Journal of Industrial and Systems Engineering
Vol. 9, No. 4, pp 47-64
Autumn (November) 2016

Design of 7×24 logistics system for hazardous materials (case study: distribution of gasoline)

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Abstract
The transportation of hazardous materials such as gasoline has unique features due the nature of these types of materials and the important role of these materials in human life. Therefore, determining the routing of these materials is more challengeable than non-hazardous one, due to more dangerous and risky conditions besides the transportation costs. Since the distribution of gasoline take places in boarding (24 hours), logistics system should be able to meet these requirements in all of days. In this paper, a new model is developed for planning the route of vehicles as 7×24 (boarding) in order to minimize the risk of hazardous materials. The proposed vehicle routing model in this paper has been attempted to consider minimization of transportation costs, reduce emissions due to gasoline distribution, consumption, diminishing the route's risk and suggesting suitable time for servicing customers. The proposed model turns in to a single objective model using compromise programming and then solved by mathematical software using real data from our case study. Results are reported and analyzed.

Keywords: Hazardous, risk; 7×24 logistics system, compromise programming

1- Introduction

The logistics industry is based on an hourly retail basis, just in time requirements, home delivery. Therefore, increasing the transport vehicles cannot satisfy the customer's need in daily hours. Logistics and transportation systems should fulfill costumers in boarding. Such a system can be classified in 7×24 logistic system framework.

Gasoline, as a part of the urban cargo transport, should be moved to the terms of special measures. Today urban accidents has become as one of the main challenges and problems of transportation accidents occurring during the transportation of hazardous materials, has great potential to become a human tragedy. Abkowitz et al. (1992) illustrated that if you are looking to find only safe routes in the routing, the average costs will be twice than of the shortest paths. In this paper we discuss about gasoline transportation in urban routes with regard to boarding distribution.7×24 logistic systems.

A supportive concepts of 7×24 logistic systems for gasoline distribution in described in section 2. Section 3 represents investigated problem and mathematical modeling in the field. The solution method, case study and conclusions are stated in sections 3, 4 and 5 respectively.

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2- Literature review

The required concepts for 7×24 logistics in literature and each of them is briefly described.

2-1-The vehicle routing with time window

Polacek et al. (2004) have studied multiple storage vehicle routing problem with time windows and minimizing the traveling distance by all vehicles. Dondo and Cerdá (2007) have studied the routing problem of vehicles in order to minimize costs considering heterogeneous vehicles and having limited capacity and time. Polacek et al. (2008) are considered the capacity of vehicles in limited manner and allocation. In addition, a new algorithm has presented based on variable adaptive neighborhood search. Bettinelli et al. (2011) are taken into account the fixed costs for vehicle use and transportation vehicle in their model. Xu et al. (2012)carried out another study with assuming different vehicles and penalty for violation of maximum timing of work. They solved their model by using a new meta-heuristic algorithm based on variable neighborhood search. Afshar-Nadjafi and Afshar-Nadjafi (2014), are considered limited number of vehicles, hard time window and heterogeneous fleet.

2-2- Transportation of hazardous commodities

In all countries, the transportation of hazardous commodities has specific regulations and due to the safety of society, routes have some limitations. For example a predefined distance must be taken from crowded areas such as hospitals and schools. Tee Jun Fan et al. (2015) considered the issue of transportation of hazardous materials for urban areas. In this paper, in addition to the costs, risk is also considered such a way to calculate the rate of accidents on urban streets and in each district. Finally, a balance is established between risk and route cost. Fan et al. (2015) and Kang et al. (2014) have considered the hazardous materials routing problem by defining the value of risk. They stated initially the old ways of calculating risk in their article and then conducted a comparison of the value of their risk with similar works. In addition, a borderline have been designated for risk of their route thus total risk of selected years should not be more than a predefined value. Van Raemdonck et al. (2013) have been studied the risk analysis system for the transportation of hazardous materials to calculate the risk that can use two rates, namely the accident of transporter vehicle and transportation region. Ehsani Ali (2011) in addition of introducing scenarios with mathematical model tailored to each scenario, considered the effect of traffic policy in determining the capacity of different routes in routing of hazardous materials. In addition, Kara and Verter (2004) offered a two-level integer linear model with the aim of minimizing the total risk arisen from choosing the route and considering a variety of hazardous materials. This model with using of Karush-Kuhn-Tucker conditions, converts to a single goal mixed-integer programming model. Erkut and Gzara (2005) introduced a bi-level model like the model of Kara and Verter (2004). Zografos and Androutsopoulos (2004) introduced a heuristic algorithm to solve the problem of the distribution of hazardous materials. From their prospective, the routing of hazardous materials can be a bi-level model with the time window in which minimization of the risk and the cost is done together. Erkut and Alp (2007) investigated the design problem of hazardous material network with lowest risk as a problem in Steiner selection tree. Erkut and Gzara (2008) are introduced a model for transportation of hazardous materials in which, the network of routes determined by local state and transportation firms should select a best route in this network. They formulated the problem as bi-level network. Androutsopoulos and Zografos (2010) offered a model with routing criteria and timing in distribution of hazardous materials and proposed an algorithm for solving of bi-criteria proposed model. Pradhananga et al. (2010) introduced a meta-heuristic algorithm based on ant colony for optimizing hazardous materials transportation with time window. Their algorithm used similar routs idea. However, Clark and Besterfield-Sacre (2009) argue that, while in the previous studies the risk of a particular route was analyzed starting from methods based on operations research (multi-criteria analysis or multi-criteria routing models), there is only little or no focus on probabilistic or statistical approaches, in which historical accident data can be used (Erkut et al., 2007). Using this way, overall insecurities in risk assessment can be avoided (Fabiano et al., 2002) and the risk for double counting and rank reversal which occurs when using MCDA can be avoided (Carnets, 2008, Van Geirt and Nuyts, 2006). Additionally,Clark and Besterfield-Sacre (2009) mentioned that the use of a statistical analysis of historical data permits the ranking of the independent variables on the basis of their impact on the dependent variables. Abkowitz and Cheng (1988) also argue that, when the necessary data is available, it is less ambiguous to determine the risks of hazmat transport by means of this historical data and establish an adequate estimation of the probability of an incident to happen and the resulting consequences. Ardjmand et al. (2016) proposed a new stochastic model for transportation, location, and allocation of hazardous materials. The cost of transportation is considered to be of a stochastic nature. The objective function minimizes the total cost and risk of locating facilities and transportation of HAZMATs. Cordeiro et al. (2016) proposed a methodological framework for mapping the environmental risk of transporting hazardous materials by road. The multicriteria analysis employed proved to be feasible with regards to the selection and weighing the criteria by an expert panel, which can be applied for different locations.

