Research Paper

Logistics Network Design Considering the Location of Logistics Hubs: A Case Study of Western Iran

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A R T I C L E I N F O	**A B S T R A C T**
	Today, logistics is recognized as one of the most important factors in the development of countries. One of the characteristics of an efficient logistics structure is the design of a suitable logistics network with the requirements of the region and the existing infrastructure to meet the commercial and industrial needs at different scales. Facility location is the most important factor for the success of the facility and the designed network. One of the interesting topics in location issues is the hub location issue. Hubs are facilities that are used as our points of integration, communication, and switching between source and destination nodes. In a hub network, non-hub nodes are assigned to the hubs individually or multiple times so that the total system cost is minimized and service requirements are met. Given the current economic conditions and competitive environment, logistics hubs play an important role in the logistics network of companies, especially on a large scale, for countries. The function of logistics hubs is similar to that of logistics centers, but due to the network structure, they are known as logistics hubs. In this paper, the problem of logistics network design with emphasis on the location of logistics hubs is investigated. The mathematical model of the problem is multidimensional and unallocated, and the designed hub network is an incomplete network. In this case, the purpose is to meet the requirements of the mathematical model while minimizing the costs of logistics network consisting of three costs of facility construction, interstate network construction and transportation.

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1. Introduction

One of the topics that has received a lot of attention in recent years in the field of logistics and transportation is the issue of hub location. The reason for this is its applicability and the increasing strategic importance of logistics and supply chain in the economies of countries. In recent years, customer service requirements and cost efficiency have changed the strategy and logistical organization, resulting in a concentration of production and distribution, reduced inventory and time-based competition (Groothedde et al., 2005). Hubs are transmitter facilities that allow network configuration so that many of our direct connections between nodes (including suppliers, warehouses, customers, etc.) can be replaced by fewer indirect connections (Sirikijpanichkul et al., 2007). Hub facilities are used as collection and distribution points in distribution networks with high supply and demand points. The flow of goods in the hub facility is aggregated to scale to take advantage of the economy (Ghahremani Nahr et al., 2021). In hub networks, sometimes called axis and blade networks, our current is not transmitted directly between two nodes, but through a set of nodes designated as hubs. Due to the increase in traffic on our routes between the hubs, larger vehicles can be used or the capacity of the existing vehicles can be used more efficiently, which leads to a reduction in transportation costs. Hub networks are generally defined as location-allocation issues in which the number of aggregation terminals (hubs) and the location of each of them must be determined so that nodes (e.g. cities, retailers, etc.) that are non-hub, be allocated to hubs (Zahedi & Nahr, 2020).

The goal is to minimize total costs, which consist of two components, fixed and variable. The hub location problem is in the NP-hard class of problems and is one of the hybrid optimization problems that combines location and network design decisions (Contreras et al., 2012). For this reason, this issue has been considered both in the real world for its applicability and in academic studies for the development and presentation of the solution method.

Most hub location issues consider the following three assumptions:

1) A hub network is a complete graph in which each pair of hub nodes are connected to each other.

2) There is economies of scale by a discount factor for the cost of our flows between hubs.

3) Direct flow between non-hub nodes is not allowed.

In practice, some of these assumptions may not be met. For example, there are issues in which part of the network is not completely connected (Contreras et al., 2009; Ghahremani Nahr et al., 2018). Other limitations that may apply to a conventional hub network include the capacity limit of the volume of currents collected in the hub, which leads to different types of networks, such as no-capacity, multiple-capacity, single or multiple non-hub node allocations. Indicate the hubs, and the number of hubs required, which can be predefined or considered as a decision variable. In all cases, however, the goal is to locate the hubs and allocate other nodes to them so that the total cost is minimized (Shahparvari et al., 2020). Some papers have considered only the aspect of problem allocation, but since optimal allocation is influenced by hub location and optimal hub location is influenced by allocation decisions, in designing the hub network, location and allocation issues should be considered together (Atta & Sen, 2020). These problems, in terms of exact solution algorithms, have a great variety of different methods that have been used to solve. Also, as mentioned, due to the complexity of solving these problems on a large scale, inaccurate and innovative solution methods have been used to find an acceptable answer. In addition to the common hub location issues, other issues can be addressed. These include location-routing problem, multidimensional hub location, multi-period problems, dynamic location problem, and segmented location problem.

The issue of logistics network design with regard to the location of logistics hubs is one of the topics that has been considered by many governments and companies in terms of its application in the real world. A logistics center is an area where all activities related to transportation, logistics and distribution of goods for national

and international operations are carried out by different operators (Mohammadi et al., 2015). Logistics hubs can be classified into several categories depending on their use. Depending on the geographical location, there are four types of logistics hubs: international, regional, local, and industrial. Factors that affect the location of logistics areas can be classified into two main criteria and sub-criteria. The main criteria are infrastructure facilities, proximity to the market, land availability, industry and government support, and labor supply (Ghahremani Nahr & Bathaee, 2021). In most studies to locate the hub, only a few factors were involved. This is despite the fact that in many real-world issues, qualitative factors along with quantitative factors are important and should be considered. Qualitative factors play an important role in the problem of locating logistics hubs, especially from the perspective of logistics network design, which must be considered both in the mathematical model and independently.

Iran is located in one of the strategic regions of the world in terms of geographical location. The Middle East region has great potential to support logistics due to its geopolitical characteristics. Iran is also known as a potential logistics country due to its trade route between Asia and Europe and its exceptional position in terms of trade relations. Iran ranks second in the world with 7 land border countries, 8 water border countries and a total of 15 border connections. There are 20 road border terminals on the land border, and with water connections from the north and south, 15 major ports have been developed under the supervision of the Ports and Shipping Authority. Iran, by being located in the path of five important international transit corridors including East-West, North-South, South Asia corridor, Europe-Asia-Caucasus transport and development of Asia-Asia ground transport infrastructure, can with proper planning, these special benefits **make** the most of it. Among the above transit corridors, the north-south corridor is of special importance. Iran's strategic, geopolitical and geo-economics position has always been considered as one of the country's special strengths and potentials. The convenient location of railways and roads and Iran's access to long shores in the Persian Gulf, the Sea of Oman, the Makran Sea, and the shores of the Caspian Sea in recent years has been much considered by major world economic producers. If some of the unfinished railways and roads of Iran are completed, Iran can make better use of the passage and transit of goods through its railways and roads.

