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Providing the vehicle routing model for distribution of various items with the objective of optimizing travel operational costs (Case Study: The Port and Maritime Organization of Gilan province)

PooriaGiahiKhomeyran[a], SeyedJafarSadjadiParsa[b]
[a]*MSc Student of Maritime Engineering, School of Marine Engineering, Chabahar Maritime university, Iran*
[b]*Faculty Member of Chabahar Maritime university, Chabahar, Iran*

ABSTRACT
Perishable items such as food products, vegetables, flowers, ready-mixed concrete, blood and etc. are usually destroyed during production and delivery process, so to prevent spoilage of such products, these products must reach the customer at the appropriate time to the manufacturers. One of the effective factors in the timely delivery of various products to the customer is the choice of the optimal delivery route, which is referred to as the issue of vehicle routing. The issue of vehicle routing for the distribution of various products is one of the most widely used issues in the field of operations research, which is very useful in planning the transportation fleet.In this Research, we seek to determine the operational plan of homogeneous vehicles with limited capacity to send products from the central warehouse to a group of customers that are geographically dispersed in different areas, so that the number of vehicles and travel costs are minimized.
Most existing studies on decision-making issues have assumed the issue in an environment of conclusive data. However, in many cases it is observed that it is difficult to determine the exact values for the parameters and the values must be fuzzy. As a result, one of the most important decisions to be made in the supply chain is the issue of efficiency and effectiveness of this chain along with parameters and variables with uncertainty. Uncertainty in the supply chain leads to non-optimization of decisions made on the assumption of uncertainty, so to match the uncertainty, some problem parameters such as travel time, shipping cost, as well as the start and end of customers' time windows in the chain Supplies are considered as fuzzy numbers.
Due to the fact that the mentioned problem is a very complex problem and for its large dimensions we cannot find a suitable quality answer in a short time with accurate methods, so to solve this model on a smaller scale, Gams software has been used.
Finally, to show the application of the proposed model in the real world, the issue of product distribution among customers in the Ports and Maritime Organization of Gilan Province (Bandar Anzali) has been investigated, which shows that distributors can use this method to reduce their operating costs.
Keywords: Vehicle routing issue, Supply chain, Gilan Province Ports and Maritime Organization, Operating costs of travel

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I. INTRODUCTION

The problem of vehicle routing is a general name that refers to the category of issues that include meeting customers. The problem of vehicle routing in the literature is also known as the timing and distribution of vehicles or simply as delivery problem. Routing issues in applied modes are not directly associated with the physical distribution of items and are periodically appearing. Student's boarding school buses, delivery of goods between supermarkets and large shops, distributing book and newspaper types, distribution tours and maintenance, refrigerator distribution, etc, are all issues in which items and vehicles can take various forms. Perishable items such as dairy products, food and medicine, a variety of vegetables, flowers and plants, ready-made concretes and blood packages, etc, can typically be disposed of over time from production to delivery. The value of perishable items begins to decline immediately after production and continues until they are delivered to the consumer. Therefore, the income of producers and distributors depends on the conditions of these items at the time of delivery, so the timely production and distribution of these items will have a significant impact on the income of producers and distributors. The continuous and rapid perishability of this type of items causes the producers to delay the production time of these items as much as possible and to deliver the produced items to the consumer as soon as possible. For this reason, one of the factors affecting vendor's revenue is fast and efficient transportation along the supply chain, Chen et al. (2009).

The problem of vehicle routing for the distribution of different items is a practical type of routing problem. The problem of vehicle routing for the distribution of various items was first proposed by Dantzig and Ramser (1959), and is still one of the most popular and efficient field of research in operations due to the difficulty of solving and its many applications in today's world. Routing is one of the most challenging optimization issues, and for more than 50 years we have been trying to design an optimal set of transport fleet routes to serve all customers. The problem vehicle routing has a variety of constraints which can be referred to as constraints of vehicle capacity, time window, length of paths, etc. the problem of vehicle routing is a general name for a set of optimization problems which serve consumers using a number of vehicles. The vehicles leave the warehouse, serve the network consumer, and return to the station after completing their journey, and finally the cost function of the problem is minimized and consumer satisfaction is maximized. Fig.1 shows a view of common inputs for the problem and one of the possible outputs.

