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Mathematical Approaches for Finding a Dry Port Optimum Location on the Level of Intermodal Transport Networks

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ABSTRACT: In an increasingly dynamic business environment, the goal of any supply chain is providing competitive services to customers, especially in terms of costs. This is why over the last years there has been a remarkable growth of interest regarding the establishment of the location of the intermodal transport networks hubs that carry out the goods transfer, consolidation and grouping. Throughout this study we will try to perform a theoretical transition from the usual intermediate storage platform to the concept of "dry port" (a key component of the intermodal transport chain) in order to determine the optimal location for establishing it. We will approach two distinct methods that can be used to determine the optimal location of a facility, a genetic algorithms and a linear programming, in order to establish which of these methods give us the more appropriate results in accordance with our economic set goal. Theoretical discussions will be transposed at different ports of Dobrudja, respectively seaports: Constanta, Mangalia, Midia and river ports: Murfatlar, Medgidia and Cernavoda. Although it seems a local approach, the optimal solution that was found has a particular significance due to the geographical position of these ports (the Rhine-Main-Danube Canal and the Danube-Black Sea Canal), but also due to their importance and their share in the transit of goods inwards Europe.

1 INTRODUCTION

The development of international trade of goods, the increase in the beneficiary requirements and the diversification of imports and exports have increased the importance of international transport and shipments. Transport costs have been meant to be reduced throughout the years, while transport represents a defining element in determining the final cost of a merchandise. Thus, it was tried to combine the advantages of transport in order to ensure significant cost reductions finally.

This is how the need for intermodal transport has emerged, which according to the common definition given by the European Commission, the European Conference of Ministers of Transport and Economic Commission for Europe of the United Nations (UN/ECE, 2001, p.17), is the "*transport of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods when changing modes.*"

Achieving intermodal transport, taking into account the globalization involves the existence of an appropriate infrastructure in order to achieve a "gate-to-gate" transport chain as productive as possible. It is supposed to allow for the passage of means of transport in terms of high performance, reduced parking in certain points of the transport networks and the use of modern facilities tailored for different categories of goods (Remes 2011).

As Floden (2007) states in his paper, one of the basic elements of the system of intermodal freight transport (along with the collection and distribution of goods and transport system flows of freight over long distances) is the intermodal transport terminal.

The intermodal transport terminal decisively contributes to the efficiency of the whole transport process, as it is an element that ensures effective transfer of load units (containers, swap bodies or semi-trailers) on a modal system of transport to another. Its role is more complex, as terminals represent an enclosed area, provided with special equipment and infrastructure, where various operations are carried out: transshipment, storage, and other logistics operations. For this reason, intermodal transport terminals are considered key elements in intermodal transport networks.

2 THE DRY PORT CONCEPT

In the course of time, the logistics system led to major changes in its elements being executed a gradual shift from platform usual intermediate storage, transport terminal, or more to the concept of "dry port".

As stated above, the transport terminal is a key element in intermodal transport networks, generally defined as nodes. The connections made between these hubs are basically the carried out transport, finally making up the intermodal transport network (Roso et al., 2008).

Globalization, the development of transport and the freight volume growth led to major improvements in transport terminals and to the enhancement of activities thereof, for the purpose of increasing efficiency of the entire transport chain. Thus, the development of terminals has become a crucial factor in ensuring competitive advantages of seaports.

In this regard the literature makes the transition from classical storage platform to more complex elements of the intermodal transport network designed to provide efficiency and profitability: intermodal terminal or dry port (Jaržemskis and Vasiliauskas, 2007).

Over time many definitions of the concept of "dry port" have been formulated, but a comprehensive definition was offered by Roso in 2008: *"a dry port is an inland intermodal terminal directly connected to a seaport by large means of transport (at least two different modes of transport), where customers can leave / pick up their standardized merchandise just like in a seaport"* (Roso, 2008).