In order to change the unfavorable logistics situation of the country, it is necessary to form a macro approach to support logistics developments for economic growth and then by formulating plans in the short and long term, to continuously improve the existing conditions. One of the measures that can be taken to improve the country's logistics is the development of logistics hubs on a national and international scale. Due to the importance of logistics hub development, this paper presents a mathematical model of hub location. The main purpose of identifying hubs and allocating non-hub nodes to hubs is to reduce logistics costs. For this purpose, the developed model is implemented in the western region of Iran and its results are analyzed.

2. Literature Review

The hub networking problem was first introduced by Goldman (1969). However, O'kelly (1987) proposed the first known mathematical formulation for the hub location problem by studying the passenger airline network. His formulation was related to the problem of locating multiple single-hub hubs. Assigning the nearest node to the hub - provided in the O'kelly (1987) model - does not necessarily guarantee an optimal answer. Thus, Aykin (1990) formulated a difference in the objective function and defined a procedure for finding the optimal allocation of demand points to a set of hubs. The problem of hub location in network design differs from its classical models in the literature. For example, in addition to locating hub facilities and allocating nodes, Carello et al. (2004) have considered the cost of installing the capacity required by each ridge to carry traffic within that ridge. Yaman and Carello (2005) studied a similar problem as the problem of locating a capacityless hub with the capacities of a scale edge. Hub location problems are also categorized as the type of objective function of the mathematical model and its assignment structure. The problem of hub

location with single or multiple allocations for the purpose of total transportation cost (average), minimum-maximum (center) objective function, and constraints with coverage type have been investigated in the literature. Campbell et al. (2002) reviewed these issues. Many studies on hub location assume that the network connecting the hub nodes is complete despite the connection between all pairs of hubs. In fact, many incomplete load and communication networks do not operate on the complete network structure of the hub. Competition is a relatively new topic that has received little attention in hub location issues and is becoming increasingly important given the conditions of the global economy. Abyazi-Sani and Ghanbari (2016), in continuation of presenting an innovative solution method to solve the hub location problem, have proposed an efficient forbidden search algorithm to solve the problem, assuming that there is no capacity constraint and in a single allocation mode. Zhai et al. (2016) have studied the problem of locating a capacityless hub in a two-step modeling process in conditions where demand is uncertain, and have also solved the problem on a larger scale by presenting a genetic algorithm. Various studies have been conducted on the design of interfacial logistics network. In transportation systems, there is usually a choice between road, air, rail and water transport methods. For example, freight companies mainly use air and road transportation. Numerous studies have been conducted on the design of the non-directional transport network. A review of indiscriminate transportation is provided in the article by Bontekoning and Priemus (2004). However, since the focus of the present study is on locating hub facilities, studies related to hub location decisions in multidimensional networks will be further explored. An important aspect that is less addressed in the design of hub networks is the choice of transport method. In most hub location models in the literature, it is assumed that there is only one type of hub and one type of transport method. The concept of choosing a transport method for locating a hub was first introduced by O'kelly and Lao (1991). In this study, they considered two hubs (one main hub and one small hub) at fixed locations and analyzed the allocation of air and ground transportation methods. A nonlinear hub network can be expressed by a graph whose nodes represent supply and demand points and its edges represent our transport connections between nodes (Guelat et al., 1990). The best place for uninterrupted hubs in such networks depends on several factors such as flow between source and destination points, transportation costs, economies of scale, service time performance, and fixed costs and method connection (Merrina et al., 2007). Conventional one-way network design models ignore the interactions between multiple modes of transportation, differences in cost structure, interconnection, and balances between service times (Macharis & Bontekoning, 2004). In their research, Kayışoğlu and Akgün (2021) studied the multiple allocation tree of the hub location problem in an incomplete network and solved the model developed by Banders innovative algorithm in 500 nodes. Korani and Eydi (2021) have examined the issue of reliable hub location by a two-tier planning model and KKT penalty operator with the aim of minimizing construction costs and the flow of goods between hubs. Logistics hubs also facilitate logistics. Maharjan and Hanaoka (2019) have studied the logistics problem of relief and distribution of essential items in the form of a temporary multi-objective model based on the validity of the location-allocation of logistics hubs under uncertainty. Mokhtarzadeh et al. (2021) solved the hub allocation location model using a combined clustering method and meta-innovative algorithm.

According to the literature of the studied subject, in the following, a hub location problem is modeled based on the research gap.

3. Development of a mathematical model for the problem of locating and designing a hub network

In this section, according to the stated assumptions and the existing view, the mathematical model of the problem will be developed. The aim of the present mathematical model is to locate different types of hubs and determine the transport method supported in hubs, assign non-hub nodes to hubs, determine the type of direct or hub-based transport between our two nodes and determine the type of inter-hub connection and

network design based on minimum Build the cost of the entire network. The assumptions of the mathematical model are:

- The number of normal nodes and potential nodes to be selected as hubs are known;
- The number of hubs of each type to be located is known;
- The location of all nodes is known;
- The overall network structure of the problem is directionless;
- The hub communication network is incomplete;
- Hubs have no capacity limit;
- The allocation of other nodes to hubs is a single allocation;
- There are no budget constraints;
- Transportation methods are examined in three categories: road, rail and air;
- Direct communication between two non-hub nodes is allowed;
- For intercom hobbies, there is a time discount factor;
- Interstitial transportation is examined in two categories of roads and other methods.

According to the stated assumptions, the model developed in this paper is modeled based on the following definitions:

3.1. Sets

$i, j = \{1, 2, \dots, N\}$	The whole set of network nodes
$k, l = \{1, 2, \dots, H\}$	A set of potential nodes for building a hub
$t = \{1, 2, \dots, T\}$	Set of different types of hub facilities
$m = \{1, 2, \dots, M\}$	Set of transportation methods (g: road transportation method)
$e = \{1, 2, \dots, E\}$	Set of type of goods transported
$v = \{1, 2, \dots, V\}$	Set of different types of road vehicles