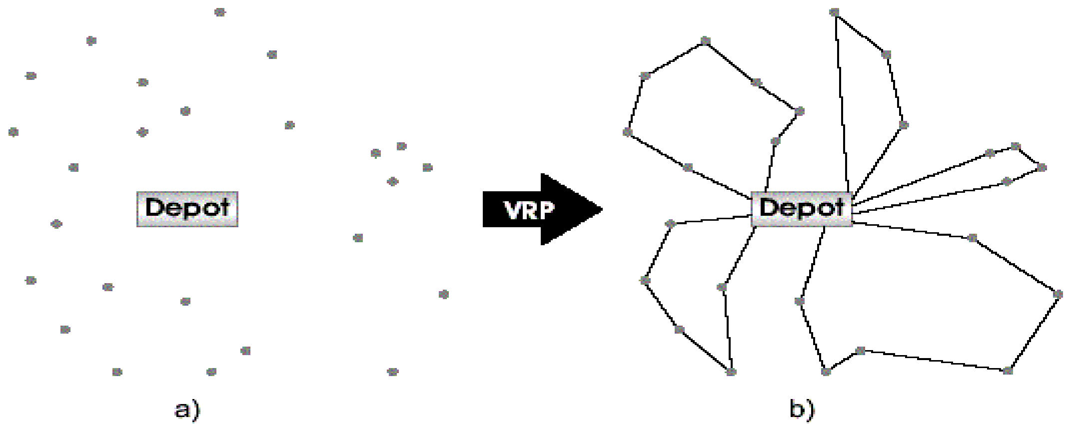

Fig. 1. Problem Solving (b) - Example of a Vehicle Routing Problem (a)

The problem of vehicle routing for the distribution of various items is an extension of the problem of the traveling salesman. The issue of the traveling salesman is one of the most fundamental issues in the routing and planning of transportation. In the case of TSP, the goal is to find the shortest route that passes through a set of cities, meets each city only once, and then returns to the original city from which it started. In fact, the TSP problem is a type of VRP problem with a vehicle, with no restrictions and no known origin, so that customers have no demand, so VRP is much more complex than TSP. The simple route routing problem specifies the optimal routes in such a way that each node meets only once with one transport vehicle, while the beginning and end of the routes are at a point called the warehouse. Figures 2 and 3 show the TSP and VRP problems.

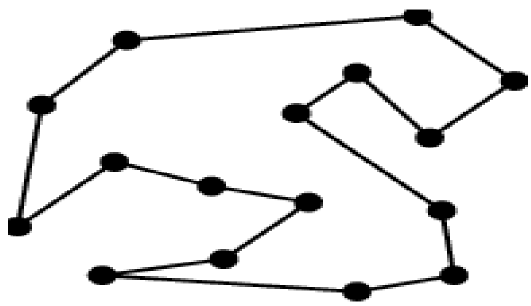

Fig. 2. The issue of the traveling salesman

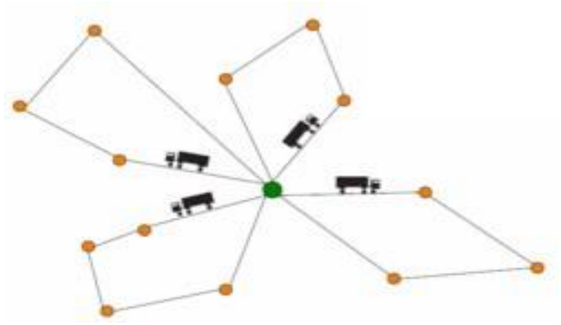

Fig. 3. Vehicle routing issue

The problem of vehicle routing for the distribution of various items is an extension of the problem of the traveling salesman. The issue of the traveling salesman is one of the most fundamental issues in the routing and planning of transportation. In the case of TSP, the goal is to find the shortest route that passes through a set of cities, meets each city only once, and then returns to the original city from which it started. In fact, the TSP problem is a type of VRP problem with a vehicle, with no restrictions and no known origin, so that customers have no demand, so VRP is much more complex than TSP. The simple route routing problem specifies the optimal routes in such a way that each node meets only once with one transport vehicle, while the beginning and end of the routes are at a point called the warehouse. Figures 2 and 3 show the TSP and VRP problems. In the last decades, many research projects have been done on different kinds of routing problems and their methods for solving them, but compared to the classical routing problem that many research has been done, less research has been done to the problem of vehicle routing for the distribution of various items by considering time windows. The VRPTW problem is the design of a set of routes for a fleet of vehicles, which are beginning and ending the routes in the warehouse, and the service is given to a certain number of users scattered across different geographic areas. Each consumer must be met by one of these routes in a specific time window and the goal is to minimize the total cost of customer service, HashemiAmiri (2013). One of the main reasons for this research is the high cost of travel and movement of various items from origin to destination, which in this research will try to minimize the operating costs of goods by providing an efficient mathematical model.

