INTERMODAL HUB LOCATION FOCUSING DRY PORT (CASE STUDY: IRAN)

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ABSTRACT

Lack of sufficient container storage space, high land costs, and inadequate origin-destination accessibility of goods are the serious problems facing the coastal ports today due to the growing use of containers in the maritime transport. The most appropriate way to overcome these problems is to use the dry port concept as a multimodal transportation terminal with adequate distance from coastal ports and the main origins/destinations within the country.

Effort has been made in this research to model the dry port locating problem as a multimodal transportation terminal using the median P-hub location-allocation approach, and to be closer to the real-world conditions, the demand parameter has been assumed to be uncertain to propose a robust model resistant against uncertainty. Robust scenario-based optimization models have the potential to generate justified optimal solutions against the fluctuations of the problem's uncertain parameters. The data used in this model are the real ones from Iran Railway-Road Network.

Results of applying the proposed model show that Kerman, Fars, and North Khorasan provinces in Iran have the potential for dry port construction. The robust model's validation results presented at the end of the paper show 31% improvement in the model performance (output efficiency).

Keywords: *dry port, hub locating, multimodal transportation.*

1. INTRODUCTION

Considering increased container transportation in the world since the mid-1950s, construction of huge container transport ships developed rapidly. Marine transportation traffic towards coastal ports, insufficient space for ships' docking, poor management of empty containers, lengthy customs clearance process, high transportation costs, lack of optimal use of mixed transportation, failure to observe the time of goods delivery to destinations, and low security in cargo transportation increased so much throughout the world that they necessitated facilities to manage them properly in cargo transport especially in the network connected to marine roads (Cullinane & Wilmsmeier, 2011; Jarzemskis &Vasiliauskas, 2007; Roso & Lumsden, 2010; Veenstra, Zuihwijk &Van Asperen, 2012).Dry ports are offshore mixed terminals connected to one (or more) coastal port through one (or more) high-capacity transport mode. They are equipped with sufficient, necessary equipment to handle the traffic caused by the use of several modes of transportation and customers can send/receive their cargo to/from them; according to this definition, such a facility is called a “dry port” (Woxenius, Roso, & Lumsden, 2004). Progress and benefits from dry port construction are different depending on current approaches, costs spent, routes used, facilities provided, and local conditions. The actual and potential benefits of establishing dry ports can be listed as follows (UNCTAD, 1991):

* *Enhancing business flows*
* *Reducing door-to-door freight rates*
* *Avoiding late unloading and delays in records recording*
* *Optimum use of road/rail transport*
* *Using national railway*
* *Making better use of potentials*
* *Making better use of containers*
* *Making possible more national controls over transportation*
* *Reducing delays and better information flow through reduced paperwork*

In any dry port, effort is made to enhance transport efficiency and effectiveness by using different transportation modes. The most important problem in addressing this solution is to find appropriate locations for dry port construction which has led to the opening of many research grounds in this connection (Ambrosino & Sciomachen, 2012; De

Langen, 2004). Problem of assessing points appropriate for dry port construction can be considered as a special hub locating problem which has recently attracted much attention in scientific societies.
With such great sea ports as ShahidRajaee, ShahidBahonar, and Imam Khomaini, and their access to ocean routes, Iran is capable of being connected to different parts of the world and participating in international competitive markets, and the transportation of about 90% of the cargo by sea is the main reason for Iran cargo transportation network's need for the construction and development of dry ports. The reason why this research is necessary in Iran is that multimodal transport development and simultaneous combination of road and rail in cargo transport network will result in reduced time of sending goods from ports to applicants (which increases desirability) and saving in network costs. Presently, there are 3 railway lines in Iran which, compared to road lines, are not considerable; accordingly, this research aims at hub locating of dry ports which makes possible the maximum use of railway transport in addition to reducing the related transportation costs.
Some innovations addressed in this research include determination of the No of ports/dry ports by the model endogenously, locating ports/dry ports using locating problem approach and allocating import/export centers to them considering chord displacement constraints in goods transportation considering operational costs in dry ports, and, most important of all, using TRANSCAD Software to determine candidate points for dry port construction considering computation criteria.
This paper has been so structured as to review the related literature in Section 2, precisely define the problem and propose model in Section 3, study the results and case study in Section 4, and finally present the conclusions and suggestions for future studies in Section 5.