3.2. Parameters

P^t	Number of t-type hubs to be constructed
FH_k^{mt}	Fixed cost of building a t-type logistics hub at potential location k
f_{ij}^e	The flow of our e-type goods between two nodes
$\hat{C}_{ij}$	Our shipping cost between two nodes in case of direct shipping
C_{ij}^m	The cost of our transportation between two nodes in interstitial transportation using the transportation method m
HL_{kl}^m	The cost of connecting an interstitial network using the transportation method m
cap^v	Capacity of road transport vehicle type v
CV^v	The cost of using a v-type road vehicle
$Size^m$	Container capacity used in transportation method m (other than road method)
d_{kl}^m	The cost of unloading and loading the container used in the transportation method m (other than the road method) in our transportation between hubs k and l

tt_{ij}^m	Transport time between two nodes using transportation method m
ot_k^m	Operating time required by the transport method m in the hub k
α^m	Interfaith time discount coefficient of transportation method m
SB_{ij}	Service time range between two nodes
M	One enough large number

3.3. Decision Variables

H_k^{mt}	If a t-type hub is constructed at a potential location k with support for the m transport method, one; Otherwise zero
$\hat{Y}_{ij}$	If the transport between the two nodes is done directly, one; Otherwise zero
Y_{ijkl}^m	If the transport between two nodes is done through the hub link k and l using the transport method m, one; Otherwise zero
Z_{kl}^m	If a h transport link is established between the two hubs k and l, one; Otherwise zero
X_{ik}	If node i is assigned to hub k, one; Otherwise zero
TFG_{kl}^m	The amount of goods transported between h and k through the road transport method
num_{kl}^v	The required number of v-type vehicles between k and l
ICG_{kl}^m	The cost of moving goods between hubs k and l by road transport
TFM_{kl}^m	Amount of goods shipped between hubs k and l by other means of transportation (other than road)
ICM_{kl}^m	Cost of moving goods between hubs k and l by other means of transportation (other than road)
ST_{ij}	Shipping time between two nodes

Based on the set, parameters and decision variables presented, the final model is developed as follows.

$$\min \sum_{k,m,t} FH_k^{mt} H_k^{mt} + \sum_{k,l,m:k \neq l} HL_{kl}^m Z_{kl}^m + \sum_{i,j,e} f_{ij}^e \hat{C}_{ij} \hat{Y}_{ij} + \tag{1}$$

$$\sum_{i,j:i \neq i, k,l:k \neq l, m,e} \left(C_{ik}^g + C_{kj}^g \right) Y_{ijkl}^m f_{ij}^e + \sum_{k,l:k \neq l \neq, m=\{g\}} ICG_{kl}^g + \sum_{k,l:k \neq l, m \neq \{g\}} ICM_{kl}^m$$

Subject to:

$$\sum_{k,m} H_k^{mt} = P^t \; \forall t \in T \tag{2}$$

$$\sum_k X_{ik} = 1 \; \forall i \in N \tag{3}$$

$$\sum_i X_{ik} \leq M \sum_t H_k^t \; \forall k \in H \tag{4}$$

$$\sum_t H_k^t \leq M \sum_i X_{ik} \ \forall k \in H \tag{5}$$

$$\sum_i X_{ik} \leq MX_{kk} \ \forall k \in H \tag{6}$$

$$2Z_{kl}^m \leq H_k^{mt} + H_l^{mt} \ \forall k,l \in H : k \neq l, m \in \acute{M}, t \in T \tag{7}$$

$$2Z_{kl} \leq \sum_{m,t} H_k^{mt} + \sum_{m,t} H_l^{mt} \ \forall k,l \in H : k \neq l \tag{8}$$

$$\sum_{l:l \neq k,m} Z_{kl}^m \geq 1 + M(X_{kk} - 1) \ \forall k \in H \tag{9}$$

$$\sum_{k,l:k \neq l,m} Y_{ijkl}^m = 1 - \hat{Y}_{ij} \ \forall i,j \in N : i \neq j \tag{10}$$

$$\sum_{l:l \neq k,m} Y_{ijkl}^m - \sum_{l:l \neq k,m} Y_{ijlk}^m = X_{ik} - X_{jk} \ \forall i,j \in N : i \neq j, k \in H \tag{11}$$

$$Y_{ijkl}^m + Y_{ijlk}^m \leq Z_{kl}^m \ \forall i,j \in N : i \neq j, k,l \in H : k \neq l \tag{12}$$

$$TFG_{kl}^m = \sum_{i,j:i \neq j,e} f_{ij}^e Y_{ijkl}^m \ \forall k,l \in H : k \neq l, m = \{g\} \tag{13}$$

$$num_{kl}^v \geq \frac{TFG_{kl}^m}{cap^v} \ \forall k,l \in H : k \neq l, m = \{g\}, v \in V \tag{14}$$

$$ICG_{kl}^m = num_{kl}^v CV^v \ \forall k,l \in H : k \neq l, m = \{g\}, v \in V \tag{15}$$

$$TFM_{kl}^m = \sum_{i,j:i \neq j,e} f_{ij}^e Y_{ijkl}^m \ \forall k,l \in H : k \neq l, m \in \acute{M} \tag{16}$$

$$ICM_{kl}^m = (TFM_{kl}^m/Size^m)(C_{kl}^m + d_{kl}^m) \ \forall k,l \in H : k \neq l, m \in \acute{M} \tag{17}$$

$$ST_{ij} = \left[\sum_{k:k \neq i} tt_{ik}^g X_{ik} + \sum_{k,l:k \neq l,t} ot_k^m + (\alpha^m tt_{ij}^m) + ot_l^m + \sum_{k:k \neq j} tt_{kj}^g X_{kj} \right] Y_{ijkl}^m$$
$$+ tt_{ij}^m \hat{Y}_{ij} \ \forall i,j \in N : i \neq j \tag{18}$$

$$ST_{ij} \leq SB_{ij} \ \forall i,j \in N : i \neq j \tag{19}$$

$$H_k^{mt}, X_{ik}, Z_{kl}^m, Y_{ijkl}^m, \hat{Y}_{ij} \in \{0,1\} \tag{20}$$

$$TFG_{kl}^m, num_{kl}^v, ICG_{kl}^m, TFM_{kl}^m, ICM_{kl}^m, ST_{ij} \geq 0 \tag{21}$$

