Developing a risk covering based model for locating rescue and relief centers in hazardous materials transportation (An empirical study: Guilan province of Iran)

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Abstract

Although hazardous materials (Hazmat) transportation plays an important role in the economy, it has always raised authorities' concerns on the potential risks to humans and the environment. A Hazmat accident may impact serious damage to the people within the scope of the incident so in the areas where special relief centers do not exist, Hazmat accidents may be more severe. In the present research work, a mathematical model for locating the relief and rescue centers has been developed in which the network risk coverage is maximized. A procedure has been developed to determine the optimum sites for constructing special relief and rescue centers based on Hazmat transport risk. In order to validate the proposed model, an experimental intercity road network including 46 nodes and 126 two-way edges (252 edges) in the Iranian northern province of Guilan has been selected as the case study. The results revealed that solving locating problems in terms of risk coverage and distance coverage have different results on location, so local or national authorities who are dealing with Hazmat transport planning should be aware on attributes considered for locating rescue and relief centers.

Keywords: Hazardous Materials, Routing-Locating Problem, Transportation Risk, Set Covering Problem

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 to 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

Since 1980, a number of experts and researchers' studies have been focused on Hazmat transportation and several techniques have been presented to design transportation routes in terms of transport costs and risks. While single objective models use the shortest path algorithm, multi-objective models combine attributes to a utility function and solve the problem in the same way that used for single objective function (Verter& Kara, 2001).
Researches on this subject mainly focuses on two major problems in transportation problem that includes: the risk assessment of Hazmat transit by the road system, and the identification of a route to minimizing the transportation risk (Fanti et al., 2015) The main issue is the routing that ought to be considered in the requirements 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 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 a 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. Set Covering Problem

The set covering problem (SCP) is a classical combinatorial optimization problem (Garey& Johnson, 1979). It has been shown to be strongly NP-hard (Gao et al., 2015), also difficult in terms of theoretical approximations (Lund & Yannakakis 1994). This is a combinatorial optimization problem with many usages that is central in a type of routing, location and scheduling in railways to the job assignment problem in manufacturing and service location, truck routing and line balancing. (Bautista &Pereira 2006 and Garey&Johnson1979).In addition, many industrial engineering problems have been modeled as SCP; examples of such problems include the facility location problem (Vasko& Wilson, 1984.), steel production (Vasko et al., 1987), ship scheduling (Fisher& Rosenwein, 1989), vehicle routing problem (Foster&Ryan, 1976), and most recent multi-depot train driver scheduling (Yaghiniet al. , 2015). It is about choosing a subset of columns that have the least sum of costs to cover a set of rows. Church and ReVelle are introduced the maximum covering location problem (MCLP) (Church &ReVelle, 1974), the aim of that is to locate a number of facilities such that the demand of customers undercover is maximized. As a result, at least one of the facilities covered a customer, if the customer is posited in a specific distance from facilities. In the context of networks, almost all models assume that demand only happens at nodes. While this assumption is reasonable for several applications, for others the demand is rather distributed along the edges and should be treated as such (Li et al., 2011). One of the best-known problems of the covering problem is the set covering location problem (SCLP) in which one must choose a minimum cost set of facilities so that every demand point is covered at least once. The drawback of the SCLP is that it often leads to costly or unrealistic solutions because it gives the same importance to every demand point, regardless of its position and size. To overcome this weakness, two main variants have been studied in the location theory, literature one of them is the maximal covering location problem (MCLP) requires choosing a subset of facilities that maximize the demand covered while respecting a budget constraint on the cost of the facilities; and the other one is the partial set covering location problem (PSCLP) minimizes the cost of the open facilities while forcing a certain amount of demand to be covered. The MCLP is often defined as the problem of maximizing demand coverage with a fixed number of facilities. Location problems with covering objectives or constraints are commonplace in the service sector (schools, hospitals, libraries, restaurants, retail outlets, bank branches) as well as in the location of emergency facilities or vehicles (fire stations, ambulances, oil spill equipment's (Farahaniet al., 2012). Oded Berman et al. presented a mathematical model that considers two covering location problems on a network where the demand is distributed along the edges. The first is the classical maximal covering location problem. The second problem is the obnoxious version where the coverage should be minimized subject to some distance constraints between the facilities. It is first shown that the finite dominating set for covering problems with nodal demand does not carry over to the case of edge-based demands. Then, a solution approach to the single facility problem is presented. Afterward, the multi-facility problem is discussed and several results for tree networks are presented for the case that the demand is constant on each edge (Berman et al., 2016). José and César introduce a number of normalizations rules and demonstrate the superiority of the classical Chvátal rule, especially when solving large scale and real-world instances. Directions for new advances on the creation of more elaborate normalization rules for surrogate heuristics are also provided (Ablanedo-Rosas & Rego, 2010). Chao et al. propose a new row weighting local search (RWLS) algorithm for solving the uni-cast variant of the SCP, i.e., USCPs where the costs of all sets are identical. RWLS is a heuristic algorithm that has three major components united in its local search framework: (1) a weighting scheme, which updates the weights of uncovered elements to prevent convergence to local optima, (2) Tabu strategies to avoid possible cycles during the search, and (3) a timestamp method to break ties when prioritizing sets. RWLS has been evaluated on a large number of problem instances from the OR-Library and compared with other approaches (Gao et al., 2015).