2. LITERATURE REVIEW

Compared to other sea ports, traditional ones tolerate pressure to improve competitiveness and preserve or increase their market shares. Sea ports can enhance their service levels, potentials, and storage areas in pre-located combined terminals inside the country with the concept of dry port. Dry port construction is a strategic decision that involves considerable costs and any mistake in making it will cause huge damage (Feng et al, 2013). To solve the dry port locating problem (finding locations and their No), the clustering method was proposed in 2011(Li, Shi, & Hu, 2011). Later, a model was developed for locating sea port-dry port network that provided a novel viewpoint in the sea port-dry port relationship through developing Greedy Algorithm and Genetic Algorithm, and then dry port locating problem was addressed for cargo transportation in the multimodal transportation using the MILP Model (Ambrosino & Sciomachen, 2014). In addition, other researchers proposed and developed different fuzzy, data envelopment, and weighting methods of factors effective in selecting locations for dry port construction (Bourgani & Stylios, 2013; Hanaoka, 2012; Wang & Wei, 2009; Zhang & Wang, 2011).
Hub is a special facility used as a switch center in long distance systems. In a hub network, the flow between nodes is shown on the edges; this variable can be cost, time, distance, and so on. In the wheel and hub system, flow is considered as unit demand between each 2 nodes. Since "locating" is a known issue, a review of such papers as Alumur & Kara, 2008; Campbell & O'Kelly, 2012; Farahani et al., 2013; O'Kelly & Miller, 1994, …, can be quite useful.
Considering dry port-related literature and works done in the world (and especially in Iran) for finding the best location to construct it, the related literature gaps include:

1) Determining the optimum No. of dry port(s) endogenously by the model.
2) Locating dry port(s) using locating problem approach and allocating Iran export &import centers to them.
3) Determining the optimum No of dry port(s).
4) Considering chord displacement constraints in goods transport.
5) Considering operational costs in dry ports.
6) Using TRANSCAD Software to determine the No of candidate points for dry port construction.
7) Considering different goods/services in goods being transported in the network.
8) Applying time periods for goods delivery.
9) Applying true conditions such as fluctuations in data and parameters (dry port construction costs, goods demand, etc.).
10) Determining environmental criteria in optimum selection of dry port site.
11) Using optimization and robust methods under uncertain conditions.
This research has studied items 1-6 and 11 above as research innovations.

3. PROBLEM DEFINITION

Cargo transport network in Iran contains nodes among which goods move; part of the cargo enters/leaves the country through sea ports. This paper aims at the optimum design of a transportation network of goods entering Iran via sea ports; this optimum design and reduced network costs will result in the construction of dry ports. The network

discussed in this research involves goods export/import centers in different cities of Iran, Shahid Rajaee & Imam Khomeini Sea ports in the south of Iran, and existing road axes.
This paper aims, first, at investigating the necessity of dry port construction and then locating and determining the No of locations considering multimodal transportation as a combination of road and rail, and allocation of import/export centers and coastal ports to them. To develop railroads, it has been assumed that there are rails between all network points and the reasons for selecting train and its development in the problem are such issues as high goods security that leads to the enhancement of the applicant's satisfaction and desirability, environmental adaptability, higher train capacity compared to truck, lower space requirement compared with road, and lower railway transport costs. On the other hand, since goods storage time in coastal depots is high leading to ships' traffic and high waiting time for docking, loading, and unloading in the sea port, many cargo ships towards Iran go to such high speed ports as Jabal Ali in the UAE and then enter Iran by paying costs in the common border; this causes currency outflow because of the low service efficiency in the coast and coastal port. This problem can be solved by constructing dry ports and rapid cargo transport from sea ports to them.
Assumptions made in the model are: 1) origin-destination routes are not necessarily single-dry port; they can have more (e.g. origin-dry port-dry port-destination), 2) after dry port location is specified, no direct origin-destination routes shall exist, and 3) as regards transportation, time and cost parameters are considered together, but regarding goods transport, time parameter is omitted because it is negligible and optimization is applied only on cost parameter.