Equation (1) is the objective function of the problem, which consists of six cost parts. In the first part, the fixed cost of construction of facilities, in the second part, the cost of construction of inter-religious infrastructure, in the third part, the cost of transportation in case of direct transportation of goods and in the fourth, fifth and sixth parts, the cost of transportation in case of hobby network are calculated. The limit (2) specifies the number of hubs to be constructed of any type with the support of a particular mode of transportation. Constraint (3) states that each non-hub node can be assigned to only one hub. Constraints (4) and (5) establish a relationship between the two types of facilitator construction variables. Constraint (6)

indicates that a node can be assigned to a hub when the hub in question is constructed. The function of constraint (7) is that an intra-Jewish connection can be established using a transport method (other than roads) when both nodes are selected as hubs and support the method. This communication in the independent road transport method is of the type supported in the hubs because road communication, like other methods (rail and air) does not require special communication facilities and equipment and unloading and loading. This problem is shown in constraint (8) where by constructing two hubs at two points, the road connection between the two hubs can be established regardless of the type of method supported. Constraint (9) states that if one point is selected as a hub, it will be connected to another hub with an inter-hub connection. In constraint (10), we choose between direct and hub-based transportation methods. Constraint (11) is the constraint of our current balance between nodes. This limitation determines which interfaith connection is used to transport between the two nodes. Constraint (12) ensures that the flow of goods takes place only on the hobby links constructed. Constraint (13) Calculates the total amount of goods transported between two hubs using the road transport method. Constraint (14) determines the number of vehicles required of each type, and constraint (15) calculates the cost of transportation between interstate roads. In constraint (16) the total amount of interstitial transported goods is calculated for other modes of transport (other than roads) and in constraint (17) the cost of this type of transport is determined between our two hubs. Constraint (18) calculates the total service time between two nodes and in constraint (19) specifies the corresponding boundary. Constraints (20) and (21) indicate the decision variables.

4. Analysis of Results

## 4.1. Analysis of experimental problems

In this section, more diverse cases of experimental problems are solved and different scenarios are analyzed. The parameters considered in this analysis are the number of nodes in the whole network, the number of potential nodes in the hub, the number and type of hubs, the discount rate of inter-hub transportation cost (alpha factor), the problem solving time and the network costs. Therefore, 18 sample design problems and the results of problem solving with GAMS software are shown in Table (1).

Table 1. Analytical results of experimental problems.

n	k	Type	p	α	CPU Time (s)	FH	FT	FL	Total Cost
10	5	1	3	0.60	1.46	286581	1365260	696000	2347840
10	5	1	3	0.75	1.69	286581	1152180	696000	2134760
10	5	1	3	0.90	1.55	286581	1003590	696000	1986180
10	5	1	2	0.90	1.80	206039	1005250	447000	1658290
10	5	1	4	0.90	2.09	393613	998291	963000	2354900
20	10	1	4	0.90	16.20	450103	3573410	784500	4808020
20	10	1	4	0.60	12.90	450103	3582010	784500	4816610
20	10	2	2-3	0.75	286.45	426907	4288720	1944000	6659620
20	10	1	4	0.90	49.24	422659	4462870	975000	5860530
20	10	1	3	0.90	27.35	315627	4472890	708000	5496510
25	12	1	5	0.75	120.53	496836	5321160	754290	6652290
25	12	2	2-3	0.75	778.85	390212	5436160	598230	6424600
25	12	2	2-3	0.90	662.91	390212	5802200	598230	6790640
25	12	1	3	0.60	62.29	429411	5123470	494190	6047070
30	15	1	5	0.75	973.84	437130	7951700	1710000	10098800
30	15	1	8	0.90	1615.08	763317	8355430	2685000	11803700
30	15	1	6	0.60	588.14	575743	676906	216900	9513800
30	15	1	4	0.75	761.99	359593	8260100	1257000	9876690

The analysis of the results of the experimental problems is shown in Figures (1) to (3).
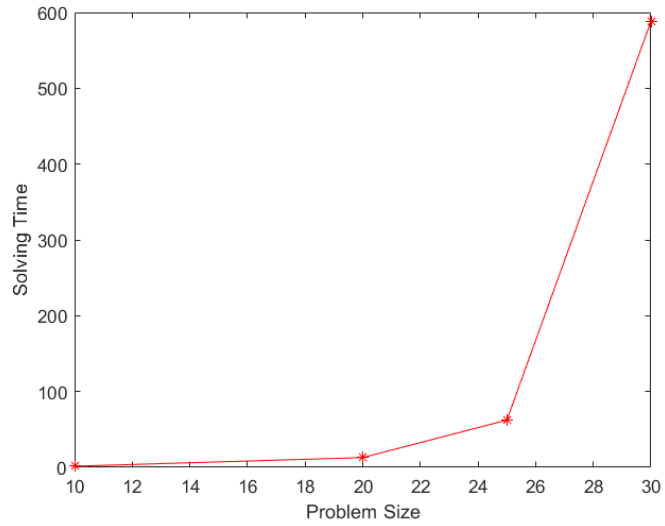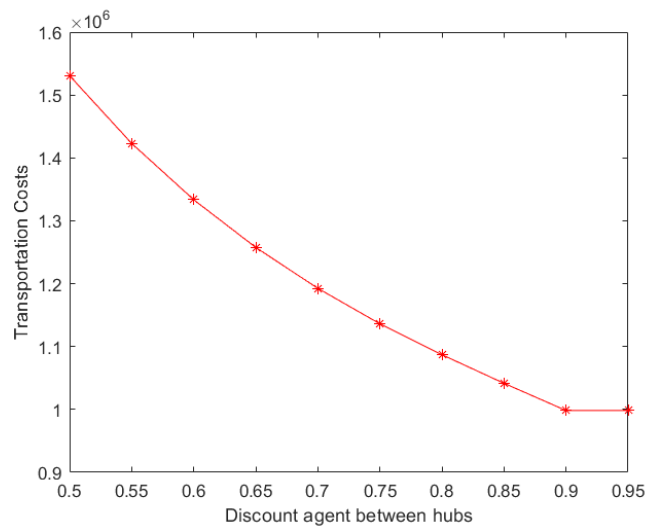
Fig. 1. Solving time proportional to the size of the problem
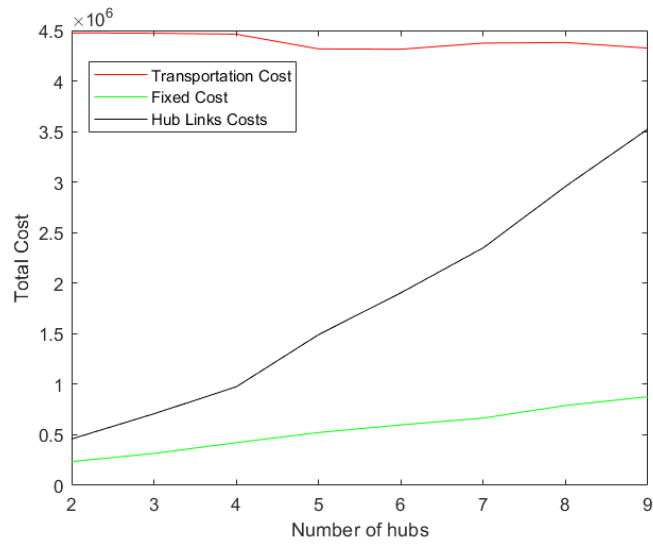
Fig. 2. Number of hubs and costs