1.6. Vision

The first step of the procedure to determine the optimum site locations for the construction of relief and rescue centers in Hazmat transportation is the existing routes over the network. Two important factors influencing the development of the model and the solution are increasing the edge coverage by considering the risk and the length of the edges. In fact, the length of the link is considered as a parameter of cost. The length of all routes considered as transport costs has been defined as objective function as well as a maximum range of distance and maximum range of coverage are defined as main constraints. The main procedure on locating rescue and relief centers is to maximize the risk associated to the intercity network while the maximum distance and coverage for centers are also considered as constraints. In this case, the model focuses on risk coverage instead of cost or traveled distance mainly used as an attribute over emergency response location problems.

2. Mathematical Modeling

The road network is composed of some nodes and the edges that connect nodes. Three types of nodes are defined in the network, including origin, destination, and connective nodes. In intercity road networks, the edges are mainly defined as two-way roads. To locating relief centers from among the candidate centers, candidate center with maximum coverage of communication routes will be selected as relief centers, so that each route can be covered by a relief center to cover more routes of the network. According to the definition of the problem and the purpose of the mathematical model, an important factor influencing the development of the model is to increase the coverage of the edges by simultaneously considering the risk and the length of the routes as transport cost. The formulation is closely similar to the classic set-covering model with additional constraints. The main view of this study is to limit the centers that each route can cover by a relief center, for the most coverage on the network. In order to minimize the number of relief centers that cover one or more links in the network, a minimum objective function is formulated which determines that each route can only be covered by a relief center, then the whole network is examined. It determines which routes are covered by each relief center in order to have the most coverage alongside the relief centers. Thus, the objective function of the model is formulated by Equation (1) where i represents the start node of link i= (1, 2, 3, . . ., m), j denotes the end nodes of link j= (1, 2, 3, . . ., m), Rij represents the risk of link (i, j), Lij represent the length of each link (i, j). Z denotes transport cost when the maximum coverage of the network occurred by relief centers, and G represents the network or graph and the considered two-way paths (i, j), (j, i) ∈ G, k represents the number of candidate center for relief center and Yijk is a binary variable assigned by 1 if candidate node k covers the link (i, j), otherwise 0. Linearization technique should be also applied here because the equation (1) is nonlinear. Equation (2) satisfies the above consideration where S_{ij} is obtained by the model. In this case, the objective function and corresponding constraints are changed to equations (3), (4) and (5).

$$Max\ Z = \sum_{(i,j)\in G} R_{ij} \times L_{ij} \times Min\ (1, \sum_{k\in K} Y_{ijk}) \tag{1}$$

$$S_{ij} = Min(1, \sum_{k\in K} Y_{ijk}) \tag{2}$$

$$Max\ Z = \sum_{(i,j)\in G} R_{ij} \times L_{ij} \times S_{ij} \tag{3}$$

s.t:

$$S_{ij} \leq \sum_{k\in K} Y_{ijk} \tag{4}$$

$$S_{ij} \leq 1 \tag{5}$$

Equations (6) and (7) respectively ensure that the start and end nodes of the link (i, j) are covered if and only if one or more facilities are placed inside the standard limited coverage length. Where, Nik represents the standard amount of distance between node i and k which k can cover the start node of link (i, j), X_{ik}^{S} is a binary variable, 1 if the start node of link (i, j) covered by candidate center of k, otherwise 0, M_{jk} represents the quantity of distance between node j and k that end node of link(i, j) can cover with candidate center of k, $X_{jk}^{E}$is a binary variable, 1 if the end node of link (i, j) covered by candidate center of k, otherwise 0. As above mentioned, a relief center covers link while, always the start and the end of that link is covered by the same relief center, equation (8) represents that. Equation (9) also implies that even if the start node or the end node of the link does not cover via the candidate relief center, it follows that the link cannot be covered by the relief center.