The transportation system in today's industrial world has a very important role in economic development due to the possibility of consuming items in places far away from their place of production. Delivering the final product to a customer requires the transfer of raw materials from suppliers to manufacturers, the transfer of semi-finished products between factories, and finally the delivery of the final product to customers and target markets. Due to the number of transportation activities, transportation costs account for a high percentage of logistics costs (between 40 and 70%) and The design of distribution networks has also become one of the most important issues in the field of supply chain and logistics management due to its significant impact on reducing logistics costs and improving the quality of service, Ghiani et al. (2004). It is also possible to develop existing active markets and create new markets using efficient transportation systems, delivered perishable products to consumers around the world in the shortest possible time, and used the competitive advantages of developing countries to produce more cost-effective products, Karaoglan et al. (2012).

II. LITERATURE REVIEW

Federgruen et al. (1986), considering the costs of commodity shortages, the cost of corruption, and the costs associated with transporting goods, they presented an efficient mathematical model for transporting various items and optimal allocation, which in this study showed that items produced from a central warehouse to specified locations demand for goods is probable, they are sent. In the relevant model, the goods produced in the central warehouse are perishable and must be used for a certain period of time, otherwise the goods will be rotten and unused. In their model, different states for delivery of goods to consumers considered that in the first part the demand for each consumer is met separately and in the second part consumers are assigned to certain routes.

In an article published by Tarantilis and Kiranoudis (2001), they presented a precise and quick solution to the problem model of dairy distribution in Greece. In this study, the problem was formulated as a model of vehicle routing with an unbalanced fleet, which due to the complexity of the model, to date, no suitable solution has been found for this problem. Tarantilis and Kiranoudis developed a threshold-based algorithm to meet the needs of the organization. These two people tried to provide solutions to increase the efficiency and productivity of the organization by using the results of the solved model. In another research paper, Tarantilis and Kiranoudis (2002) formulated the problem of distributing meat products from warehouses between distribution centers in Greece as a model for the problem of routing multi-warehouse vehicles. To solve this model, they used a meta-innovative solution method called random search, which shows the high economic savings for the organization.

Hsu and Hung (2003) published a paper on the routing of time-limited vehicles for the distribution of frozen food products. Given the high demand of consumers, they came up with a solution in which more goods should be loaded than consumer demand. The model presented by them specifies limitations such as the number of vehicles required, the carrying capacity and travel time of each vehicle and the relevant routes.

Azi et al. (2004) published an article entitled presenting a Model of Vehicle Routing Problem with Time-Limit Window in which the vehicle model had to be assigned to more than one route in a given day. Applications of this model include the delivery of perishable goods such as food to urban centers, which due to the shortness of the relevant routes, a vehicle can serve several different routes during the day.

In a paper, Belenguer et al. (2005) formulated the problem of the distribution of protein products in an organization in Spain as a model for the problem of vehicle routing with respect to time window constraints. They introduced algorithms to solve the model and presented them as a computer package as a support system to manage the proper distribution of products.

In an article, Ambrosino and Sciomachen (2006) formulated the issue of food distribution in an Italian organization as a model for the problem of navigating a capable vehicle. In this regard, they were looking for a suitable solution for the distribution of two types of goods through the national network. To solve this model, they proposed an innovative two-step approach, in the first stage, consumers are segmented and consumer groups and routes related to each vehicle are identified, and in the second stage, by changing consumers between designated routes, operating costs are minimized.

Zaeri et al. (2007) conducted a research study entitled presenting a Mathematical Model for Newspaper Production and Distribution in which the relationship between production and distribution operations is critical. Given that the issue of newspaper production and distribution is an example of perishable goods, they presented an innovative method in this study that, using cluster-to-cluster analysis and the itinerant vendor model, were able to provide relevant routes and points of demand to allocate vehicles.

Hsu et al. (2007) presented a research paper on the problem of vehicle routing with respect to time constraints as well as examining the delivery process of perishable items, a mathematical model for obtaining the optimal delivery route, the capacity of each vehicle and provided the time of departure of the vehicles. Their model minimizes fixed vehicle costs, freight costs, energy consumed, and time-window fines. In this study, they have discussed the movement time of vehicles, the effect of route traffic on travel time at different hours of the day, temperature changes during the day and changes in the objective function, the limitations and parameters of their model and the algorithm they also introduced TONNH creatively and innovatively to solve the problem model.