Considering the time of transportation as a continuous parameter is an important contribution of this paper. This idea is used with regard to 7×24 logistic system. The demand must be modified in order to consider this continuous time. Also, with regard to reviewing the literature of vehicle routing discussion, we focused on limitation of vehicle numbers and times of using vehicles. Also, the heterogeneity of the vehicles is intended as differences in capacity in all papers that here heterogeneity of vehicle with regard to vehicle emissions and risk of accidents for each device is intended. Another point that has not been attentive by researchers in the literature is optimizing the efficiency of the vehicles. Various parameters are considered for risk in papers related to hazardous materials discussion that according to peer-reviewed papers, these points are considered as length route between two nodes, density of route crowding between two nodes and the neighborhood radius of route between two nodes from crowded places. Also, the route selection used in this paper is based on Baghalian et al. (2013).

3-Problem description

The 7×24 logistic system is based on a case study about gasoline distribution in Tehran oil district (Fig. **1**). Oil depots are located in four districts: north, south, east and west. After loading from the oil depots, trucks will be transferred toward the gas stations. The intended problem is modeled according to the National Iranian Oil Refining & Distribution Company is seeking to reduce their costs and also to satisfy all demands on time. But according to the importance of environmental issues in recent decades, the company is looking to reduce pollution from gasoline distribution. Furthermore, according to sensitivity of the country about air pollution and environmental contaminants, National Iranian Oil Refining & Distribution Company decided to consider the effects of environmental pollutants in their plans. Therefore, the company is looking for changing people demands’ toward gasoline which cause the reduction of the pollution rate. In this study, the departure time of vehicles from oil depot to gas stations in the allowed time window is considered to be continuous. On the other hand, due to the high demand of customers and shortage of capacity of the existing gas stations, new gas stations must be constructed in the best locations. Also, due to the difference in the four parameters of time, cost, risk and rate of contamination on routes between oil depots and gas stations, optimal route is selected with regard to the objective function of the model. Another point in this research is considering vehicle efficiency because of high vehicle’s cost.

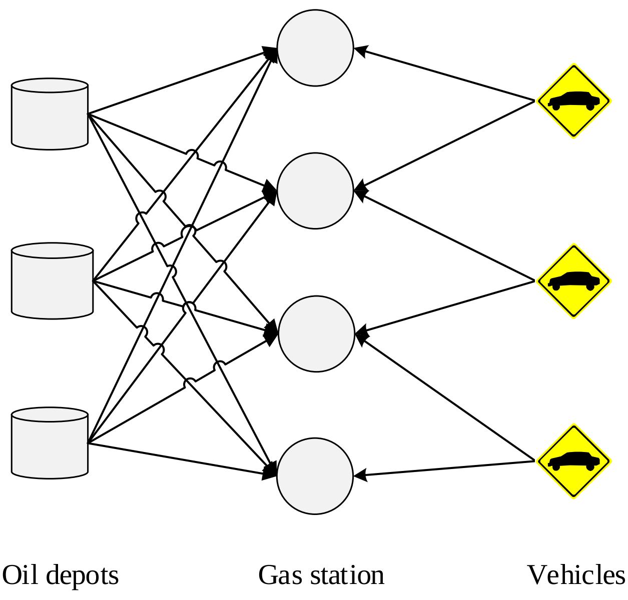

Fig. 1. The logistic network topology of intended problem

3-1-Assumptions

- The proposed model is multi-product and multi-period.
- Shortage is not allowed.
- Construction of new gas stations is allowed.
- Each vehicle may be used more than once.
- Different capacities and vehicles are used.
- The capacity of oil depots and gas stations are limited.
- An oil depot can be allocated several times in each period to one gas station.
- Each oil depot uses only one route to the gas station.
- Strategic, tactical and operational decisions are made simultaneously.
- A time period last for 7 days.
- A shift last for 8 hours.