$$X_{ik}^{S} \leq N_{ik} \qquad \forall\ (i,k) \tag{6}$$

$$X_{jk}^{E} \leq M_{jk} \qquad \forall\ (j,k) \tag{7}$$

$$2Y_{ijk} + 1 \geq X_{ik}^{S} + X_{jk}^{E} \qquad \forall\ (i,j,k) \tag{8}$$

$$2\left(Y_{ijk} - 1\right) < X_{ik}^{S} + X_{jk}^{E} \qquad \forall (i,j,k) \tag{9}$$

In order to cover the link by a relief center, in addition to equation (9), another limitation is also required to show that if the relief center covered both start and end nodes, then each candidate center that can cover the start or end node of the link, the total route distance that can cover. Equation (10) shows this limitation where L_{ij} represents the length of the link (i, j), U is a scalar and shows the maximum length which is allowed for the length of the route is covered by relief center. Equation (11) indicates that at least one node of the candidate nodes should be selected as the center of relief. Where p_k is a binary variable, 1 if the relief center is located at candidate center k., otherwise 0. Equation (12) respects that the quantities of relief center should always be equal to or smaller than the number of relief center is considered from the candidate node. Where represents the number of candidate center can be selected at most.

$$\sum_{(i,j)} Y_{ijk} \times L_{ij} \leq U \tag{10}$$

$$P_k \leq Y_{ijk} \tag{11}$$

$$\sum_{k} P_k \leq w \tag{12}$$

3. Experimental Studies

Since the present study focused on locating and constructing relief centers, validation is required. The road network of the Guilan province of Iran has been selected as the case study. The network, which is shown in figure 1, has 49 nodes and 126 links (63 two-way link), which 12 nodes have been selected among the nodes and nominated as candidates including Amlash, Astara, Astaneh, Bandar-e Anzali, Chaboksar, Rasht, Rudbar, Shaft, Sowme'eh Sara, Kiashahr, Langarud, and Masal. The risk and the length of each route were specified according to the selected model. The maximum coverage of the routes via the relief centers is considered to solve the model using the well-known software of General Algebraic Modeling System, (GAMS) and results tabulated in table 1, where U is the maximum range for coverage via a relief center, N_{ik} is the maximum range of distance between the relief center and start node of the link and M_{jk} is the maximum range of distance between the relief center and end node of the link. The first column is the selected relief centers. Each route should be covered by a relief center, the second column shows the routes covered by a relief center. Each route has a start node and an end node, the second column shows the start and end nodes of each route that covered via the relief center. The third column shows the length of each route, which considered as a parameter in the model. There is a condition for a covered route from relief center, that is the maximum range for the distance between the selected relief centers and start and end node of is shown in the fourth column of the table, last but not least is the fourth depicts the total amount of routes covered by each relief center. For example, the first row means Bandar-e Anzali relief center should be cover the route from Bazar Jomeh and Rezvanshahr. The distance from Bandar Anzali to Kiashahr is 17 Km. Moreover, the distance between Bandar Anzali relief center and Bazar Jomeh is 49 Km, in addition, the distance between Bandar Anzali relief center and Rezvanshahr is 32 Km which are under the Maximum range of range distance between relief center and start and end node of the route. Bandar Anzali relief center covers the other routes include Bandar-e Anzali and Khomam, Bandar-e Anzali and Kiashahr, Bandar-e Anzali and Rezvanshahr, and Khoshk-e Bijar and Khomam. The number which is next to the end node of the route is the length of the route can cover by relief center. Eventually, the total length of coverage of Bandar Anzali relief center is 130 Km that is fewer as the Maximum range of coverage. In order to make a sensitivity analysis, a global sensitivity analysis has also been made for the proposed model and results are tabulated in table 2.

