A Locating-Routing Model for Hazardous Materials Transport Planning based on Time Value of Money for Establishing and Operating Costs (Case study: Northwest Area of Iran)

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Abstract

Transportation of hazardous materials (Hazmat for short) has always raised authorities' concerns about the potential risks to humans and environment. But Hazmat transportation plays an important role to the economy in both developed and developing countries. In addition to the selection of routes from the origin to destination, Hazmat transportation often includes facilities that may also known as the sources of potential risks for environment. Thus, it is necessary to address the integration of locating and routing decisions from both economic and safety aspects. The mail purpose of the present paper is to develop a mathematical model to find optimum sites for the construction of fuel distribution centers as well as to determine different states of lifetime for the construction of those during the operating period to reduce the total costs of the project. Both construction and transportation costs are given based on the time value of money which is the contribution of the present research work. The objective function is defined at two levels in which the first level specifies the total network risk and the second level aims to find the construction sites with their respective lifetime considering the value of the establishing and operating costs. The proposed model has been validated using experimental data in the selected case study of the northwest region of Iran. The results revealed that considering time value of money in Hazmat transport planning plays a significant role over locating the optimum sites as fuel distribution centers, so local or national authorities who are dealing with Hazmat transportation can utilize the proposed model to find the best locations of fuel distribution centers.

Keywords: Hazardous Materials, Routing-Locating Problem, Fuel Distribution Centers, Transportation Risk, Time Value of Money

1. Introduction

1.1 Hazmat Transportation

Developing the urbanization and industries, especially the logistics industry, increasingly complicates the movement of people and commodities while urban development entails the increased level of demand and the increased number of distribution firms in the transportation industry (Ho et al., 2008). One of the most important materials carried over the world is known as hazardous material (abbreviated as Hazmat). Every day, millions of tons of goods are transported in the transit routes of different countries whilst some of them contain hazardous materials. United Nation classifies Hazmat into nine categories: explosives, gases, flammable liquids, oxidizing materials, toxic and infectious materials, radioactive materials, corrosive materials, and finally waste products (Environmental Health & Safety, 2011). In fact, the impact of the hazardous materials may be due to the heat of combustion or explosion, the mechanical effects of the explosion, the toxic effects by breathing, contact with or consumption of toxic chemicals due to leakage, and/or the effect of radioactive materials due to ionizing radiation (Mabrouki et al., 2015).

1.2 Hazmat Transport Risk and Safety

French Standardization Association (Association Française de Normalisation; AFNOR), the representative of ISO in France, defines the risk of Hazmat transport as "combining the probability of an event and its consequences" or "combining the likelihood of damage and its seriousness". Also, risk the mathematical expectation of the loss of life, injuries, and impairments to properties, and damages to economic activity over a specific period and in an assumed region defined for a specific hazard. The risk is the multiplication of hazard by vulnerability (Mabrouki et al., 2015). Hazmat transportation forms a main part of the economy in the developed countries so that the transport of these cargoes globally amounts to 4 billion tons per year (Mahmoudabadi et al., 2016). Since, over 90% of the commodities in Iran are transported by the in-land transport system a part of these commodities is Hazmat that should be transported under special conditions and measures (United Nations, 2009) and the public should be protected against their rare accidents which usually have considerable consequences. Thus, the safety of Hazmat transportation is of crucial importance in transportation planning (Mahmoudabadi et al., 2016). The transportation of Hazmat is an integrated part of the industrial societies, and these materials are mostly supplied from sites far from the final destinations (Mohammadi et al., 2015). The increasing rate of the transportation of hazardous cargoes is a source of growing concern for road and rail transport systems since they pass across crowded areas. Occasional leakage of toxic and flammable materials from the road or railway tankers triggers disasters with high casualty rate (Paltrinieri et al., 2009). Although the number casualties due to the accidents that are caused by Hazmat are almost negligible as compared to the casualties of ordinary traffic accidents, the public needs to be ensured about them (Mohammadi et al., 2015). The concerns about Hazmat transportation are related to all goods that we constantly need – e.g. fuel, gas, and fertilizer (Mabrouki et al., 2015). Following the above mentioned, Hazmat transportation management by the road system has been attracted more interests in recent years. Indeed, due to the nature of Hazmat and the related physical and chemical incidents, they pose potentially high risks to people, the characteristics and status of the roads, traffic density, and environment (Fanti et al., 2015).