Fig. 3. Discount factor between hubs and shipping costs

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As stated, the purpose of solving experimental problems is to validate the mathematical model and analyze related trends. It can be seen from Figure (1) that the problem solving time increases exponentially with increasing problem size. This is the reason why it takes time to solve the main problem with the dimensions of 63 nodes, which caused a faster computer with the mentioned specifications to be used to solve the problem accurately due to the strategic and important answer to the problem. Analyzes can also be performed according to Figure (2). As the number of hubs built on a fixed-size network increases, it is natural that the fixed cost of building the facility increases, but transportation costs decrease due to the use of an interstitial transportation structure for more source-destination pairs. Of course, with the increase in the number of network hubs, due to the need for more communication infrastructure to connect the hubs in the form of an inter-hub network, the cost of constructing communication channels between the hubs also increases. In theoretical matters, the number of hubs should be constructed so that the above costs, along with the cost of the entire network, are at a minimum. As can be seen from Figure (3), the cost of transportation increases as the interfaith mitigation factor increases.

4.2. Examining the results of the problem of western Iran

In this section, after validating the mathematical model, the main problem is solved with real data. The specifications of the problem in real dimensions are presented in Table (2). Mathematical models in these dimensions require a lot of time to solve accurately. Therefore, the mathematical model is solved in a computer with a 24-core Intel CPU and 32 GB of RAM. As stated in the previous sections, in order to provide appropriate options and related analyzes for each, the problem has been studied in several ways and the results of each have been described.

Table 2. Problem characteristics with real data for the western region of Iran.

Discount factor between hubs	Number of created hubs		Number of potential hub nodes		Number of cities surveyed in the west of the country	Total number of involved cities
	Border terminals	Logistics centres	Border terminals	Logistics centres		
0.75	3	3	8	7	20	63

Scenario 1: Strategic importance equal to domestic logistics and transit

In this case, due to the equal importance of both types of domestic transport and logistics of transit of goods, the number of logistics hubs of both types (logistics centers and border hubs) is equal to three facilities of each type. This also has a more realistic view of inter-Wahhabi communication. This means that the percentage of progress of planned highways in the western region of the country has been included in the calculations. Some examples of highways under construction in the area that can be effective in the designed network are presented in Table (3) along with the percentage of progress.

Table 3. Percentage of progress of highways under construction in western Iran.

Progress	Highway
Hamedan-Sanandaj	80
Kermanshah-Miandoab	72
Urmia-Sarv	65
Urmia-Mahabad	46

Therefore, in the first case, the cost of constructing our highways between the selected areas for the construction of the logistics hub has been calculated taking into account the current developments.

Scenario 2: Complete construction of inter-Wahhabi communication infrastructure

In this case, the strategic importance of both domestic and foreign transport is assumed to be equal, but in the case of the construction of inter-religious communication, the road is considered a highway and the construction of all roads is assumed from the beginning. Thus, if determined by the mathematical model, a highway will be built between the two cities and its costs will be fully calculated. This is useful for cases where a highway under construction between two cities is not planned, and can offer decision-makers to build such a connection along with logistical cost analysis to decision makers.

Scenario 3: Implicit attention to better domestic and international transportation

The third case explicitly assumes the equal importance of the two types of logistics, but since the interstate road connections in this case are of the freeway type, it is possible to plan for the development of international freight transport and transit logistics by providing quality infrastructure and It acted in accordance with regional and international standards. Due to the fact that we do not have a freeway under construction between the cities and areas under study, its full costs have been included in the calculations from the beginning.

Scenario 4: The greater the importance of domestic transportation

In this case, due to the assumption of more attention of decision makers to in-country logistics, the number of logistics centers is three and border hubs are considered two. Interstate communication is also a highway due to the adequacy of the highway compared to the cost of its construction.

Scenario 5: The greater the importance of foreign transportation

Unlike the previous case, the fifth case emphasizes foreign logistics and the number of hubs is the opposite of the previous case, three border hubs and two logistics centers in the interior of the country. As mentioned, in order to make the most of the logistical benefits of international transit and transportation of goods, as well as to encourage transportation companies and neighboring countries to use quality and standard infrastructure in the country, in this case, road communication will be freeway-type hubs.

Scenario 6: Impact of utility coefficient

According to the explanations given about the logistical advantages of potential areas and possible connections, as well as the knowledge that factors other than the cost factor should be considered in macro-logistics decisions, in this case the fixed cost of building facilities and the cost of building appropriate interfaith communication infrastructure. Has been affected by the utility coefficient and the relevant calculations have been performed with this assumption.

Scenario 7: More emphasis on facility location

In this case, the importance of location of the facility is assumed to be greater than the design of the interfaith communication network. Although this relationship does not provide a true picture of the establishment of interstate connections, it exacerbates the impact of facility location on the final results and network implementation. In addition, the number of both types of hubs, three facilities are considered.

Scenario 8: Strategic importance equal to domestic logistics and transit, fewer facilities

This case has all the assumptions of the second case, i.e. the complete construction of the highway between the hubs is considered. However, the number of facilities has decreased compared to the previous cases, and while the strategic importance of domestic and foreign transportation is equal, two hubs of each type will be proposed for construction in the region. Table (4) presents the supplementary results of each of the above proposed scenarios and scenarios.

Table 4. Computational results of different states of the problem.