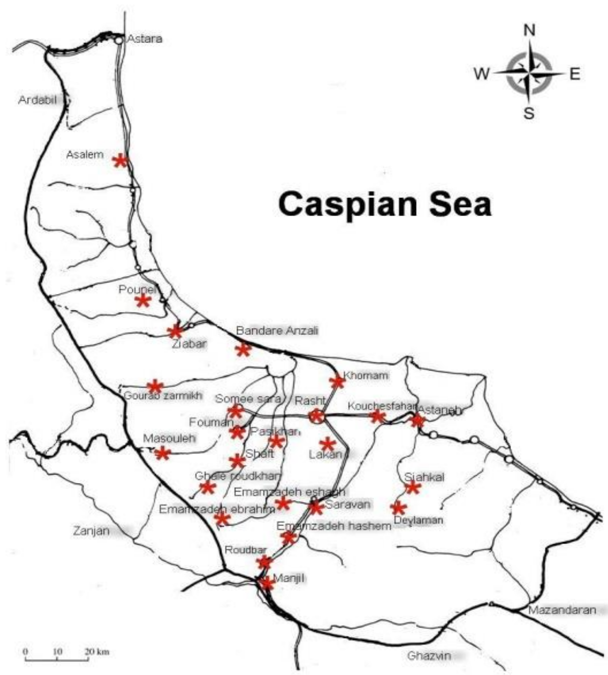

Figure 1: Guilan intercity road network map

Table 1. Model's results assuming U=150 Km and N_{ik}=M_{jk} =50 Km (Dimension: Kilometer)

Relief center	(Start, End) nodes	Rout Length	Distance from relief center (Start, End) nodes	Center Coverage
Bandar Anzali	(Bazar Jomeh, Rezvanshahr)	17	(49, 32)	130
	(Bandar-e Anzali, Khomam)	24	(0, 24)	
	(Bandar-e Anzali, Kiashahr)	46	(0, 46)	
	(Bandar-e Anzali, Rezvanshahr)	32	(0, 32)	
	(Khoshk-e Bijar, Khomam)	11	(35, 24	
Rasht	(Astaneh, Lasht-e Nesha)	13	(32, 29)	130
	(Khoshk-e Bijar, Lasht-e Nesha)	9	(26, 29)	
	(Khoshk-e Bijar, Kuchesfahan)	15	(26, 17)	
	(Rasht, Kuchesfahan)	17	(0, 17)	
	(Rasht, Shaft)	25	(0, 25)	
	(Rasht, Marjaghal)	24	(0, 24)	
	(Kuchesfahan, Lasht-e Nesha)	12	(17, 29)	
	(Lasht-e Nesha, Kiashahr)	15	(44, 29)	
Astaneh	(Amlash, Otaqvar)	2	(41, 43)	141
	(Amlash, Kumeleh)	10	(41, 31)	
	(Astaneh, Lahijan)	11	(0, 11)	
	(Astaneh, Siahkal)	18	(0, 18)	
	(Astaneh, Kiashahr)	18	(0, 18)	
	(Astaneh, Kuchesfahan)	15	(0, 15)	
	(Rudboneh, Lahijan)	6	(17, 11)	
	(Rudsar, Shalman)	7	(39, 32)	
	(Sangar, Siahkal)	24	(27, 18)	
	(Siahkal, Lahijan)	17	(18, 11)	
	(Shalman, Langarud)	7	(32, 25)	
	(Kumeleh, Langarud)	6	(31, 25)	
Rudbar	(Tutkabon, Rostamabad)	2	(20, 18)	49
	(Rostamabad, Rudbar)	18	(18, 0)	
	(Rudbar, Manjil)	10	(0, 10)	
	(Lowshan, Manjil)	19	(29, 29)	
Shaft	(Ahmadsargurab, shaft)	5	(5, 0)	110
	(Ahmadsargurab,Fuman)	17	(5, 13)	
	(Khomam, Rasht)	15	(40, 25)	
	(Khomam, Marjaghal)	39	(40, 19)	
	(Rasht, Sangar)	12	(25, 37)	
	(Sangar, Kuchesfahan)	12	(37, 42)	
	(Sowme'eh Sara, Marjaghal)	10	(24, 19)	
Langarud	(Otaqvar,Rankuh)	11	(18, 29)	118
	(Chaboksar,Kelachay)	22	(49, 27)	
	(Rankuh,Rahimabad)	5	(29, 34)	
	(Rahimabad,Kelachay)	10	(34, 27)	
	(Kelachay, Rudsar)	13	(27, 14)	
	(Kiashahr, Langarud)	43	(43, 0)	
	(Lahijan, Langarud)	14	(14, 0)	
Masal	(Bazar Jomeh, Masal)	5	(5, 0)	115
	(Pareh Sar, Rezvanshahr)	18	(40, 22)	
	(Shaft, Fuman)	13	(45, 32)	
	(Sowme'eh Sara, Fuman)	11	(21, 32)	
	(Sowme'eh Sara, Masal)	21	(21, 0)	
	(Fuman, GurabZarmikh)	19	(32, 22)	
	(Fuman, Marjaghal)	6	(32, 31)	
	(GurabZarmikh, Masal)	22	(2, 0)	
Astara	(Astara, Lavandevil)	13	(0, 13)	31
	(Haviq, Lavandevil)	18	(31, 13)	