3-2-Sets, parameters and decision variables

Sets, parameters and proposed model variables are as follows:

Sets:

I : set of oil depots indexed by *i*

L: set of gas stations (including j: available collection of gas stations and j': new collection of gas stations) indexed by *l*

R: set of routes between oil depots and gas stationindexed by *r*

K : set of vehicle indexed by *k*

S: set of shift by *s*

P: set of products indexed by *p*

F: set of repeated use of vehicles indexed by *f*

T: set of time periods indexed by *t*

Parameters:

De_{jpt} : Demand of gas station *j* for commodity type *p* in period *t*

cap_{ip} : Capacity of oil depot *i* for commodity type *p*

$ccap_{lp}$: Capacity of gas station *l* for commodity type *p*

c_{ilr} : Cost of transportation of route *r* between gas station *l* and oil depot *i*

t_{ilrs} : Time of transportation from route r between gas station *l* and oil depot *i* in shift *s*

ri_{ilrs} : Transportation risk of route *r* between gas station *l* and oil depot *i* in shift *s*

$\overline{ri}_k$: Risk of vehicle type *k*

por_{ilr} : Pollution of transportation from route *r* between gas station *l* and oil depot *i*

$o_{j'}$: Cost of open gas station j'

cin_{lp} : Holding cost of gasoline type *p* in gas station *l*

$roa_{jj'p}$: Attraction rate for gasoline type *p* from available gas station *j* to opened gas station j'

roc_{lspt} : Consumption rate of type *p* in shift *s* of period *t* in every hour (the whole of consumptions rate during shifts is equal to total demand)

ea_{lspt} : The earliest delivery time in each shift for gasoline type *p* in period *t*

la_{lspt} : The latest delivery time in each shift for gasoline type *p* in period *t*

ca_k : Vehicle capacity

pov_k : The pollution vehicles

ftv_k : The cost of machine breakdown

le : Duration of the period of change in demand

pop_p : Pollution rate of gasoline type *p*

$cadv_q$: The cost of advertising by company to change public demand from normal gasoline to high quality gasoline type $q \in p$

rom_q : The rate of changing demand from normal gasoline type $q \in p$ in any advertise

lo_k : Time of vehicle loading *k*

ulo_k : Time of vehicle discharge *k*

$time$: Time allowed to using vehicle

Decision variables

$ot_{ilkspft}$: The starting time of vehicle *k* from oil depot *i* toward gas station *l* in shift *s* in period *t* for transportation commodity type *p* for frequency *f*th

$w_{ilkrspft}$: A binary variable equal 1 if vehicle *k* from oil depot *i* is assigned to gas station *l* in order to transporting commodity type *p* with route *r* in shift *s* and period *t* for frequency *f* th; 0, otherwise.

in_{lsp} :	determining optimal inventory for commodity type *p* in shift *s* on gas station *l*
$z_{j'}$:	A binary variable equal 1 if new gas station open in location *j*; 0, otherwise.
tv_{kft} :	Duration of using vehicle *k* in frequency *f* and period *t*
adv_q :	Number of advertising for changing people demand from normal gasoline to high quality type *q*
Dem_{lpt} :	Demand for product type *p* in gas station after opening gas station *j* in period *t*
D'_{lpt} :	Demand for product type *p* after advertising in gas station *l* in period *t*
x_{kft} :	Auxiliary variable

4-Mathematical modeling

According to the symbols presented in the previous section, mathematical model for designing 7×24 logistic system is as follow:

$$\min\ F1 = \sum_i \sum_l \sum_k \sum_r \sum_s \sum_p \sum_f \sum_t w_{ilkrspft} c_{ilr} + \sum_{j'} z_{j'} o_{j'} + \sum_l \sum_s \sum_p in_{lsp} cin_{lp} + \sum_k \sum_f \sum_t \left(time - tv_{kft}\right) ftv_k + \sum_q adv_q \times cadv_q \qquad (1)$$

$$\min\ F2 = \sum_i \sum_l \sum_k \sum_r \sum_s \sum_p \sum_f \sum_t w_{ilkrspft} \left(ri_{ilrs} + \overline{ri}_k\right) \qquad (2)$$

$$\min\ F3 = \sum_i \sum_l \sum_k \sum_r \sum_s \sum_p \sum_f \sum_t w_{ilkrspft} \left(por_{ilr} + pov_k\right) + \sum_l \sum_p \sum_t pop_p D'_{lpt} \qquad (3)$$

st:

$$\sum_l \sum_k \sum_r \sum_s \sum_f \sum_t ca_k w_{ilkrspft} \le cap_{ip} \qquad \forall\, i, p \qquad (4)$$

$$\sum_i \sum_l \sum_r \sum_s \sum_p w_{ilkrspft} \le 1 \qquad \forall k, f, t \qquad (5)$$

$$ea_{jspt} \le ot_{ijkspft} + \left(t_{ijrs} + lo_k + ulo_k\right) w_{ijkrspft} \le la_{jspt} \qquad \forall i, j, r, k, s, p, f, t$$

$$ea_{j'spt} z_{j'} \le ot_{ij'kspft} + \left(t_{ilrs} + lo_k + ulo_k\right) w_{ij'krspft} \le la_{lspt} z_{j'} \qquad \forall i, j', r, k, s, p, f, \qquad (6)$$

$$\sum_i \sum_k \sum_r \sum_s \sum_p \sum_f w_{ij'krspft} \le z_{j'} \qquad \forall\, j', t \qquad (7)$$

$$\sum_i \sum_k \sum_r \sum_s \sum_f ca_k w_{ilkrspft} + \sum_s in_{lsp} \ge D_{lpt} \qquad \forall\, l, p, t \qquad (8)$$

$$tv_{kft} = \sum_i \sum_l \sum_r \sum_s \sum_p \left(2t_{ilrs} + lo_k + ulo_k\right) w_{ilkrspft} \qquad \forall k, f, t \qquad (9)$$

$$\sum_f tv_{kft} \le time \qquad \forall k, t \qquad (10)$$

$$x_{kft} \ge w_{ilkrspft} \qquad \forall i, l, r, k, s, p, f, t \qquad (11)$$

$$x_{kft} \geq x_{k(f+1)t} \qquad \forall k, f, t$$

$$\sum_i \sum_s \sum_l \sum_p ot_{ilksp(f+1)t} \geq \sum_i \sum_s \sum_l \sum_p ot_{ilkspft} + tv_{kft} \qquad \forall k, f, t \qquad (12)$$