Budchar and Sethanan (2009) presented a paper entitled An Innovative Algorithm for Solving the Routing Problem Model of Transportation in the Distribution of Perishable Items Considering the time window constraint, the objective function of the model is kept to a minimum while minimizing total maintenance costs Formulate perishable materials, fuel costs and late payment fines. In this study, Budchar and Sethanan concluded that the number of item distribution centers, the distances between distribution centers, and the number of items transported by vehicles are among the factors affecting the objective function. The results of solving this problem can be used in the real world to minimize the total operating costs of vehicle travel and delivery of items to consumers in the shortest possible time.

In an article, chen et al. (2010) presented a nonlinear programming model to investigate the possible routing problem. In this study, they considered the demand of consumers as a possibility and in the assumptions of the model, the rate of corruption of goods is clear and corruption begins after the production of goods. Therefore, the income of suppliers is not known and depends on the degree of corruption of goods. The objective function of the relevant model is also considered to maximize the expected benefits of suppliers. After solving the problem model, the optimal number of manufactured goods, the time of production start and the routes of vehicles were determined. To solve their research model, they developed an innovative algorithm that incorporates the Nelder-Mead method to solve the vehicle routing problem with time window constraints. The results of solving the model show that the algorithm used was very accurate and efficient.

In an article published by Gong and Fu (2010), they were able to propose a multi-characteristic model for the transportation routing problem of vehicles for the distribution of perishable food in large cities, given the time constraints and in formulating, they considered costs such as production operating costs, fixed vehicle costs, food spoilage costs, and time window costs.

In an article, Azi et al. (2010) considered a specific type of vehicle routing in which the vehicle in question travels more than one route in a given business day. In this model, it is possible that not all consumers receive the service, and the determination of consumers to serve them according to consumer-related income minus travel costs, they used an innovative algorithm to solve the problem model.

In an article, Farahani et al. (2012) proved that the quality of perishable products can be increased by reducing the time interval between production and delivery of items. To achieve this goal, they adopted a procedure that integrates products and careful planning for the distribution of items in a continuous structure. The problem model is formulated as an integer linear programming. In this research, the minimum required quality for perishable items is guaranteed. To solve this model, they used an innovative algorithm that classifies the production of items into two stages and offers a solution for their exact integration with the model of distribution of different items. In this way, they were able to reduce the complexity of the problem model and solve the problem in a timely manner.

In an article, Barreto et al. (2012) planned various routes for the distribution of frozen items. Vehicle routing issues are characterized by the distribution of frozen items, maintaining the quality of items and preventing their corruption.

III. PROBLEM DEFINITION AND MATHEMATICAL MODEL

The vehicle routing problem is represented by a graph G = (V, A) in which the set V = {V0, V1…Vn} represents a set of nodes and A = {(Vi, Vj)|Vi, Vj∈ V, i ≠ j} also represent a set of arcs connecting nodes. Warehouse point V0 and V1 to Vn also indicate consumers. Ci, j associated with each arc (i, j), indicates the distance traveled or the time and expense spent on travel. For each consumer Vi, a delivery demand of di ≥ 0 and a withdrawal demand of Pi are considered. If the vehicle k moves on the arc (i, j), the decision variable xi, j, k is number one, otherwise zero will be assigned to it, k indicates the number of vehicles intended, Solomon (1987).

The model considered in this research for the problem of vehicle routing for the distribution of different items is an Np-hard model of VRP problem models. This model includes three decision variables, eleven constraints, four indices and eight parameters, which will be fully described below. The main model of this research is as follows, Kumar et al. (2012).

$$\text{Minimize} \quad \sum_{i=0}^{N}\sum_{j=0}^{N}\sum_{j\neq i,k=1}^{K} c_{ij}x_{ijk}$$

subject to:

$$\sum_{k=1}^{K}\sum_{j=1}^{N} x_{ijk} \le K, \quad \text{for } i=0 \qquad (1)$$

$$\sum_{j=1}^{N} x_{ijk} = 1 \quad \text{for } i=0 \text{ and } k\in\{1,\cdots,K\} \qquad (2)$$

$$\sum_{J=1}^{N} x_{jik} = 1 \quad \text{for } i=0 \text{ and } k\in\{1,\cdots,K\} \qquad (3)$$

$$\sum_{k=1}^{K} \sum_{j=0,\, j\neq i}^{N} x_{ijk} = 1, \quad \text{for } i \in \{1, \cdots, N\} \tag{4}$$