1.3 Hazmat Modeling Techniques

The Hazmat transportation has been focused by researchers almost since 1980 and various techniques have been presented to design the transportation routes in terms of the costs and risks of their transport. Although, the shortest path algorithm is used in a single-objective model, in models those use objectives utility function, the weights of objectives are combined in the objective function to change the multi-objective model to a single-objective model. Then, it can be solved like single-objective models (Verter & Kara, 2001). Researches on the transportation planning problem mainly focuse on two main themes: (i) the risk assessment of Hazmat transit by the road system, and (ii) the identification of a path to mitigate the transportation risk (Fanti et al., 2015).
Routing is an important issue that should be considered in the provisions for Hazmat (Mohammadi et al., 2015). Due to the practical concerns and considerable problems, routing is perceived as one of the best subject matters for research in operation (Kheirkhah et al., 2016). This issue is important to researchers from two perspectives. The first perspective is that it is a practical problem and finding an optimum solution can lead to economic saving and the second is that its solution is challenging because the problem is so difficult to be solved (Mester et al., 2007). Routing in the transportation of Hazmat is not necessarily concerned with finding the shortest route, but it should be attempted to determine the safest route (Carotenuto et al., 2007). The determination of the route for the transportation of Hazmat is a two-aspect problem. On the one hand, local officials try to reduce the risk of their transportation for local people and on the other hand, the transportation firms try to use routes those minimize transportation costs (Erkut & Alp, 2007). Both local officials and transportation firms play a role in determining the routes for Hazmat transportation, accordingly. Therefore, bi-level mathematical models have been also developed for the routing of Hazmat transportation (Erkut & Gzara, 2008). One important measure is related to the number of people who use the routes of Hazmat carrying trucks named as the exposure to Hazmat rather than incidents (Fanti et al., 2015). Kazantzi et al. proposed a systematic framework for the development of a Hazmat transportation model in which the transportation cost is minimized and the risks are reduced to a specific level (Kazantzi et al., 2011).
Kara et al. presented two algorithms to determine Hazmat routes. The algorithm is related to the load on the linking roads on the basis of the selected paths. They claimed that their approach is an extended version of the standard path selection algorithm that does not normally yield good results (Kara et al., 2003). Pradhananga et al. proposed a Pareto-optimization method for the path selection of Hazmat transportation and addressed the scheduling with time

windows for these vehicles (Pradhananga et al., 2010). Chang et al. expanded the concept of risk creation, which has been recently considered in the path selection for Hazmat transportation, from two perspectives. The model is composed of two objective functions: one for minimizing the total asset at risk, and the other for equal distribution of risk across the route (Chuang & Kung, 2005). Serafini developed a dynamic programming model for path selection with the least risk for Hazmat transportation (Serafini, 2006). Mohaymany and Khodadadian developed a mathematical model with the assumption of a weighted combination of objectives in one single objective function. The model can be used to specify the best traffic flow in the network. They developed a linear programming model with the integer numbers by considering the population risk, environmental risk, and transportation costs (Mohaymany & Khodadadian, 2008).