Scenario / Costs	Fixed construction of facilities	Transportation	Establish connections between hubs	Total
First	604,184,000,000	5,311,910,000,000	1,699,000,000,000	7,615,100,000,000
Second	494,990,000,000	7,317,940,000,000	3,044,000,000,000	10,856,900,000,000
Third	509,896,000,000	9,308,820,000,000	7,335,000,000,000	17,153,700,000,000
Fourth	508,548,000,000	6,832,860,000,000	3,320,000,000,000	10,661,400,000,000
Fifth	427,565,000,000	9,758,480,000,000	5,895,000,000,000	16,081,000,000,000
sixth	516,914,000,000	6,907,590,000,000	3,213,850,000,000	10,638,400,000,000
Seventh	604,184,000,000	5,311,910,000,000	300,000	5,916,100,000,000
Eighth	349,935,000,000	7,701,860,000,000	2,628,000,000,000	10,679,800,000,000

Since the costs and problem data are calculated on the basis of annual reports and by year, in order to balance the costs of the whole system, the amount equivalent to the annual cost of building the hub should be considered instead of the initial fixed cost of construction. For this purpose, economic techniques and the factor of converting the initial investment amount into a uniform annual cost will be used (Figure 4). The value of this factor is obtained from Equation (22):

$$(A/P, i\%, n) = \frac{i(1 + i)^n}{i(1 + i)^n - 1} \tag{22}$$
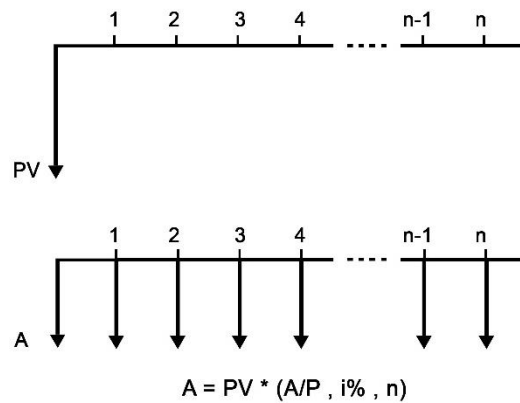
Fig. 4. Converting the amount of initial investment into a uniform annual cost

Since the value of the deduction tends to i as n increases in the above expression, and also since the lifespan of logistics facilities in the real world is usually more than 25 years, the value of the above factor can be equal to the value of i or the interest rate. Contract. The interest rate in this study is considered to be 20%. Therefore, Table (5) shows the fixed cost of constructing the facility on a balanced annual basis along with other costs.

Table 5. Computational results of different states of the problem with adjustment of fixed construction cost

Scenario / Costs	Fixed construction of facilities	Transportation	Establish connections between hubs	Total
First	120,836,400,000	5,311,910,000,000	1,699,000,000,000	7,131,746,400,000
Second	98,988,000,000	7,317,940,000,000	3,044,000,000,000	10,460,928,000,000
Third	101,979,200,000	9,308,820,000,000	7,335,000,000,000	16,745,799,200,000
Fourth	101,709,600,000	6,832,860,000,000	3,320,000,000,000	10,254,569,600,000
Fifth	85,513,000,000	9,758,480,000,000	5,895,000,000,000	15,738,993,000,000
sixth	103,382,800,000	6,907,590,000,000	3,213,850,000,000	10,224,822,800,000
Seventh	120,836,800,000	5,311,910,000,000	300,000	5,432,747,100,000
Eighth	69,987,000,000	7,701,860,000,000	2,628,000,000,000	10,399,847,000,000

Here the descriptive results of the first scenario are stated. The computational results indicate that:

1. The cities of Tabriz, Sanandaj, and Hamedan are selected as suitable points for the construction of logistics hubs in the country or logistics centers.

2. Bazargan, Tamarchin and Mehran borders are selected as centers for the development of border logistics hubs.

3. We recommend the construction of quality highways between the cities of Hamedan-Mehran, Mehran-Sanandaj, Bazargan-Tabriz, Tabriz-Tamarchin (Piranshahr) and Tamarchin-Sanandaj for better inter-Wahhabi communication.

4. The fixed cost of constructing the facilities is a total of one hundred and twenty billion and eight hundred and sixty-four million.

5. The annual transportation cost in the studied network is about five thousand three hundred and eleven billion and nine hundred and ten million.

6. The cost of developing and improving the infrastructure of the inter-Wahhabi network is one thousand six hundred and ninety-nine billion.

The logistics network of the western region of Iran, with emphasis on the location of logistics hubs, taking into account the various scenarios proposed is shown in Figure (5).
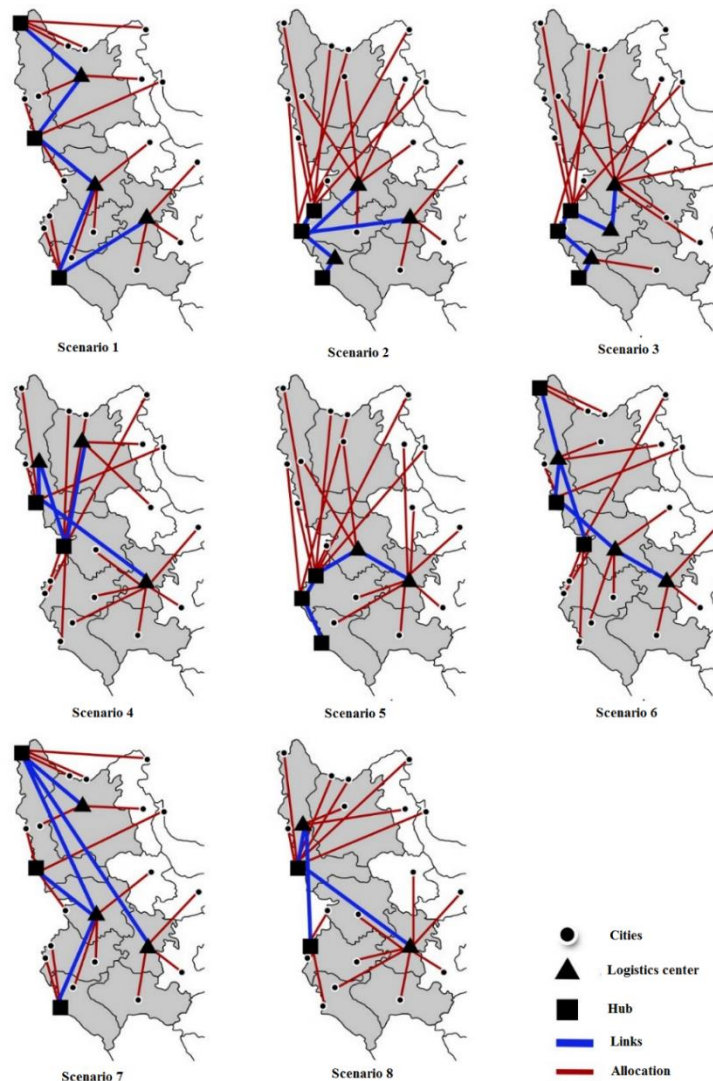

