4	Season

According to the field research data, the input parameters of the model are as follows:

Table 2. Parameters of the model

Row	Parameter	Value	Measurement unit
1	C_{im}^{WH}	50	Monetary unit
2	C_{ik}^{DH}	45	Monetary unit
3	C_{m}^{W}	4500	Monetary unit
4	C_{k}^{D}	4000	Monetary unit
5	C_{ij}^{P}	550	Monetary unit
6	C_{ijm}^{RT}	30	Monetary unit
7	C_{imk}^{TR}	32	Monetary unit
8	C_{ikl}^{TR}	37	Monetary unit
9	C_{ijt}^{l}	7	Monetary unit
10	C_{imt}^{l}	8	Monetary unit
11	C_{ikt}^{l}	8	Monetary unit
12	$D_{k}^{\max}$	4000	Number of product
13	$D_{k}^{\min}$	2000	Number of product
14	n^{DC}	400	Number of product
15	n^{W}	380	Number of product
16	n^{P}	320	Number of product
17	NS	3	Number of product
18	R_{je}	0.95	percentage
19	$W_{m}^{\max}$	5000	Number of product
20	$W_{m}^{\min}$	3000	Number of product
21	ΔT_{t}	3	Month
22	α	0.95	percentage

Table 3. Minimum and maximum values of the model parameters based on demand scenarios

row	parameter	minimum			maximum		
		Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
1	$D_{ilt}^{[s]}$	10	15	19	-	-	-
2	$I_{ijt}^{[s],\min}$	11	23	44	-	-	-
3	$I_{imt}^{[s],\min}$	13	24	34	-	-	-
4	$I_{ikt}^{[s],\min}$	12	21	32	-	-	-
5	$P_{ijt}^{[s],\max}$	-	-	-	15	26	37
6	$P_{ijt}^{[s],\min}$	20	25	33	-	-	-
7	$Q_{mk}^{\min}$	18	20	32	-	-	-
8	$Q_{kl}^{\min}$	21	29	23	-	-	-
9	$Q_{ijm}^{[s],\max}$	-	-	-	25	42	47
10	$Q_{imk}^{[s],\max}$	-	-	-	28	32	48
11	$Q_{ikl}^{[s],\max}$	-	-	-	26	33	35

Table 4. Parameters of continuous model parameters based on scenario

Row	Parameter	Scenario 1	Scenario 2	Scenario 3
1	D_k	4300		
2	$I_{ijt}^{[s]}$	13	20	23
3	$I_{imt}^{[s]}$	23	23	19
4	$I_{ikt}^{[s]}$	43	22	64
5	$P_{ijt}^{[s]}$	44	32	36
6	$Q_{ijmt}^{[s]}$	23	34	23
7	$Q_{imkt}^{[s]}$	22	23	22
8	$Q_{iklt}^{[s]}$	32	51	32
9	W_m	34	22	34

6. Result and discussion

This section presents the application of the proposed optimization model on some test problems. Due to the complexity of the model in terms of the number of variables, constraints, and data structure, the model must be programmed in an efficient manner. The proposed optimization model was programmed in GAMS 24.3.1 software. In order to increase the computational efficiency of the model, the input data of the model has been invoked from Excel directly. All the numerical experiments are conducted on a PC with Intel Core 2 Duo 3.3 GHz and 4 GB RAM.

In order to evaluate the model applicability to real-life scenarios, we compare the model's outcomes with respect to three different scenarios. The scenarios are designed based on the different configuration of the facility for making real-world production–distribution decisions. These scenarios reflect the effect of a change in demand and the effect of a change in transportation costs on the economic factors of the proposed network design model. Finally, after solving this model, solutions are provided for each scenario and the results are presented. The output is as follows:

Scenario 1

Among the potential points for the establishment of the warehouses 1, 2, 4, and 7 are established. Among the potential points for the establishment of distribution centers, sites 2, 3, 5, 7, 8, and 9 are established. Based on this, the optimal value of the first and second objective function can be determined.