1.4 Locating-Routing Problem on Hazmat Transport

The question of locating the centers was first introduced by Cooper in 1963. This is a well-known problem in the field of industrial engineering which is related to locating a set of facilities so as to minimize the total cost or total cost of transportation from the facilities to all customers. The key concept in locating the best site is in terms of attributes mainly defined as risk and cost of transport planning (Mahmoudabadi, 2015). Eiselt and Marianov presented a mathematical model for simultaneously locating and determining the optimum capacity of waste disposal sites considering two objectives of minimizing cost and pollution. They also considered the economic scales (Eiselt & Marianov, 2016). If Hazmat transportation is dealt with along with locating the supply devices, then it will turn into a different quantitative problem called routing-locating or locating-routing problem. The locating-routing problem includes two key problems: supply chain management and vehicle routing problem (Mahmoudabadi, 2015). Locating-routing problem determines the optimum locations for facilities and the best route for the transportation of Hazmat, simultaneously (Escobar et al., 2013). The logistics systems usually use this problem when locating and routing are to be designed for the sake of cost minimization (Jarboui et al., 2013). It involves the simultaneous determination of the number, location, and capacity of facilities as well as a set of the optimum routes for the supply of services to the customers. The application of this problem is exemplified in the collection of solid waste, school bus routing, and vendor routing (Nagy & Salhi , 2007). This problem has recently been developed in the context of the docking interactive concept and the novel problem-solving techniques like simulated hybrid (Mousavi & Tavakkoli-Moghaddam, 2013). The locating-routing problem for Hazmat has often been formed as multi-objective optimization models with diverse objective functions including transportation and facility risk, transportation and facility cost, trip time, and the expected number of accidents (Xie et al., 2012). Mohammadi et al. presented a new reliable mathematical model for designing Hazmat transportation network based on locating hubs in which hubs may be disturbed by external events and Hazmat incidents (Mohammadi et al., 2015). Zhang et al. presented a locating-routing model that considers highly population points of the route when locating the operation centers and routing the transportation of materials from producers to the facilities. Their model has three criteria: (i) total cost including transportation cost, the fixed cost of facility construction, and the cost of making the vehicles safe, (ii) the risk of population exposure to danger, and (iii) considering all populated centers with respect to risk exposure (Zhang et al., 2005). Alumur and Kara presented a multi-objective locating-routing problem that, in addition to locating and determining the technology required for the operation, addresses locating waste disposal sites and routing non-recyclable waste to these centers. They considered two criteria: total cost minimization and risk minimization (population at risk) (Alumur & Kara, 2007). Shuai and Zhao described a bi-objective model for locating waste operation, recycle, and disposal centers and routing the vehicles to them. They applied two criteria of cost and risk as well as the capacity of the centers and the technology requirements in addition to the limitations due to material type Shuai & Zhao, 2011).

1.5 Time Value of Money

The current value of a certain amount of money in future is equal to the amount of money one should possess today so that the same amount of money is generated in future with respect to the current interest rates (Mankiw, 2005). Since money is capable of profit generation, its value increases over time. Since the current value of money escalates towards the future, its value must be lost as one moves from future to the present time. The cash flows are of crucial importance in engineering economics because they form the basis for the evaluation of projects, equipment, and investment options (Panneerselvam, 2012). In the economic evaluation of projects, we calculate the costs incurred to the system on the basis of the time value of money and the inflation rate as two important factors in cost. Alikar et al. formulated a multi-component set of inventory redundancy allocation set as a mixed-integer nonlinear mathematical model in which (i) costs are calculated with respect to the time value of money and the inflation rate, and (ii) the limitations are related to the total warehouse capacity for the storage of components, total budget for component purchase, and the capacity of the trucks (Alikar et al., 2017).

1.6 Vision

Following the above mentioned, the main aim of this paper is to consider the concept of time value of money and develop a locating-routing problem for Hazmat transport planning of fuel in the northern part of Iran. In this case, the time period of distribution centers' construction should be considered over mathematical modeling process. Since, three types of periods including 10, 20 and 30 year-periods are defined for modeling, all possible combinations are used. The present value of all costs consist of construction and transport costs has been defined as objective function as well as distribution center capacity and demands of gas stations are defined as main constraints. In addition to minimizing cost, total risk is also minimized over the network which is a main attribute in Hazmat transport planning. Therefore, the proposed mathematical model would be a bi-level one in which the second level of objective function minimize total cost subject to an upper bound of total transport risk gained from the first level. Since, considering a crisp value for total transport risk is often not practical, a tolerance is applied for modeling in the second stage.