Considering four values for the maximum range of coverage include: 120, 150, 200 and 250 Km, also four different maximum ranges of distance including 40, 50, 60 and 70 Km, in addition, three numbers for relief center include, 3, 5 and 8. The model has been evaluated by sensitivity analysis at different conditions and the results tabulated in table 2. Drawing a chart can help us to conclude what the best result is. In order to draw a chart, different scales of Maximum distance and maximum length of coverage have been considered. So, the total amount of coverage is now investigated and depicted in figure 2.

Table 2. Total coverage of relief centers on the network (Unit: Kilometer)

Number of relief center	Allowed Coverage	Max distance allowed from Start and End nodes to Relief center			
		40	50	60	70
5	120	429	592	589	594
	150	628	714	719	721
	200	684	771	925	914
	250	683	819	898	967
8	120	769	779	898	958
	150	747	824	956	1014
	200	797	850	956	1014
	250	797	850	956	1072
10	120	784	820	991	1044
	150	899	833	1023	1014
	200	797	1098	956	1172
	250	797	850	124	1072

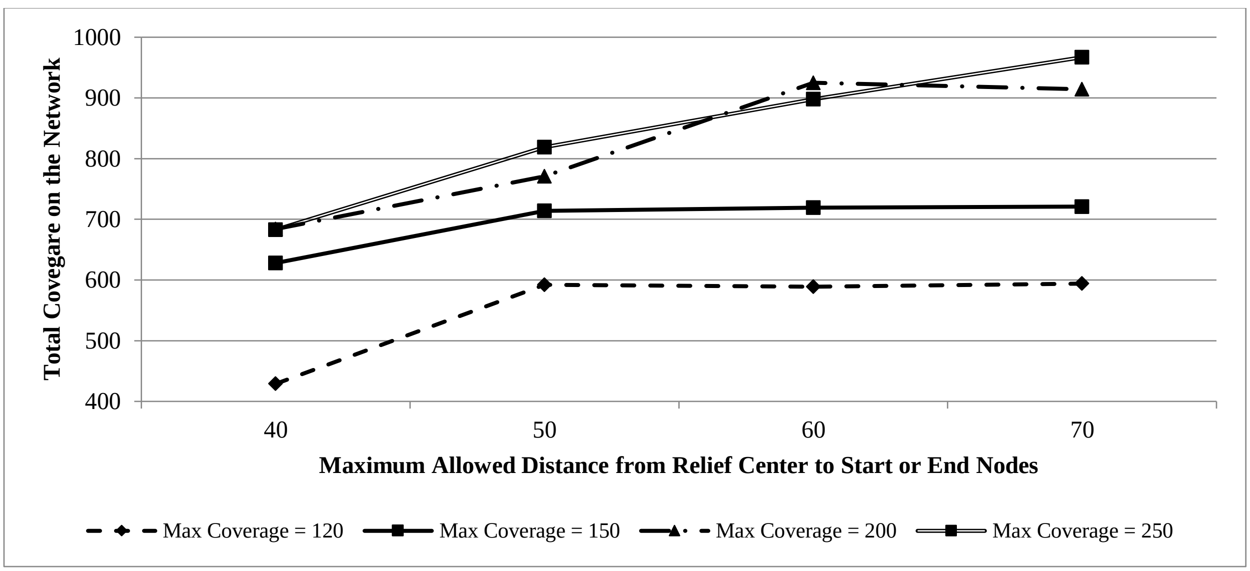

Figure 2. Total length of coverage assuming five relief centers

4. Summary and Conclusion

In this research work, locating relief centers in hazardous materials transportation has been mathematically developed inside a procedure which determines the location for relief centers by maximum coverage of the routes. The model has been run using experimental data over a case study network in the Guilan intercity roads of Iran. After running the models in locating the problem of Hazmat transportation and maximum coverage, the obtained results revealed that by increasing the range of coverage, the total amount of coverage approaches each other, where they actually have been reached almost the same value. Also, increasing the maximum distance has the same trend as increasing maximum coverage. Conclusion insures local or national authorities, who are dealing with locating relief center for transportation of hazardous material, that this model is a good technique to determine the location of relief center so that has maximum coverage over the network.

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