3.1. Problem definition

The model proposed in this part is a multi-allocation, median, P-hub, programming model with some variations in the objective function, and constraints commensurate with the problem objectives and assumptions. Indices, parameters, and variables used in the problem mathematical modeling have been described as follows:

	Indices
i	Origins that send goods (i=1,…,N)
j	Destinations that receive goods (j=1,…,N)
k	First hub in the network of hubs where cargo enters (k=1,…,H)
l	Last hub in the network of hubs where cargo leaves (l=1,…,H)
m	Transportation mode (road & rail) mϵ M={1,2}
	Parameters
f_k^c	Fixed cost of constructing hub k in case C for hub capacity level
O_i	Demand for goods transport from origins i to all destinations
χ^m	Unit cost of goods transport from origins to hubs using mode m
δ^m	Unit cost of goods transport from hub to destinations using mode m
α^m	Unit cost of goods transport inside network of axes using mode m
γ^m	Route capacity using mode m
W_{ij}	Matrix of goods demand between origins i and destinations j
ch_k	Operational cost per unit flow of goods entered hub k
d_{ik}	Distance from origin i to hub k
d_{kl}	Distance from hub k to hub l
d_{lj}	Distance from hub l to destination j
pk_k^c	Capacity level in case C for constructing hub k
	Variables
x_k	Dry port locating binary variable ($x_k \epsilon\{0, 1\}$)
u_{ik}^m	Goods transported from origin i to hub k using mode m
v_{lj}^{im}	Goods transported from origin i to destination j through hub l using mode m
y_{kl}^{im}	Goods transported from origin i to the network of hubs and transported between hubs k and l using mode m

Objective function (Eq. 1) involves costs and is made of 4 parts: 1) construction costs of each hub between dry port selected candidate points at capacity level C, 2) transportation costs from origins to axis found by multiplying χ^m (unit road/rail transport cost) by d_{ik}(origin-hub distance) byu_{ik}^m (goods flow); operational costs of each hub($\mathrm{ch_k}$) depends on the rate of flow ($\mathrm{u_{ik}^m}$) entering it, 3)transportation and operational costs inside network of hubs, and 4)transportation costs of goods flow from hubs to destinations.

$$Min \sum_{c\in C}\sum_{k\in H} f_k^c x_k^c + \sum_{m\in M}\sum_{i\in N}\sum_{k\in H}(d_{ik}\chi^m + ch_k)u_{ik}^m + \sum_{m\in M}\sum_{i\in N}\sum_{k\in H}\sum_{l\in H}(d_{kl}\alpha^m + ch_l)\, y_{kl}^{im} + \sum_{m\in M}\sum_{i\in N}\sum_{l\in H}\sum_{j\in N} d_{lj}\delta^m v_{lj}^{im} \qquad (1)$$

Model constraints are as follows:
Constraint 2 ensures that all flows sent from each origin to destinations are collected by the network of hub.

$$\sum_{k\in H}\sum_{m\in M} u_{ik}^m = O_i \qquad \forall i \qquad (2)$$

Constraint 3 ensures that all flows distributed from hub (or total flow exited from the network of hubs) are equal to the values of the demand matrix.

$$\sum_{l\in H}\sum_{m\in M} v_{lj}^{im} = W_{ij} \qquad \forall i,j \qquad (3)$$

Constraint 4 ensures that the flow transfer difference occurred in the network of hubs is equal to the difference between inflow to and outflow from that network.

$$\sum_{k\in H}\sum_{m\in M} y_{kl}^{im} - \sum_{l\in H}\sum_{m\in M} y_{lk}^{im} = \sum_{m\in M} u_{ik}^m - \sum_{j\in N}\sum_{m\in M} v_{lj}^{im} \qquad \forall i,k \qquad (4)$$