2. Mathematical Modeling

The road network is composed of the nodes and edges those connect nodes. Three types of nodes are defined in a network including supply, demand, and intermediate nodes. The proposed mathematical model is a bi-level objective linear programming model. By definition, the problem and objective of a mathematical model are two important factors influencing the development and solution of a model, the risk, and the total costs. The first level of the model aims to determine the lowest risk level for the network. The risk of each path, the length of the path as a basis for the cost parameter, the capacity of each distribution center, and the demand for each distribution center are known and pre-determined. The rate of material transportation from candidate distribution centers to all pre-determined demand sites is calculated, and the risk is reduced as far as it is minimized and the safest route for the transportation of Hazmat. The objective of the second level is to minimize the total costs of the projects including the construction cost of distribution centers with different modes during the operational period and the cost of fuel transportation from the distribution centers to demand sites. Distribution centers with three different modes are constructed during 30 years of operation. This includes the construction of a 30-year distribution center in the reference year, the construction of a 10-year distribution center in the reference year followed by the construction of a 20-year distribution center, the construction of 20-year distribution center in the reference year followed by the construction of a 10-year distribution center, and finally the construction of three 10-year distribution center in three consecutive periods. The construction cost should be minimized so as to determine in a 30-year operating period where and in which candidate nodes to construct these distribution centers so that the highest number of demand sites is satisfied with the minimum cost. This cost is included in the category of current costs. On the other hand, the transportation costs of Hazmat should be minimized over the operating period. This cost is a part of annual costs of the project. Therefore, since the goal is to calculate the current value of the costs, the transportation costs should be converted from annual to the current value by using the conversion factors of the annual value of costs to the current value in engineering economics. Finally, the results design the best route for the transfer of these materials in terms of the lowest cost. As well, they reveal the number of distribution centers and the construction mode for all individual centers and the fact that which one can be consistent with our budget and capital. Thus, the objective function of the model at the first level is as Equation (1)

$$Min\, Z_1 = \sum_{i=1}^{m}\sum_{j=1}^{n} R_{ij}X_{ij} \qquad (1)$$

where i represents subscript for the candidate points for the supply node i= (1, 2, 3, . . ., m), j denotes subscript for the demand nodes j= (1, 2, 3, . . ., m), R_{ij} represents the risk of the route from distribution centers i to the destination j (known as gas station with a predetermined value), X_{ij} shows the quantity of materials transported from the distribution centers i to the destination j. Z_l denotes the low limit of total risk assigned to the network, and G represents the linear network or graph and the considered two-way paths (i, j), (j, i) $\in$ G. The constraints of the model at the first level are delineated at Equations (2) and (3). Equation (2) implies that each distribution centers can provide service at most as great as its capacity to all assigned fuel (gas) stations. Where, Ui is the capacity of distribution center i. Equation (3) shows that each fuel station can receive service from the distribution centers at most as great as its yearly demand.

$$\sum_{j=1}^{n} X_{ij} \leq U_i \qquad \forall\, i = 1,2, \dots m \tag{2}$$

$$\sum_{i=1}^{m} X_{ij} \geq F_j \qquad \forall\, j = 1,2, \dots n \tag{3}$$

Where, F_j represents the annual demand of fuel station j.

The above equations calculate the total risk of Hazmat transport over the network. The second level of objective function is to minimize the equivalent annual value of total cost including construction and transport costs defined by equation (4). As shown, total cost is composed of annual transport and construction costs.

$$Min\, Z_2 = \sum_{i=1}^{m}\sum_{p=1}^{4} Y_{ip} CO_{ip} + \sum_{p=1}^{4} [\sum_{i=1}^{m}\sum_{j=1}^{n} C_{ijp} X_{ijp} \times (\frac{P}{A}, r\%, 10)] \times (\frac{F}{P}, r\%, N_p) \tag{4}$$

where CO_{ip} represents the construction cost of the distribution center i provided its age is p years, C_{ijp} represents the cost of Hazmat transportation from the p-year distribution center i to the destination j in the case of p year distribution center, and Yip is a binary variable for the distribution centers in node i which is p years considered for locating, r shows the interest rate, and X_{ijp} represents the amount of Hazmat transported from the p-year distribution center i to the destination j. The model's constraints for the second level are defined as below. In order to control the the binary variable Y_i Equations (5) and (6) are added to the model (Taha, 2008)

$$\sum_{j=1}^{n} X_{ijp} \leq M \times Y_{ip} \;\forall\, i = 1,2, \dots m \;\&\; p = 1,2,3,4 \tag{5}$$

$$\sum_{j=1}^{n} X_{ijp} > M \times \left(Y_{ip} - 1\right) \forall\, i = 1,2, \dots m \;\&\; p = 1,2,3,4 \tag{6}$$