Table 5. Value of objective functions

row	objective	value
1	The minimum cost of locating	42000
2	Maximum satisfaction	94%

Table 6. Optimal Cost

row	parameters	Value (monetary)
1	Cost of production	450
2	The cost of moving materials in warehouses and distribution centers	495
3	Inventory Maintenance	267
4	Transport cost	355

Scenario 2

It can be concluded from the obtained results that the potential points for the establishment of the warehouse of the 1st, 2nd and 5th places. Among the potential points for the establishment of distribution centers, sites 1, 2, 4 and 9 are established. Based on this, the optimal value of the first and second objective function can be determined.

Table 7. Value of objective functions

Row	Objective	Value
1	The minimum cost of locating	29500
2	Maximum satisfaction	88%

Table 8. Optimal cost

Row	Parameters	Value (monetary)
1	Cost of production	520
2	The cost of moving materials in warehouses and distribution centers	680
3	Inventory Maintenance	300
4	Transport cost	490

Scenario 3

Among the potential points for the establishment of the warehouse 1, 3, 4, 6, and 7 are established. Among the potential points for the establishment of distribution centers, sites 2, 4, 5, 7, 8, 9 and 10 are established. Based on this, the optimal value of the first and second objective function can be determined.

Table 7. Value of objective functions

row	objective	value
1	The minimum cost of locating	50500
2	Maximum satisfaction	98%

Table 10. Optimal Cost

row	parameters	Value (monetary)
1	Cost of production	390
2	The cost of moving materials in warehouses and distribution centers	270
3	Inventory Maintenance	550
4	Transport cost	210

According to the outcomes presented, the advantages of this research are that the final output of the model is not a unique solution, but for different scenarios; different solutions are presented. This model allows the company's management to choose between different management policies. From the analysis of different scenarios, the result is that the more the company will cost more to build, produce and distribute, the customer's satisfaction increases, and vice versa, the more costs are reduced, customer satisfaction will also decrease. Therefore, finding a tradeoff between costs and customer satisfaction is key management decisions in this scientific area.

7. Conclusion

In this research, the location model of the multi-level supply chain was investigated. In this problem, there is a need for a comprehensive approach in the supply chain to determine strategic decisions; therefore, indicators such as production rates, storage rates, and distribution levels in the supply chain were also examined. The model outputs will help to provide a more comprehensive view of the location of warehouses and distribution centers in the supply chain. Accordingly, in this research, a new multi-objective mathematical model for multi-level location in the supply chain was presented. In this model, considering fixed and annual costs variables, the aim was to minimize the total cost of the supply chain. Since determining the optimal location of warehouses depends on the amount of production and distribution, the production and storage rates are also considered in the mathematical model.

Determining the exact amount of demand for manufactured products in a supply chain is always one of the most difficult tasks and will surely have miscalculations. For this reason, the present study accounts the demand uncertainty of the products. This uncertainty is presented in the form of several scenarios for non-deterministic parameters. The results show that despite the uncertainty in demand if the company sustains more conventional charges for the establishment of warehouses and distribution centers, customer satisfaction will increase. According to the presented mathematical model, the constraints such as the production balance in different periods, factory production capacity, storage capacity and distribution centers, and supply chain network constraints are among the most important constraints of this problem.

In order to continue this topic in the future research, the following are proposed as follows: 1) Inclusion of uncertainty in demand as fuzzy numbers, 2) Investigating the effect of whipping leather on multilevel location in the supply chain, 3) consideration and examination of the

proposed model for susceptible and corruptible goods, and 4) the integration of this model with vehicle routing problem.
Another further research direction is to enhance its applicability to real-life scenarios by considering demand uncertainty. Furthermore, regarding the proposed optimization model, it is recommended to extend the formulation to a closed-loop supply chain network design. The incorporation of the reverse logistics involves the routing of the raw and recycled items in the whole network simultaneously. In this model, the decision maker can decide the location of collecting, recycling, and disposal centers that meet the economic and environmental requirement of suppliers and firms.

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