$$in_{lsp} = in_{ls-1p} + \sum_i \sum_k \sum_r \sum_f ca_k w_{ilkrspft} - le \times roc_{lspt} \times D'_{lpt} \qquad \forall l, s, p, t \qquad (13)$$

$$\sum_s in_{j'sp} \leq ccap_{j'p} z_{j'} \qquad \forall j', p, t$$

$$\sum_s in_{jsp} \leq ccap_{jp} \qquad \forall j, p, t \qquad (14)$$

$$D'_{lqt} = rom_q adv_q + Dem_{lqt} \qquad \forall l, q, t$$

$$D'_{lpt} = Dem_{lpt} - \sum_q rom_q adv_q \qquad \forall l, t \qquad (15)$$

$$Dem_{j'pt} = \sum_j roa_{jj'p} z_{j'} \qquad \forall j', p, t$$

$$Dem_{jpt} = De_{jpt} - \sum_{j'} roa_{jj'p} z_{j'} \qquad \forall j, p, t \qquad (16)$$

$$ot_{ilkspft} \leq la_{lsp} w_{ilkrspft} \qquad \forall i, l, k, r, s, p, f \qquad (17)$$

$$w_{ilkrspft}, z_i, x_{kft} \in \{0,1\} \qquad (18)$$

$$Dem_{lpt}, D'_{lpt}, in_{lsp}, ot_{ilkspft}, tv_{kft} \geq 0 \qquad \forall i, j, k, l, r, p, t, s$$

$$adv_q \in \infty \qquad (19)$$

Equation (1) shows the minimizing the costs that include fixed costs of opening, transportation costs, holding costs in gas stations, penalty of vehicle idle time and advertise cost for changing demand from normal gasoline to high quality and cleaner one. Equation (2) maximizes the risk of selected routes. The value of environmental emissions from gasoline variant, used vehicles and selected routes is minimized in equation(3). Oil depot capacity for any type of gasoline is showed in equation(4). Equation (5)guarantees that any vehicle is used at most once time in any iteration. Time window restriction is showed in equation(6). Equation (7) guarantees that an oil depot is allocated once to a new gas station, when that gas station is open. Equation(8) is for the demand satisfaction. The time of using the vehicle on one period is expressed in equation(9). The restriction of using vehicles has been showed in equation(10). Equation(11) is the constraint of iteration's predecessor. For example, a vehicle can be used in iteration 2 only when the same vehicle is used previously in iterstion1. Equation(12) shows that the starting time of vehicle in the next iteration must be greater than the total time of using the vehicle in the prior iteration. The amount of each type of gasoline at gas stations, in the periods that demand rate changes, is obtained by equation(13). Degree of gasoline storage capacity per gas station is expressed in equation(14). The amount of changing demand after advertising is showed in equation(15). The amount of demand after opening a new gas station is showed by equation(16). Equation(17) guarantees that a vehicle can be used if it has been assigned. Equations(18) and (19) define the eligible domains of the decisions variables.

4-1- Evaluation risk of routes

Risk is the primary factor that separates hazardous materials transportation issue than other transportation issues and is the most effective factor in routing of transportation hazardous materials. Transportation of hazardous materials is defined in the literature as the calculation of possibility and intensity of damage under unwanted events from hazardous material (Alp, 1995). In this paper, the calculated risk with regard to study of Chakrabarti and Parikh (2011) is as possibility coefficient of the occurrence of accidents on the route over the impact area. The volume of traffic in the case of risk occurrence depends on the following factors: the length of each route, accident rate on the route, degree of traffic and neighborhood radius of route from populated places as hospital and school and etc. with regards to parameters of equation(20), one can calculate the risk on routes. In this equation p_{ij} is the possibility of risk's occurrence. The key point is that each stated route in main risk model is obtained as follows:

l_{ij}: route length between two nodes i and j

p_{ij}: accident rate on the route between two nodes i and j

pop_{ij}: the traffic volume of route between two nodes i and j

k: neighborhood radius of route between two nodes i and j from populated places

R_{ij}: the risk of route between two nodes i and j

$$R_{ij} = l_{ij} \times p_{ij} \times pop_{ij} \times \pi k^2 \tag{20}$$

4-2- Solution method

The Three -objective model presented in Section 4 can be transformed into a single-objective model using the co-called compromise programming method.

4-2-1- Conversion to a single-objective model

Various methods exist for converting multi-objective programming to a single- objective one. For example consider goal programming (Jolai and Aghdaghi, 2008, Makui et al., 2008) and compromise programming. In this paper compromise programming is used for converting the multi-objective problem to single- objective one. To address the multiple aspects of hazardous materials route planning, it is necessary to treat it as a multi-objective optimization problem (MOP) that searches for one or a set of ''compromise'' solutions rendering the best possible trade-offs among different objectives (Li and Leung, 2011). In this study, compromise programming, an MOP approach is employed to search for the optimal routes for transporting hazardous materials. The main idea of current method is minimization of the distance between the ideal solutions and expected solutions. To use this model., first the nadir and ideal value is achieved for every objective function (Zeleny and Cochrane, 1973).The best value is achieved through optimizing model along each of the objective functions regardless of other functions and nadir value is achieved through optimizing in the opposite direction of any objective function. To achieve the nadir value of any objective function, the value of two objective functions is calculated after obtaining the ideal solution for any objective function along the model and then, the nadir value is calculated for each function. The following equations show how to implement the calculations. If objective functions on the proposed model are Z_1, Z_2, Z_3, their nadir and ideal value are $Z_1^{ideal}, Z_2^{ideal}, Z_3^{ideal}$, $Z_1^{nadir}, Z_2^{nadir}, Z_3^{nadir}$ and also Z_{pq} is stating the value of q objective function on the basis of *p* objective function, we will have:

$$\begin{cases} Z_1^{ideal} = Min\, Z_1 \Rightarrow Z_{21,} Z_{31} \\ Z_2^{ideal} = Min\, Z_2 \Rightarrow Z_{12,} Z_{32} \\ Z_3^{ideal} = Min\, Z_3 \Rightarrow Z_{13} Z_{23} \end{cases} \Rightarrow \begin{cases} Z_1^{nadir} = Max\left(Z_{12}, Z_{13}\right) \\ Z_2^{nadir} = Max\left(Z_{21}, Z_{23}\right) \\ Z_3^{nadir} = Max\left(Z_{31}, Z_{32}\right) \end{cases} \tag{21}$$