Where M is a big number and is employed for the acceptance of the distribution centers. Since each distribution center is built with a definite capacity, Equation (7) shows that the quantities of Hazmat transported from the p-year distribution center i to the destinations should always be equal to or smaller than the capacity of p-year distribution center i.

$$\sum_{j=1}^{n} X_{ijp} \leq U_i \qquad \forall\, i = 1,2, \dots m \;\&\; p = 1,2,3,4 \tag{7}$$

Since the fuel station has a definite amount of demand, according to Equation (8), the amount of product that is sent from the distribution centers to the destination j should always be at least equal to the demand of that fuel station.

$$\sum_{i=1}^{m} X_{ijp} \geq F_j \qquad \forall\, j = 1,2, \dots n \;\&\; p = 1,2,3,4 \tag{8}$$

Another limitation that is added to this step from the first step is the optimum value of the objective function from the first step. Considering a specific tolerance (α tolerance coefficient), the limitation does not allow the risk to exceed a specific value. (This tolerance is generated to apply the effect of the cost function in locating-routing.) This is presented in Equation (9).

$$\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{p=1}^{4} X_{ijp} \times R_{ij} \leq Z_1(1+\alpha) \tag{9}$$

3. Experimental Studies

Since, the present study focused on locating and constructing distribution centers (fuel stations) in different types of construction with the age of 30 years, the road network of the northwestern of Iran has been selected as case study. The mentioned part is the road network of six provinces including Azerbayejan Sharqi, Azerbayejan Gharbi, Zanjan, Ardabil, Hamedan and Kordistan shown in figure 1. The risk of each route and the demand of each station as well as the construction cost were specified according to the selected model. More details for case study and data used in this part are available at (Mahmoudabadi et al., 2016).

In addition, table 1 shows the capacity of each individual distribution centers as the inputs of the model and table 2 presents the amount of Hazmat to be transported from each supply node to the destinations (gas stations) gained after using the well-known software of General Algebraic Modeling System abbreviated as GAMS.

Figure 1. The map of case study (Mahmoudabadi et al., 2016)

Table 1. Capacity of the candidate distribution centers (Thousand tons per year)

Supply node	Capacity	Supply node	Capacity	Supply node	Capacity
Razi	1000	Oskou	1000	Poldasht	1000
Kovariom	1500	Qarah Aghaj	1500	Tazehshahr	700
Bostanabad	2000	Malekan	900	Shabestar	900
Divandareh	1000	Naqadeh	700	Hadishahr	1500
Dehglan	1000	Bukan	1000	Khajeh	1000
Zarin abad	900	Takkab	900	Kleybar	800

As can be observed in table 2, the first column is selected distribution center should satisfy demand of assigned gas stations shown in the fourth column. The third column represents the amount of Hazmat should be stored and transported by selected distribution center shown as total transported materials (TTM). For example, the first row means that Bazargan gas stations should be satisfied by Poldasht distribution center. The selected distribution center supply the other gas stations of Makou, Shout, Chaldoran, Nazila and Ghare ziaodin. The number which is next to the gas station is the amount of Hazmat should be transported from distribution center to gas stations.

Table 2. Results assuming 5% tolerance and 8% interest rate (thousand tones)

Distribution center	Construction plan	TTM*	Total materials transported to the demand site (distribution center, the amount of transported materials)
Poldasht	Three 10-year distribution center	800	(Bazargan, 100) , (Makou,100) , (shout, 100) , (Chaldaran, 200), (Nazila, 150) , (Ghare ziaodin,150)
Tazehshahr	Three 10-year distribution center	700	(khouy, 300) , (Salmas, 150) , (Oroumieh, 250)
Shabestar	Three 10-year distribution center	200	(Firoz, 100) , (Soufian, 100)
Hadishahr	Three 10-year distribution center	400	(Marand, 300) , (Jolfa, 100)
Khajeh	Three 10-year distribution center	950	(Tabriz, 700) , (Varzaghan, 150), (Heris, 100)
Kleybar	Three 10-year distribution center	750	(Ahar, 100), (Soltanali, 150), (Aslandooz, 200) , (Meshkinshahr, 300)
Razi	Three 10-year distribution center	750	(Pars abad, 50) , (Bileh savar, 100), (Jafarabad, 100), (Gharmi, 200), (Ardabil, 300)
Kovariom	Three 10-year	1500	(Namin,200), (Astara,100), (Ardabil, 500), (Sareeyn, 300),