$$\sum_{k=1}^{K} \sum_{i=0, i\neq j}^{N} x_{ijk} = 1, \quad \text{for } j \in \{1, \cdots, N\} \tag{5}$$

$$\sum_{i=1}^{N} m_i \sum_{j=0,\, j\neq i}^{N} x_{ijk} \le q_k, \quad \text{for } k \in \{1, \cdots, K\} \tag{6}$$

$$\sum_{i=0}^{N} \sum_{j=0,\, j\neq i}^{N} x_{ijk} \left(t_{ij} + f_i + w_i\right) \le r_k, \quad \text{for } k \in \{1, \cdots, K\} \tag{7}$$

$$T_0 = w_0 = f_0 = 0 \tag{8}$$

$$\sum_{k=1}^{K} \sum_{i=0, i\neq j}^{N} x_{ijk} \left(T_i + t_{ij} + f_i + w_i\right) \le T_j, \quad \text{for } i \in \{1, \cdots, K\} \tag{9}$$

$$e_i \le \left(T_i + w_i\right) \le l_i \quad \text{for } i \in \{1, \cdots, N\} \tag{10}$$

Sets
i: Starting city
j: Destination city
k: Total number of vehicles
N: Total number of customers
Principal Decision Variables
Ti: Arrival time at node i
Wi: Wait time at node i
Xijk□ {0,1}, 0 if there is no arc from node i to node j, and 1 otherwise
Parameters
Cij: Cost incurred on arc from node i to j
tij: Travel time between node i and j
mi: Demand at node i
qk: Capacity of vehicle k
ei: Earliest arrival time at node i
li: Latest arrival time at node i
fi: Service time at node i
rk: Maximum route time allowed for vehicle k

The descriptions of the objective function and the constraints of the model are as follows:
The objective function minimizes the operating cost of transport trips. Constraint set 1 guarantees that the number of tours is K by selecting at most K outgoing arcs from the depot (i=0).
The constraint set 2 ensures that for each vehicle, there is exactly one outgoing arc from the depot is selected. Similarly, the constraint set 3 ensures that for each vehicle, there is exactly one arc entering into the node with respect to depot (i=0). These two constraint sets (constraint set 2 and constraint set 3) jointly ensure that a complete tour for each vehicle is ensured.
The constraint set 4 makes sure that from each node i only one arc for each vehicle emanates from it. The constraint set 5 ensures that for each node j, only one arc for each vehicle enters into it. These two constraints (constraint set 4 and constraint set 5) make sure that each vehicle visits each node only once.
The constraint set 6 sees that for each vehicle, the total demand (load) allocated to it is less than or equal to its capacity.
The constraint set 7 ensures that the total time of travel of the route of each vehicle is less than or equal to the maximum route time allocation to that vehicle.
The constraint set 8 sets the arrival time, waiting time and service time of each vehicle at the depot to zero. The constraint set 9 guarantees that the arrival time of each vehicle at the node j is less than the specified arrival time at that node. The constraint set 10 guarantees that the sum of the arrival time and the waiting time of each vehicle at each node i is more than equal to the earliest arrival time at that node and less more than or equal to the latest arrival

time at that node i. Constraint sets 8-10 define the time windows.

Case study

By examining the transportation system of the Ports and Maritime Organization of Gilan Province (Bandar Anzali), the information required to write the relevant model was obtained, which is as follows.

The information intended for 10 working days is the transportation system of the Ports and Maritime Administration of Gilan Province (Bandar Anzali) and based on the information of these 10 days, the relevant model has been written as an example, the information needed to write a vehicle routing model is as follows.

Table 4
Times of first arrival in the city i.

i	1	2	3	4	5	6
e_i (min)	135	195	285	405	225	435

Table 5
Last times of arrival in the city i.

i	1	2	3	4	5	6
l_i (min)	210	285	390	515	320	545

Table 6
Duration of service in the city i.

i	1	2	3	4	5	6
f_i (min)	55	70	80	90	65	85

Table 7
Maximum time allowed for travel by vehicle k.

k	1	2	3	4	5	6
r_k (min)	170	240	280	410	275	495

Table 8
Travel time between city i and city j.

T(i , j)	1	2	3	4	5	6
1	110	180	220	350	215	435

Table 9
Cost of routes traveled between city i and city j.