The difference value of each objective function from their ideal solution in one objective function is minimized after determining the above solutions. The following function can convert the model from multi objective to single objective in which Z_{Sobj} and w_i are the value of single-object of objective function and the weight of any objective function, respectively.

$$Z_{Sobj} = w_1 \frac{Z_1 - Z_1^{ideal}}{Z_1^{nadir} - Z_1^{ideal}} + w_2 \frac{Z_2 - Z_2^{ideal}}{Z_2^{nadir} - Z_2^{ideal}} + w_3 \frac{Z_3 - Z_3^{ideal}}{Z_3^{nadir} - Z_3^{ideal}} \tag{22}$$

5- Computational Results and case study

In this section in order to evaluate the efficiency of the proposed model, we used the data extracted from the case of National Iranian Oil Refining & Distribution Company. National Iranian Oil Refining & Distribution Company in the Tehran area has four oil storage facilities in the regions of North, South, East and West of Tehran and these facilities can satisfy demand of gas stations. The factors such as increasing demand rate from costumers, high cost of energy carriers for material transportation and the importance of the timely arrival of vehicles to gas stations caused that the company planned a program to distribution of gasoline to gas stations in order to decreasing the cost of gasoline and give the gasoline in timely manner to gas station and replenishment is performed without delay. The main point that in this case study must considers, is accepting the limitations and objective function related to hazardous materials that includes risk objective function that should added to7×24 logistic. Furthermore, the reason that using the route selection method instead of routing is related to current restrictions for gasoline distribution. The reported result gained for the GAP of 0% and all the result are exact in an appropriate time.

The primary structure of supply chain network including nodes related to oil depots and gas stations are shown in Fig. **2**. To solve the presented model, mathematical software is used.

Fig. 2.illustration of nodes of studied supply chain network

5-1- Verification of model

The presented model in this section is solved in small dimension by using random data in order to consider verification of the model. Given that the proposed model has three objective functions, the following table shows that the objective functions are in conflict with each other. These numbers are solved with solving one problem in dimensions of $|L|=8$, $|J|=4$, $|j'|=4$, $|K|=8$, $|P|=4$, $|S|=4$, $|R|=4$, $|F|=4$, $|I|=4$, $|T|=4$. As can be seen in Table 1, the weight of one of the three objective functions and the weights of another objective functions is changed in the example in such a way that the weight of one function remains greater than the others. The obtained objective function values indicate that there is a contradiction between the objective functions in such a way that weight gain in each objective function causes improvement of the same objective function and deterioration of another objective functions.

Also, to ensure the validity and accuracy of the model, the analysis has been done on the parameter of holding costs. As we expected, total rate of held stock in all periods of changing demand rate is decreased with increasing of holding cost of each depot which is the signal of validation of model execution trend. The results are shown in Table 2.

Table 1.The comparison of various functions with different weights

Test number	Weight			Objective function			Single-objective function
	W1	W2	W3	Min Z1	Min Z2	Min Z3	
1	5	35	60	112912100	99240	23727790	2795210
2	35	25	40	110164000	99716	29000670	1110560
3	35	40	25	108543100	71200	24255400	2874193
4	35	5	60	110660600	137796	23992380	1789196
5	25	65	10	97554621	67581	18903993	1133750

Table 2. The impact of increased Holding costs on the model

Holding cost for a liter of gasoline		The amount of goods stored at the end of each shift				Total stored stock (liter)
		1	2	3	4	
1	30	98.74	88.78	98.76	69.642	355.917
2	33	98.53	76.17	74.34	96.614	345.644
3	36	77.68	64.61	86.22	97.431	325.938
4	39	66.62	73.54	76.6	85.711	302.462
5	42	81.54	67.28	82.47	54.386	285.674
6	45	73.47	32.19	58.39	97.241	261.287
7	48	39.39	82.11	94.18	26.06	241.735

5-2- Numerical results of case study

Now, we can solve the case study for regular and super gasoline data introduced in Table 3 and Table **4**. The results are shown in **Error! Reference source not found.**.

Table 3. Data about holding capacity of regular gasoline and super gasoline in gas stations

Tehran gas stations	Holding capacity for regular gasoline (liter)	Holding capacity for super gasoline (liter)	Demand rate for regular gasoline(liter)	Demand rate for super gasoline(liter)
gas station (1)	8000	20000	0	0
gas station (2)	75000	25000	65000	15000
gas station (3)	80000	22000	0	0
gas station (4)	66000	24000	54000	18000
gas station (5)	70000	18000	0	0
gas station (6)	75000	26000	70000	20000
gas station (7)	80000	23000	0	0
gas station (8)	60000	19000	0	0
gas station (9)	70000	21000	60000	16000
gas station (10)	75000	25000	0	0

Table 4. Data related to fixed costs of opening and potential holding capacity of gas stations

Tehran gas station	Capacity (liter)	Opening fixed cost
Gas station (11)	75000	700000000
Gas station(12)	60000	700000000
Gas station(13)	68000	700000000
Gas station(14)	45000	700000000
Gas station(15)	50000	700000000