Distribution center	Construction plan	TTM*	Total materials transported to the demand site (distribution center, the amount of transported materials)
	distribution center		(khalkhal, 400)
Bostanabad	Three 10-year distribution center	200	(Nir,100) , (Sarab, 100)
Oskou	Three 10-year distribution center	800	(Khoramshahr, 100) , (Mamaghan, 100) ,(khodabandeh, 100) , (Abhar,200) , (Soltanieh,300)
Qarah Aghaj	One 20-year and one 10-year distribution center	600	(Maraghe, 100) , (Hashtroud, 200) , (Miyaneh, 300)
Malekan	Three 10-year distribution center	650	(Azar shahr, 200) , (Ajabshir, 50) , (Bonab, 100) , (Likan,100) , (Mahabad, 200)
Naqadeh	Three 10-year distribution center	700	(Orumie,650) , (Eshnavieh, 50)
Bukan	Three 10-year distribution center	1000	(Miyandoab, 200) , (Mahabad, 100) , (Piranshahr, 100) , (Saghez, 200) , (Baneh, 300) , (Sardasht, 100)
Takkab	Three 10-year distribution center	100	(Shahin dezh, 100)
Divandareh	Three 10-year distribution center	346.519	(Bijar,100) , (Marivan, 146.5) , (Kamyaran, 100)
Dehgalan	Three 10-year distribution center	853.481	(Marivan, 53.5) , (Sanandaj, 700) , (Gharve, 100)
Zarinabad	Three 10-year distribution center	900	(Zanjan, 900)

*Total Transported Material

In order to make a sensitivity analysis, many interest rates of 8, 10, 15 and 20 percents are used for solving the locating-routing problem and tabulated in table 3. In addition, since, the model behavior at different conditions has been evaluated by sensitivity analysis. The values of total cost function are reduced with the variations of the tolerances of risk range assuming three different risks (5, 15, and 50%) and the variations of interest rate for the project costs assuming three different interest rates (8, 10, and 12%) in model solution.

Table 3. Model results 5%, 15% and 50% risk tolerances (α) and 8%, 10% and 12% interest rates (r)

Construction plan	Distribution centers and the amount of transported materials	(α, r)
Centers as three 10-year distribution centers, except for Kovarium, Bostanabad, Qarah Aghaj, one 20-year and one 10-year center constructed.	(Poldasht, 800), (Taze shahr, 700), (Shabestar, 200), (Hadishahr, 400), (khajeh, 950), (Kilibar, 600), (Razi, 1000), (Kovarim, 1500), (BostanAbad, 100), (Oskou, 1000), (GhareAghaj, 500), (Malekan, 900), (Naghadeh, 700), (Bouka, 650), (Takab, 100), (Divandareh, 200), (Dahgalan, 1000), (ZarinAbad, 900)	(8%, 15%)
All centers as three 10-year distribution centers	(Poldasht, 800), (Tazeshahr, 700), (Shabestar, 200), (Hadi shahr, 400), (khajeh, 950), (Kilibar, 600), (Razi, 1000), (Kovarim, 1500), (BostanAbad, 100), (Oskou, 1000), (GhareAghaj, 500), (Malekan, 900), (Naghadeh, 700), (Bouka, 650), (Takab, 100), (Divandareh, 200), (Dahgalan, 1000)	(8%, 50%)
All centers as three 10-year distribution centers	(Poldasht, 800), (Taze shahr, 700), (Shabestar, 200), (Hadishahr, 400), (khajeh, 950), (Kilibar, 750), (Razi, 750), (Kovarim, 1500), (BostanAbad, 200), (Oskou, 800), (GhareAghaj, 600), (Malekan, 550), (Naghadeh, 700), (Bouka, 1000), (Takab, 100), (Divandareh, 247), (Dahgalan, 853), (ZarinAbad, 900)	(10%, 5%)
All centers as three 10-year distribution centers	(Poldasht, 800), (Tazeshahr, 700), (Shabestar, 200), (Hadishahr, 400), (khajeh, 950), (Kilibar, 600), (Razi, 1000), (Kovarim, 1500),	(10%, 15%)