Constraint 5 ensures that the goods flow between 2 hubs in the dry port network is less than that from origins to hubs (sometimes, goods leave the network as soon as they enter it without any inter-hub transport; in other words, for some goods, the optimum origin-destination route involves only one hub in the network of hubs).

$$\sum_{l\in H}\sum_{m\in M} y_{lk}^{im} \le \sum_{m\in M} u_{ik}^m \qquad \forall i,k \qquad (5)$$

Constraint 6 ensures that the total flow from any origin to a hub is less than that leaving that origin; in other words, if candidate point k is selected as a hub, total flow from origin i to hub k is less than that leaving origin i.

$$\sum_{m\in M} u_{ik}^m \le \sum_{c\in C} O_i x_k^c \qquad \forall i,k \qquad (6)$$

Constraint 7 ensures that the outflow from the last axis in the network of dry ports in the optimum route between a pair of specific origin-destination is less than the demand between the two.

$$\sum_{m\in M} v_{lj}^{im} \le \sum_{c\in C} W_{ij} x_l^c \qquad \forall i,j,l \qquad (7)$$

Constraint 8 ensures that the inflow to any hub is less than its capacity.

$$\sum_{k\in H}\sum_{m\in M} u_{ik}^m \le \sum_{c\in C} \Gamma_k^c x_k^c \qquad \forall k \qquad (8)$$

Constraint 9 ensures that each hub is constructed at only one capacity level.

$$\sum_{m\in M} x_k^c \le 1 \qquad \forall k \qquad (9)$$

Constraints10, 11, and 12 ensure that road and rail chord capacity limitations will be applied.

$$u_{ik}^m \le \gamma^m \qquad \forall i,k,m \qquad (10)$$

$$v_{lj}^{im} \le \gamma^m \qquad \forall i,j,l,m \qquad (11)$$

$$y_{kl}^{im} \le \gamma^m \qquad \forall i,k,l,m \qquad (12)$$

Constraint 13 states that the locating variable is a binary one.

$$x_k \in \{0,1\} \qquad \forall k \qquad (13)$$

And finally, constraint 14 ensures that the network's origin-hub, hub-hub, and hub-destination flow is positive.

$$u_{ik}^m, v_{lj}^{im}, y_{kl}^{im} \ge 0 \qquad \forall i,j,k,l,m \qquad (14)$$

4. MODEL ASSUMPTIONS AND DATA

The following assumptions and data have been used in this case study:

1-The dry port construction candidate points have been selected from among roads-railroads connection points and those specified by experts from previous surveys in Iran and include Tehran, Isfahan, Khorasan Razavi, North Khorasan, Kerman, Fars, and Yazd (Fig. 1).