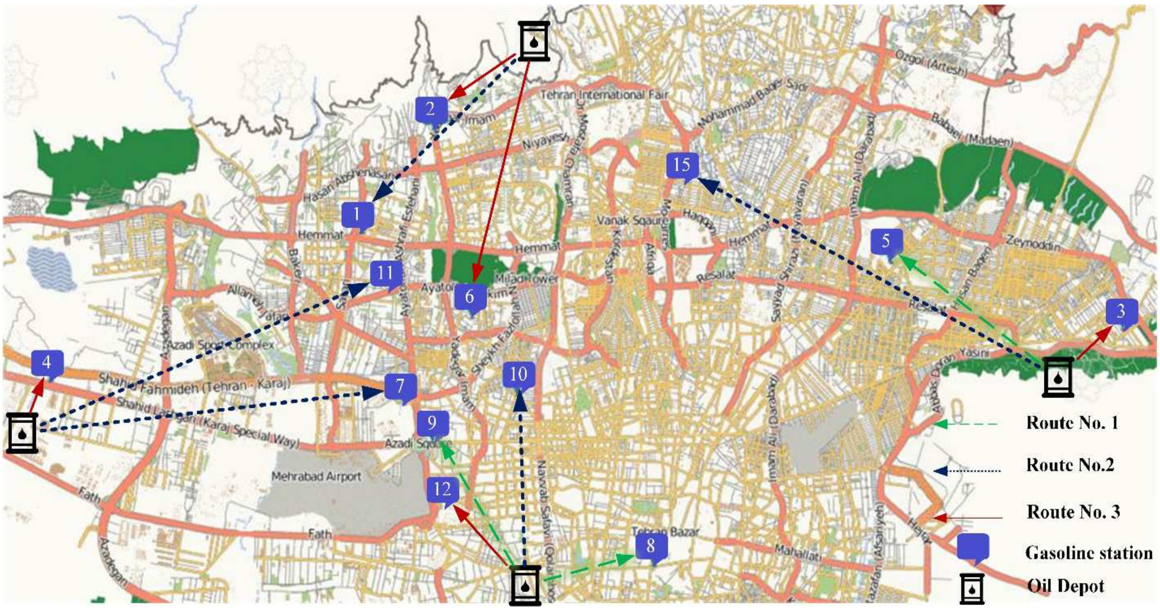

Fig. 3. The result of solving problem of logistic network design for gasoline distribution

Allocation to gas stations in one period is shown in **Error! Reference source not found.**. As can be seen in **Error! Reference source not found.**, three locations in addition to current gas stations should be located in Tehran according to company needs and current restrictions. The type of transmission and allocation of gas stations and oil depots in Tehran are shown **Error! Reference source not found.**. The significant point in **Error! Reference source not found.** is that the model tries to allocate the gas stations with regard to the closest oil depot, but due to the restriction of oil depots capacities, sometimes this allocation was for farther depots. Only one route is selected with regard to the volume of traffic.

5-3- Sensitivity analysis of the model

In this section, firstly the analysis has been done over the demand of gas stations based on various demands. This analysis is done due to the imprecise demand for gas stations. The results of the sensitivity analysis are shown in Table 5.

Table 5. The comparison of various demands from gas stations

Sample	Demand(one thousand liter)	Objective function 1	Objective function2	Objective function 3	Integrated objective function
1	18	107260000	5418000	1856000000	12/58
2	20	114019400	10102000	1932000000	31/66
3	22	113189000	11102000	3348000000	31/64
4	25	116196000	12594000	3448000000	43/85
5	27	117749000	17900800	3794000000	52/98
6	30	131878880	20764928	45148600	59/47

Another analysis which can be done in order to verify the proposed model is the analysis of the time of using vehicle in any period. Table 6 and Fig. **4** illustrate the objective functions value.

Table 6.Allowed time for using of vehicle

Time (min)	8000	7200	6400	5600	4800
compromise programming's objective function	21.28	21.76	22.50	23.08	23.86
objective function 1	111064700	100593400	8983325000	68347770	60505100
objective function 2	128832	124632	126712	129432	138624
objective function 3	23639270	23905440	2500000	25050000	25650000

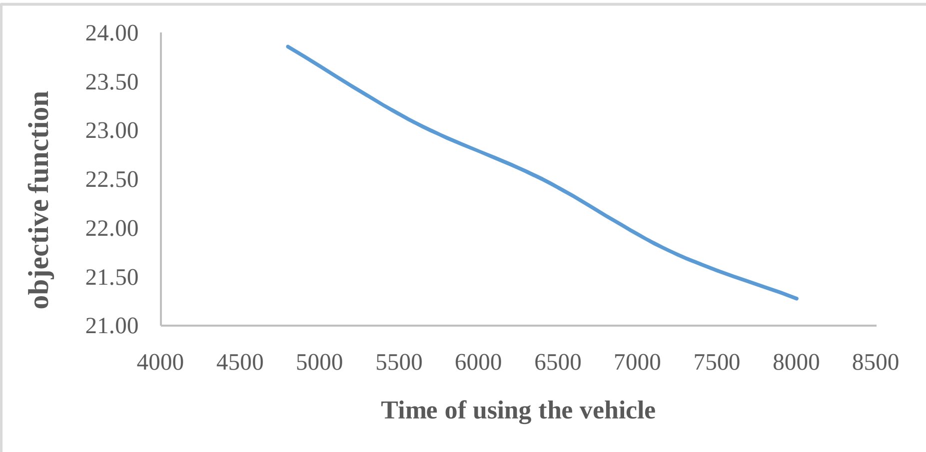

Fig. 4.Analysis of the time allowed for using vehicle

We will look at the impact of the facility capacity on the objective function. The effect of changing capacity of gas stations on integrated objective function problem is seen in Fig. **4** and Table 6. Also, the effect of changing vehicle capacity over problem has been expressed.