Construction plan	Distribution centers and the amount of transported materials	(α, r)
	(BostanAbad, 100), (Oskou, 1000), (GhareAghaj, 500), (Malekan, 900), (Naghadeh, 700), (Bouka, 650), (Takab, 100), (Divandareh, 200), (Dahgalan, 1000), (ZarinAbad, 900)	
All centers as three 10-year distribution centers	(Poldasht, 800), (Tazeshahr, 700), (Shabestar, 200), (Hadishahr, 400), (khajeh, 950), (Kilibar, 600), (Razi, 1000), (Kovarim, 1500), (BostanAbad, 100), (Oskou, 1000), (GhareAghaj, 500), (Malekan, 900), (Naghadeh, 700), (Bouka, 650), (Takab, 100), (Divandareh, 200), (Dahgalan, 1000), (ZarinAbad, 900)	(10%, 50%)
All centers as three 10-year distribution centers	(Poldasht, 800), (Taze shahr, 700), (Shabestar, 200), (Hadishahr, 400), (khajeh, 950), (Kilibar, 750), (Razi, 750), (Kovarim, 1500), (BostanAbad, 200), (Oskou, 800), (GhareAghaj, 600), (Malekan, 550), (Naghadeh, 700), (Bouka, 1000), (Takab, 100), (Divandareh, 247), (Dahgalan, 853), (ZarinAbad, 900)	(12%, 5%)
All centers as three 10-year distribution centers	(Poldasht, 800), (Tazeshahr, 700), (Shabestar, 200), (Hadishahr, 400), (khajeh, 950), (Kilibar, 600), (Razi, 1000), (Kovarim, 1500), (BostanAbad, 100), (Oskou, 1000), (GhareAghaj, 500), (Malekan, 900), (Naghadeh, 700), (Bouka, 650), (Takab, 100), (Divandareh, 200), (Dahgalan, 1000), (ZarinAbad, 900)	(12%, 15%)
All centers as three 10-year distribution centers	(Poldasht, 800), (Tazeshahr, 700), (Shabestar, 200), (Hadishahr, 400), (khajeh, 950), (Kilibar, 600), (Razi, 1000), (Kovarim, 1500), (BostanAbad, 100), (Oskou, 1000), (GhareAghaj, 500), (Malekan, 900), (Naghadeh, 700), (Bouka, 650), (Takab, 100), (Divandareh, 200), (Dahgalan, 1000), (ZarinAbad, 900)	(12%, 50%)

A global sensitivity analysis has also been made for the proposed model and results are shown in table 4. As shown, increasing risk tolerance cause to reduce total cost. Increasing the risk tolerance allow the proposed model to obtain less costly routes as well as less selected distribution centers. On the other hand, increasing the interest rate makes to receive less present value of cost.

Table 4. Total cost of construction and transport (Billion per year)

Risk Tolerance	Interest Rate		
	12%	**10%**	**8%**
5%	8005	9339	8112
15%	7652	8927	8063
50%	7652	8927	8063

4. Summary and Conclusion

Since, Hazmat transport is a main concern in transport planning a bi-level objective model has been developed for solving locating and routing problem. The first level of objective function determines the risk of the network and its value is included in the second level as a constraint. The second level solves the model to specify the extent of Hazmat transportation from each distribution center to the destinations and to locate the distribution centers among the candidate sites. For validating the proposed model, the northwest part of Iran has been selected as case study and results have been analyzed. Results revealed that while risk tolerance is increased, the proposed model is capable to find better routes over the network. For the future studies, it is recommended to work more on considering time value of money during different combinations of periods while they are assumed as variables.

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