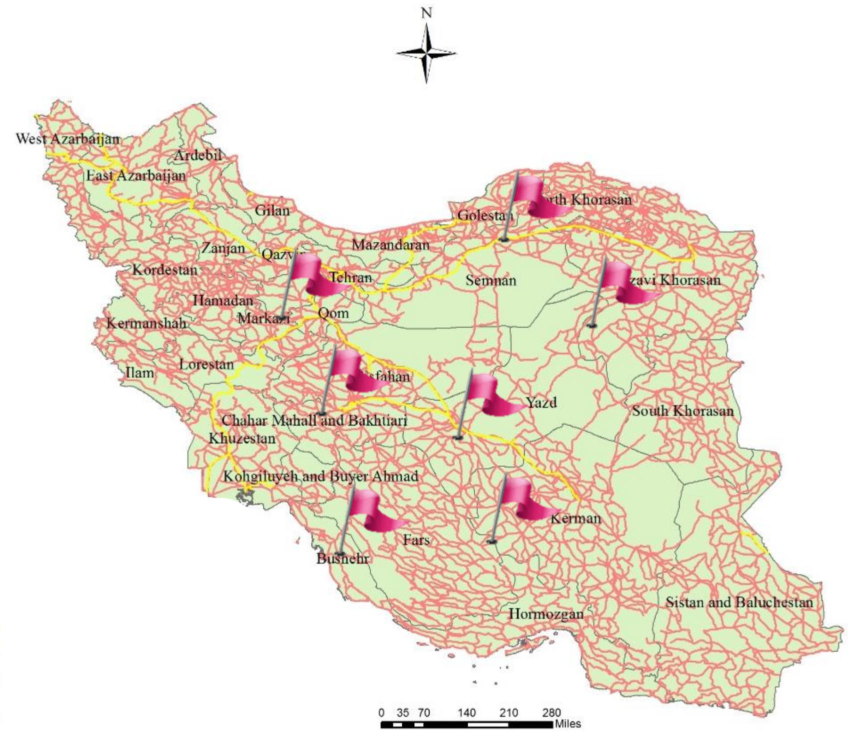

Fig. 1- candidate points for dry port construction

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2- A very important economic factor that affects the developed model is the dry port construction and operational costs; the land price in each region has been determined by experts.

3- The load flow data between various points of the transportation network has been extracted from the information obtained from the Ports and Maritime Organization and Road Maintenance & Transportation Organization.

4- There are three specific railways in Iran; to develop transportation by train, it has been assumed that there is a rail link between all points in the network.

5- Based on the available historical data, three scenarios have been considered for the demand parameter and their average has been used to obtain the result of the exact model.

6- The road and railway load transportation capacities have been assumed to be 8000 and 10000 tons/year, respectively.

7- Assumed dry port capacities used in the model are shown in Table (1).

Table 1- Capacities assumed in the model for dry port construction

ID code of the dry port construction candidate point	1	2	3	4	5
Dry port capacity (1000 tons)	30	45	50	65	70

4.1. Model results

In this section, the most important results obtained from the exact and robust median P-hub location-allocation models applied in the case study have been analyzed and their differences investigated. It is worth noting that the models have been solved using the CPLEX solver of the GAMS Optimization Software Version 24.1.2.

4.2. Total cost of the network and computational performance

First, it is necessary to compare the dry port transportation network design models in the exact and robust states as regards the total costs of the transport network and computational performance. Table (2) shows the total costs of the transport network in both the exact and robust states.

Table 2: Comparison of objective functions under robust and exact states

Model	Aghazof	Exact
Value of the objective function (rials)	12 E + 168000	11E + 126000

Results show that compared to exact models, robust optimization models will result in higher transportation costs due to increased network stability and overcoming demand uncertainties.

4.3. Optimal design of the transport network in both the exact and robust states

A very important decision made in this research is to determine the locations and capacities of dry ports and allocating Iran's internal sea ports and import-export centers to them. Figs. 2 and 3 show the locations of the dry ports and how the load transport network points are allocated under the exact and robust models. Results reveal that since both models suggest similar candidate locations for dry ports, it can be concluded that the optimal locations of the dry ports are largely robust; in other words, the optimality of these decisions do not change when data fluctuate. This means that these locations remain optimal for almost all uncertain parameters. These points include: Kerman, Fars, and North Khorasan and the optimum capacity found from the proposed model is 50 million tons.