Table 7. The results of changing gas stations capacity

Gas station capacity	60000	80000	100000	120000	150000	200000
Integrated objective function	32	32	31	31	28	28

According to Table 7 and Fig. **5**, increasing the capacity of gas station despite increasing cost caused by improvement of capacity, causes a decrease in the objective function due to the second and the third objective functions. With increasing the risk capacity of the problem due to using of larger vehicles and then decreasing the checking times of gas station, problem risk and environmental pollution decrease. Moreover, increasing the capacity of gas station to more than 200,000 liters has no impact on the problem.

Table 8. Results of changing the vehicle capacity

Capacity of vehicle (liter)	18000	20000	25000	30000	35000
Objective function 1	109588200	114660300	116437000	118333200	118333200
Objective function 2	149452	126900	101020	71700	71700
Objective function 3	3045000	24940000	24370000	23540000	23540000
Integrated objective function	27	42	42	43	43

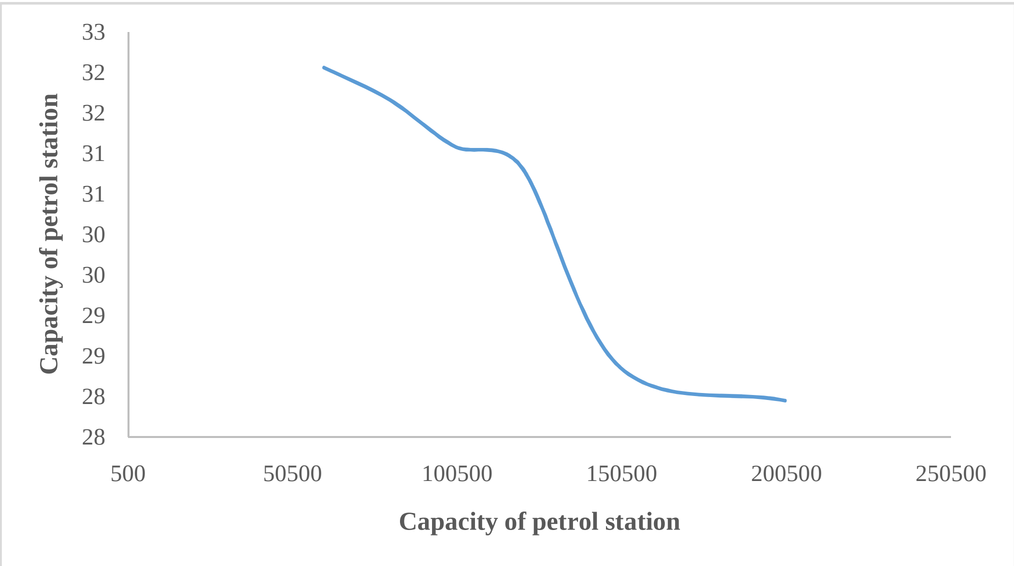

Fig. 5. The analysis of changing gas station capacity

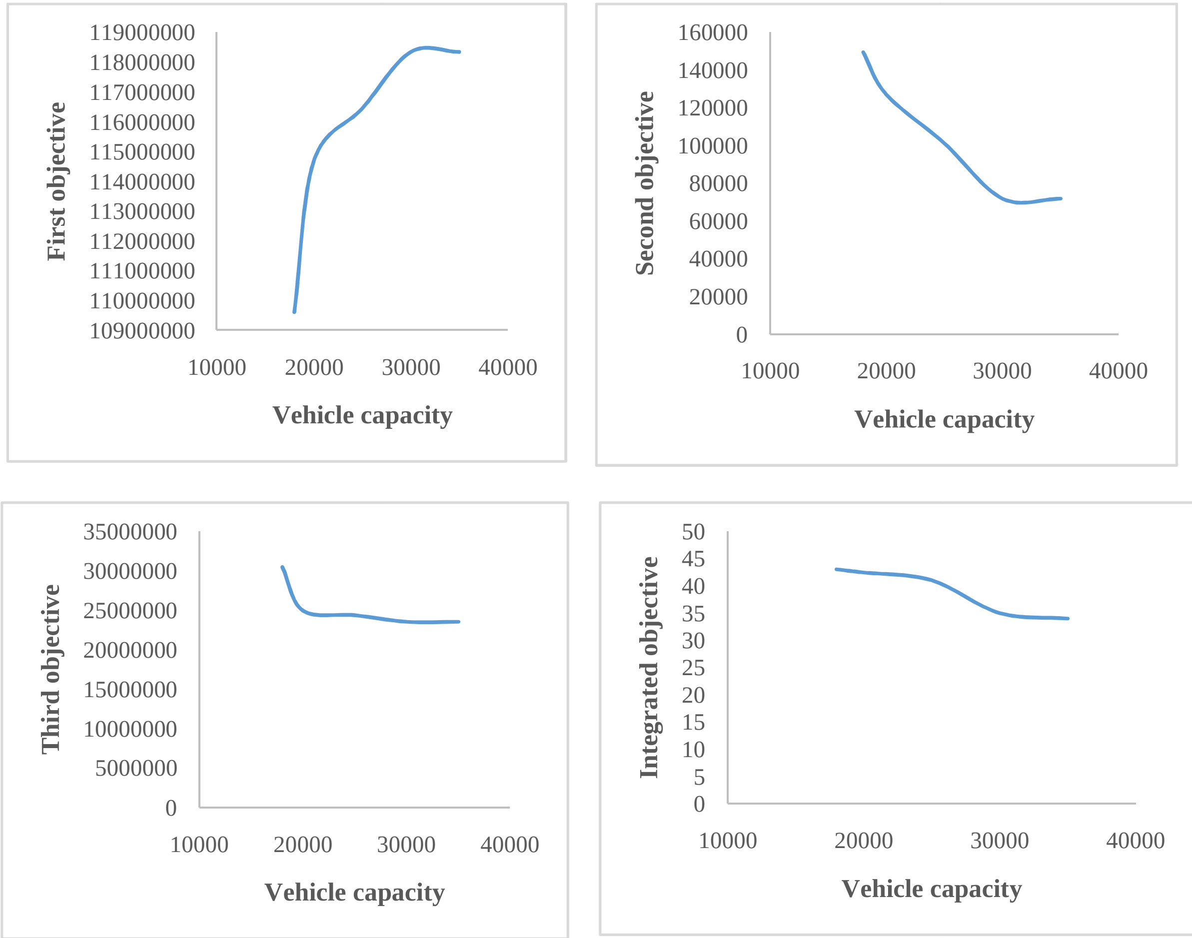

Fig. 6. Analysis from changing the vehicle capacity

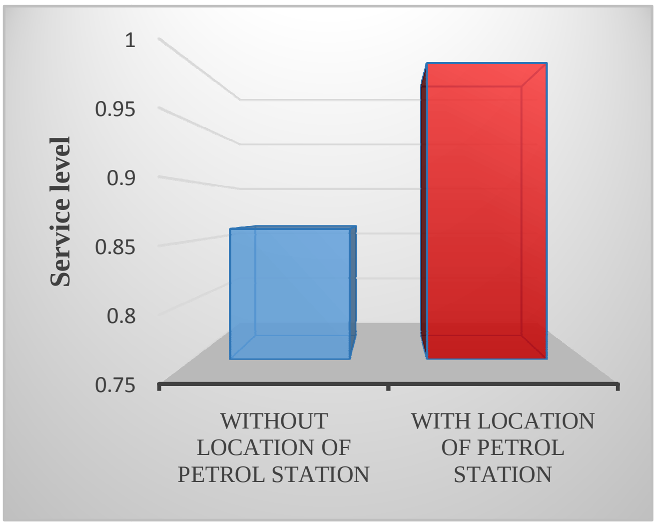

Fig.7. Comparison of the level of service available and new design for network

According to Table 8 and Fig. **6** and also increasing the capacity of vehicles, the cost is increasing due to increasing of primary cost of vehicle and holding cost.