Fig. 5. Logistics network of the western region of Iran in different scenarios

5. Conclusions and future suggestions

Mathematical model The problem of designing the logistics network of the western region of Iran with emphasis on selecting optimal locations for different types of logistics hubs, as stated, was solved in different scenarios, the results of each of which are given in this section:

Scenario 1: In this case, the cities of Sanandaj, Tabriz and Hamedan were selected as logistics centers and the borders of Bazargan, Tamarchin and Mehran were selected as border hubs. Proposed highways for construction are: Hamedan-Mehran, Mehran-Sanandaj, Bazargan-Tabriz, Tabriz-Tamarchin (Piranshahr) and Tamarchin-Sanandaj. The total cost of the network in this case is equal to 77131746000000 Tomans. In this scenario, logistical and external importance are assumed to be equal.

Scenario 2: Similar to the first scenario, in this case the importance of both types of logistics is the same and the cost of building a highway between the two cities is fully calculated. In this case, the cities of Sanandaj, Hamedan and Ilam were selected as logistics centers and the borders of Parviz Khan, Khosravi and Mehran were selected as border hubs. Proposed highways for construction are: Sanandaj-Khosravi, Parviz Khan (Qasr Shirin) -Khosravi, Hamedan-Khosravi, Khosravi-Ilam and Ilam-Mehran. The cost of the whole network in this case is equal to 1046092828 million.

Scenario 3: The difference between this scenario and the previous two is the construction of a freeway in the interstate network to emphasize the importance of pioneering logistics and international transit. Similar to the previous cases, three logistics centers should be built in Sanandaj, Kermanshah and Ilam cities, three border hubs in Parvizkhan, Khosravi and Mehran and Sanandaj-Kermanshah, Kermanshah-Parvizkhan, Parvizkhan-Khosravi, Mehran-Ilam and Ilam-Khosravi freeways. The total cost of the network in this case is 16745799000000.

Scenario 4: In this case, three logistics centers will be built in the cities of Tabriz, Urmia and Hamedan and two border hubs will be built on the borders of Tamerchin and Bashmaq. The approach of this scenario is on the development of domestic transportation. The construction of Tabriz-Bashmaq (Marivan), Urmia-Tamarchin, Urmia-Bashmaq and Tamarchin-Hamedan highways and the total cost of the designed network is 1025456900000000.

Scenario 5: This scenario has the opposite approach to Scenario 5 and places more emphasis on the development of the country's transit logistics through the western region of Iran. Two logistics centers in Sanandaj and Hamedan cities and three border hubs in Parviz Khan, Khosravi and Mehran regions are proposed for construction. The inter-Wahhabi connection is of the freeway type and is: Hamedan-Sanandaj, Sanandaj-Parvizkhan, Parvizkhan-Khosravi and Khosravi-Mehran. The total cost of the network in this scenario is 1573899300000000.

Scenario 6: In this case, three logistics centers will be built in the cities of Urmia, Sanandaj and Hamedan and three border hubs in the borders of Bazargan, Tamarchin and Bashmak. Intermediate relationship between Bazargan-Urmia, Urmia-Tamarchin, Urmia-Bashmaq, Tamarchin-Sanandaj and Sanandaj-Mehran couples is suggested as a highway. The difference between this scenarios is the effect of the utility coefficient obtained from the logistics of the region as a qualitative factor in the costs of building the hub and the interfaith relationship. The total cost of the network in this case is 1022482222000000.

Scenario 7: In this case, by calculating the cost of interfaith communication in another way, more emphasis is placed on the location of the problem under study. Three logistics centers will be built in the cities of Tabriz, Sanandaj and Hamedan and three border hubs will be built in the borders of Bazargan, Tamarchin and Mehran. Also, the established inter-Wahhabi connections are: Bazargan-Tabriz, Bazargan-Hamedan, Bazargan-Sanandaj, Tamarchin-Sanandaj and Sanandaj-Mehran. The cost of the logistics network of the western region of Iran in this scenario is estimated at 543274747000000.

Scenario 8: According to this scenario, two logistics centers in the cities of Urmia and Hamedan and two border hubs on the borders of Tamerchin and Parviz Khan are proposed for construction. The communication routes between the cities of Urmia-Tamarchin, Hamedan-Tamarchin and Urmia-Parviz Khan will be of the highway type and the total cost of the network will be 10399847000000.

By reviewing the literature on the subject as well as the background of the previous chapters, it is possible to make more suggestions and areas of study for research on the subject of network design, hub location, and logistics hubs. Emphasizing the applicability of future research in the real world and existing issues, the following are:

Investigate the problem of logistics network design with emphasis on the location of logistics hubs and hub-related considerations in more detail such as different types of vehicles, shipping strategies, warehousing policies and vehicle routing.

- Development and improvement of proposed mathematical models.
- Check the problem in the segmented network mode. Since one of the goals of logistics network development at the regional scale and strategic level is to cover the segmented zones of the main zone, the mathematical model can be developed in a segmented state and depending on different criteria and conditions, in each sub region the appropriate requirements and structure of that sector Implemented.

References

- Abyazi-Sani, R., & Ghanbari, R. (2016). An efficient tabu search for solving the uncapacitated single allocation hub location problem. *Computers & Industrial Engineering*, *93*, 99-109. https://doi.org/10.1016/j.cie.2015.12.028

- Atta, S., & Sen, G. (2020). Multiple allocation p-hub location problem for content placement in VoD services: a differential evolution based approach. *Applied Intelligence*, *50*(5), 1573-1589. https://doi.org/10.1007/s10489-019-01609-y

- Aykin, T. (1990). On "a quadratic integer program for the location of interacting hub facilities". *European Journal of Operational Research*, *46*(3), 409-411.

- Bontekoning, Y., & Priemus, H. (2004). Breakthrough innovations in intermodal freight transport. *Transportation Planning and Technology*, *27*(5), 335-345. https://doi.org/10.1080/0308106042000273031

- Campbell, J., Ernst, A., & Krishnamoorthy, M. (2002). Hub location problems.