C(i , j)	1	2	3	4	5	6
1	600	750	850	1000	820	1600

Travel times in Table 8 are in minutes and expenses in Table 9 are in thousands of tomans, and the last three digits are not considered.
In the case study, in addition to the numerical information presented in the tables above, other information is required to write the model, which is presented as follows:

1. The information of the transportation system in this research has been considered as a random sample for 10 working days of the transportation system of the Ports and Maritime Organization of Gilan Province (Bandar Anzali).
2. The transportation system of the Ports and Maritime Organization of Gilan Province (Bandar Anzali) sends various goods and items to all parts of Iran, in this research rectangular wooden boards are considered as an example.
3. vehicles in the Ports Organization includes trucks, 10-wheel and 18-wheel trailers, etc, each of which has a specific capacity, and depending on the type of demand from the customer, the type of vehicle for transporting items and goods is determined.
4. Gilan Ports and Maritime Organization (Bandar Anzali) has 6 private companies active in the field of unloading and loading, in this research,

Iran Ports Company as an example is considered as the basis of research work for writing the relevant model and the information of this company has been used to write the vehicle routing model.

5. The transportation system of the Ports and Maritime Organization of Gilan Province (Bandar Anzali) sends the relevant items and goods to most cities in Iran. In this research, 6 cities that are applying for rectangular wood boards are considered as an example for writing the relevant model, and the information in this research for writing the model is based on sending rectangular wood boards to these 6 cities and in 10 working days. These 6 cities include: 1- Talesh 2- Astara 3- Qazvin 4- Tehran 5- Shahsavar 6- Sari. The model sets are written in the order of cities, which is arranged according to the respective cities in Tables 10 and 11.

Table 10
Set i is related to the starting city.

i	1,2,3,4,5,6
Starting city	Bandar Anzali Port Organization

Table 11
Destination cities are listed in Table 11.

j	1	2	3	4	5	6
Destination cities	Talesh	Astara	Qazvin	Tehran	Shahsavar	Sari

6. The information obtained to write the research model is only a random sample of the transportation system information of Bandar Anzali Ports Organization (Variables, item and company is randomly selected).

Computational results
Based on the solution of the model by GAMS software, the values related to each decision variable were determined and the operating costs of each vehicle trip to the relevant cities were reduced to a minimum.

Table 12
Travel expenses before and after solving the model.

Cities	Talesh	Astara	Qazvin	Tehran	Shahsavar	Sari	**Total Costs**
Total travel expenses before solving the model	600	750	850	900	1000	820	4920
Total travel expenses after solving the model	521	662	753	808	916	747	4407
The difference between the two costs	79	88	97	92	84	73	513

Costs are in terms of one thousand tomans. As shown in Table 12, the operational costs of the trip have been reduced, with the highest percentage reduction in the cost associated with the city of Talesh and the lowest percentage of the cost reduction related to the Shahsavar city. The graph of the percentage reduction of travel operating expenses is given in Figure 5.

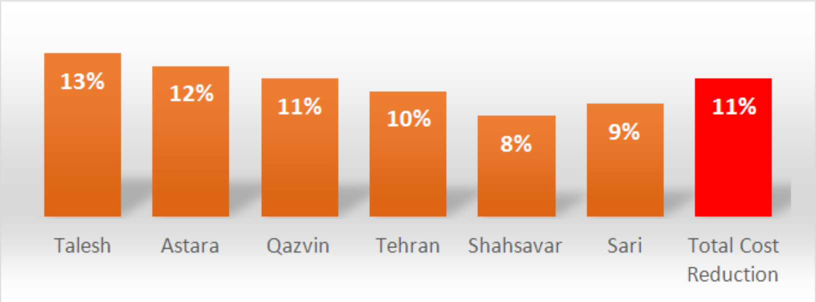

Fig. 5. Percentage reduction chart of travel operating expenses

The results of the solution were analyzed in Excel software as a statistical chart and the operating costs for the desired routes were minimized.

IV. CONCLUSION

To show the application of the vehicle routing problem according to the data and information of the transportation system of the Ports and Maritime Organization of Gilan Province (Bandar Anzali), a mathematical model for the vehicle routing problem for the distribution of various items was presented. This model was coded in GAMS software environment and the results of optimal problem solving were presented.

The purpose of this study was to write an efficient mathematical model that can be used to minimize the operating costs of vehicle travel, in this regard, one of the models of vehicle routing problem was presented and with a study that was done from the transportation system of the Ports and Maritime Organization of Gilan Province (Bandar Anzali), it was possible to provide a real example of the relevant system for modeling vehicle routing to show the application of the model in this research in the real world, So it is possible to use different mathematical models in different fields to minimize the costs of each organization and increase their performance and efficiency.

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