As can be seen in Fig.7, the rate of servicing level in current situation of gasoline distribution network was equal to %86. Namely %86 of costumers demand arriving to gas stations was satisfied. But with by using the new model this servicing level is becoming %100. According to Fig. **8** if advertising is not considered, the amount of Co2 driven by type of gasoline is about 4600000 cubic meters, but if the advertising is considered, this amount will be decreased.

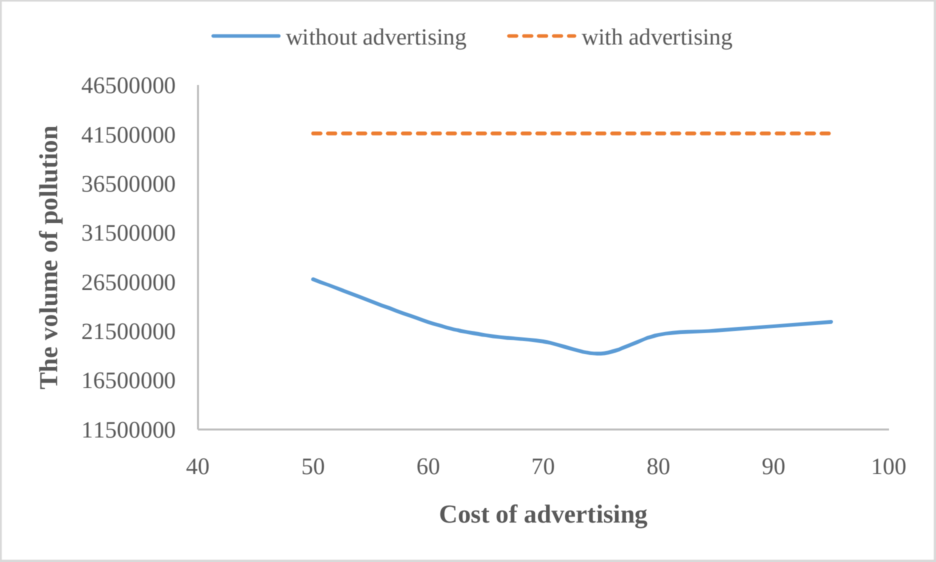

Fig. 8. Comparison of emissions caused by changes in demand due to the cost of advertising

6- Conclusion

Due to the population growth and the increasing number of vehicles, the need for energy carriers, especially gasoline, increased sharply. This has led to special attention to the gasoline distribution system. On the one hand, gasoline is a strategic commodity and shortage of gasoline in gas stations leads to crises. The remarkable point is that the gasoline distribution is boarding, namely, this commodity must be distributed on boarding. The gasoline distribution due to its explosion risk should be done with prudence. In addition, an important issue arising in recent years is considering environmental pollutants. Managers believe that focusing on the cost and time is not enough in today's world and they should consider the environmental factors in their planning.

Applying reliability can lead to a richer model to cover the disorders arising in the routes between two nodes, in vehicle and or in the time of unloading, to facilitate meeting demands on time. The way back from gas station to oil depot in this model can make the model closer to real conditions. In the proposed model the customer satisfaction and responsiveness are also considered.

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