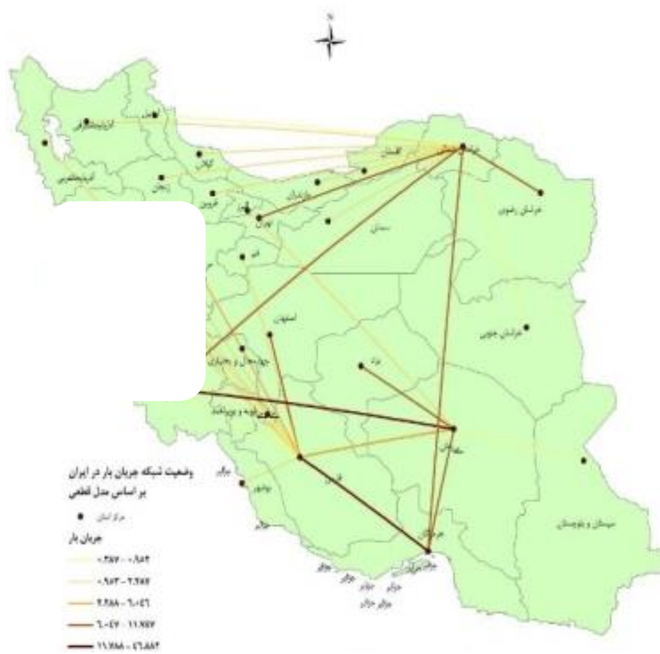

Fig. 2- Situation of the load flow based on the exact model

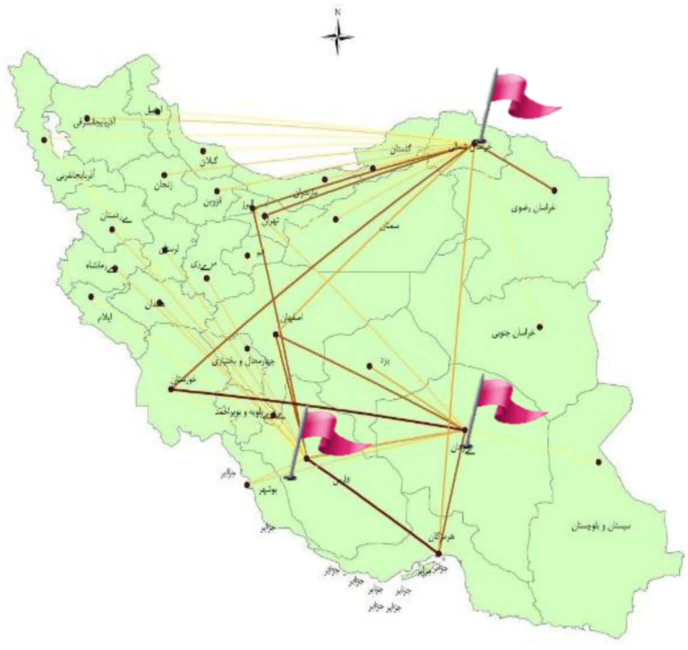

Fig. 3- Situation of the load flow based on the robust model

Fig. 4- Comparison of the transportation network costs for different candidate points for dry port construction

According to what was explained, it can be inferred that using the robust programming approach is justified to redesign the load transport network under disorder conditions. So far, some studies have been done on dry port construction in Yazd, Sarakhs, Shahid Motahhari Terminal, and Aprin, but none has yielded its final results; selection of each of these as the candidate point for the construction of a dry port has been exogenous and the cost of the network has been investigated only for Yazd. Now, placing the mentioned points in the proposed model's objective function their network costs are estimated. Fig. 4 shows that the transportation network costs for Kerman, Fars, and North Khorasan found endogenously by the model are less than other cases.

As shown, the load transport network costs, considering only one dry port as a presumption, is much more than when the model determines the number and location of the dry ports endogenously under optimal conditions. Therefore, Aghazov's robust model presents the best solutions for the number/location of dry port/ports considering the demand parameter fluctuations under different scenarios. Now, the candidate points and their exact selection will be addressed.

5. CONCLUSIONS

This paper first addressed the necessity of constructing dry ports in the marine cargo transport network and then justified the necessity of their presence in Iran. Since the most important question in dealing with the construction of dry ports is about their proper location, an exact median P-hub locating model that makes decisions on the appropriate number and location of dry ports and allocating import-export points to them in the sea ports and inside the country, was proposed for locating dry port/ports considering multimodal transportation. The objective function of the proposed model minimizes the transportation, operational, and construction costs and the model specifies the optimal capacity of each dry port and the amount of load transported in the network by each road and railway combined and simultaneously. To cope with the inherent ambiguity of such problem parameters as demand, use was made of the robust optimization method that specifies a robust, optimal, and justified solution considering the trend of the historical data of the desired parameter. The model flow numerical outputs showed that, under all circumstances, the rail was primarily used for the cargo transport. The model results suggest that use should be made of the railroads to transfer loads between all network points. The model validation too revealed that specifying the number and location of dry ports exogenously and as a presumption did not necessarily lead to an optimal solution as regards the minimization of the network transport costs. The model suggests that three dry ports should be constructed in Kerman, Fars, and North Khorasan with a proposed capacity of 50,000 tons.

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