- Carello, G., Della Croce, F., Ghirardi, M., & Tadei, R. (2004). Solving the hub location problem in telecommunication network design: A local search approach. *Networks: An International Journal*, *44*(2), 94-105. https://doi.org/10.1002/net.20020

- Contreras, I., Cordeau, J. F., & Laporte, G. (2012). Exact solution of large-scale hub location problems with multiple capacity levels. *Transportation Science*, *46*(4), 439-459. https://doi.org/10.1287/trsc.1110.0398

- Contreras, I., Fernández, E., & Marín, A. (2009). Tight bounds from a path based formulation for the tree of hub location problem. *Computers & Operations Research*, *36*(12), 3117-3127. https://doi.org/10.1016/j.cor.2008.12.009

- Costa, A. M., França, P. M., & Lyra Filho, C. (2011). Two-level network design with intermediate facilities: an application to electrical distribution systems. *Omega*, *39*(1), 3-13. https://doi.org/10.1016/j.omega.2010.01.005

- Ghahremani Nahr, J., & Bathaee, M. (2021). Design of a Humanitarian Logistics Network Considering the Purchase Contract. *Journal of Decisions and Operations Research*. DOI: 10.22105/dmor.2021.270988.1311

- Ghahremani Nahr, J., Kian, R., & Rezazadeh, H. (2018). A modified priority-based encoding for design of a closed-loop supply chain network using a discrete league championship algorithm. *Mathematical problems in engineering*, *2018*. https://doi.org/10.1155/2018/8163927

- Ghahremani-Nahr, J., Nozari, H., & Bathaee, M. (2021). Robust Box Approach for Blood Supply Chain Network Design under Uncertainty: Hybrid Moth-Flame Optimization and Genetic Algorithm. *International Journal of Innovation in Engineering*, *1*(2), 40-62. https://doi.org/10.52547/ijie.1.2.40

- Goldman, A. J. (1969). Optimal locations for centers in a network. *Transportation Science*, *3*(4), 352-360. https://doi.org/10.1287/trsc.3.4.352

- Groothedde, B., Ruijgrok, C., & Tavasszy, L. (2005). Towards collaborative, intermodal hub networks: A case study in the fast moving consumer goods market. *Transportation Research Part E: Logistics and Transportation Review*, *41*(6), 567-583. https://doi.org/10.1016/j.tre.2005.06.005.

- Guelat, J., Florian, M., & Crainic, T. G. (1990). A multimode multiproduct network assignment model for strategic planning of freight flows. *Transportation science*, *24*(1), 25-39. https://doi.org/10.1287/trsc.24.1.25

- Kayışoğlu, B., & Akgün, İ. (2021). Multiple allocation tree of hubs location problem for non-complete networks. *Computers & Operations Research*, *136*, 105478. https://doi.org/10.1016/j.cor.2021.105478

- Korani, E., & Eydi, A. (2021). Bi-level programming model and KKT penalty function solution approach for reliable hub location problem. *Expert Systems with Applications*, *184*, 115505. https://doi.org/10.1016/j.eswa.2021.115505

- Macharis, C., & Bontekoning, Y. M. (2004). Opportunities for OR in intermodal freight transport research: A review. *European Journal of operational research*, *153*(2), 400-416. https://doi.org/10.1016/S0377-2217(03)00161-9

- Maharjan, R., & Hanaoka, S. (2019). Fuzzy multi-attribute group decision making to identify the order of establishing temporary logistics hubs during disaster response. *Journal of Humanitarian Logistics and Supply Chain Management*. https://doi.org/10.1108/JHLSCM-02-2018-0013

- Merrina, A., Sparavigna, A., & Wolf, R. A. (2007). The intermodal networks: a survey on intermodalism. *World Review of Intermodal Transportation Research*, *1*(3), 286-299. https://doi.org/10.1504/WRITR.2007.016275

- Mohammadi, H., Ghazanfari, M., Nozari, H., & Shafiezad, O. (2015). Combining the theory of constraints with system dynamics: A general model (case study of the subsidized milk industry). *International Journal of Management Science and Engineering Management*, *10*(2), 102-108. https://doi.org/10.1080/17509653.2014.920123

- Mokhtarzadeh, M., Tavakkoli-Moghaddam, R., Triki, C., & Rahimi, Y. (2021). A hybrid of clustering and meta-heuristic algorithms to solve a p-mobile hub location–allocation problem with the depreciation cost of hub facilities. *Engineering Applications of Artificial Intelligence*, *98*, 104121. https://doi.org/10.1016/j.engappai.2020.104121

- O'kelly, M. E. (1987). A quadratic integer program for the location of interacting hub facilities. *European journal of operational research*, *32*(3), 393-404. https://doi.org/10.1016/S0377-2217(87)80007-3

- O'Kelly, M. E., & Lao, Y. (1991). Mode choice in a hub-and-spoke network: A zero-one linear programming approach. *Geographical Analysis*, *23*(4), 283-297. https://doi.org/10.1111/j.1538-4632.1991.tb00240.x

- Shahparvari, S., Nasirian, A., Mohammadi, A., Noori, S., & Chhetri, P. (2020). A GIS-LP integrated approach for the logistics hub location problem. *Computers & Industrial Engineering*, *146*, 106488. https://doi.org/10.1016/j.cie.2020.106488

- Sirikijpanichkul, A., FERREIRA, L., & LUKSZO, Z. (2007). Optimizing the location of intermodal freight hubs: an overview of the agent based modelling approach. *Journal of Transportation Systems Engineering and Information Technology*, *7*(4), 71-81. https://doi.org/10.1016/S1570-6672(07)60031-2

- Yaman, H., & Carello, G. (2005). Solving the hub location problem with modular link capacities. *Computers & operations research*, *32*(12), 3227-3245. https://doi.org/10.1016/j.cor.2004.05.009

- Zahedi, M., & Nahr, J. (2020). Designing a hub covering location problem under uncertainty conditions. *Management Science Letters*, *9*(3), 477-500. *DOI:* https://doi.org/10.5267/j.dsl.2020.2.002

- Zhai, H., Liu, Y. K., & Yang, K. (2016). Modeling two-stage UHL problem with uncertain demands. *Applied Mathematical Modelling*, *40*(4), 3029-3048. https://doi.org/10.1016/j.apm.2015.09.086