The specialized literature shows several benefits of dry port sites, which are those that determine their competitive advantages (Cullinane, 2012). Indian Customs (2004) establishes the following advantages - thus, they:

- represent important points of concentration of goods over long distances;
- provide customs clearance (which is most often available near the centres of production and consumption);
- reduce the risks of theft from the actual amount of merchandise;
- ensure a low level of demurrage;
- influence the final cost of transportation;
- eliminate the need for customs inspections in seaports;
- contribute to increased trade flows;
- reduce he transit of empty cargo units (especially empty containers) etc.

Ciortescu (2016) identifies in his doctoral thesis the competitive advantages that a dry port area brings along in terms of its location. This causes a series of positive aspects both socially, economically, and in terms of environmental protection. Thus, on a social level, it substantially reduces the number of road accidents by traffic decongestion, increases the level of safety and security of containers, and especially contributes to the increase in the number of jobs. Economically, it reduces the time required for handling operations/operating containers, especially reducing existing costs in container traffic. Regarding environmental protection, it creating a dry port contributes to the reduction of external costs of transport units loads (lowering the noise level in road infrastructure, it contributes to the road traffic decongestion at the gate of the seaport, it may contribute to the decrease of fuel consumption by using transport rail etc.).

The implementation of a dry port contributes to the massive reduction of the number of links to/from seaports (Beresford et.al., 2012). As can be seen in the figure below, a conventional transport is based on a large number of road or rail links at great distances from the seaports. Carriage to be achieved through one or more dry ports allows for short-distance transport, grouped and consolidated accordingly. They are supposed to increase productivity by increasing the capacity of intermodal terminals, along with the operation of very large capacity vessels (Roso and Lumsden, 2009; Roso, 2007).

The classification of dry port sites in terms of the distance between the sea ports that they serve and between themselves categorises them in: close, mid-range and distant dry port (Woxenius et al., 2004).

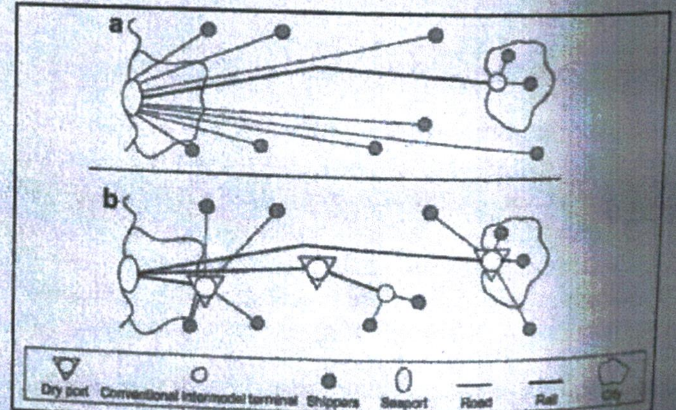

Figure 1. (a) Conventional hinterland transport and (b) implemented dry port concept (close, mid-range and distant dry port).
Source: Roso, V., 2007

3 MATHEMATICAL APPROACHES FOR FINDING A DRY PORT OPTIMUM LOCATION

In an ever-increasing dynamic business environment, the goal of any supply chain aims to provide competitive services to customers, especially in terms of costs. In this respect, an increasing importance is given to establishing the location of points in the intermodal transport networks that carry out the transfer, consolidation or group of commodities.

The location of a dry port requires a decision influenced by many factors (both qualitative and quantitative), which in the long run, affects the costs and revenues over which no later change can be made (Eroglu & Keskinturk, 2005). It must be located in such a manner as to ensure customer satisfaction by providing the shortest distance transport.

In this paper we address two different ways by which one can determine the optimal location, genetic algorithms and linear programming, trying to determine which of these methods give us results that correspond our proposed economic purpose.

The problem of determining the optimal location of a site of some kind is a matter of planning already addressed through operational research techniques, being first introduced in 1965 by Balinski (1965). This issue aims to minimize transportation costs, as well as fixed costs associated with the site, while also considering the restrictions and conditions data.

Establishing the optimal location for a dry port, can be done through several methods, such as:

- genetic algorithm;
- linear programming method.

In this article, we critically analyse the results of the two methods for the ports of Dobrudja.

4 CASE STUDY

Theoretical discussions presented above will be implemented in the Dobrudja ports, i.e. sea ports Constanta, Mangalia and Midia on the one hand and river ports Murfatlar, Medgidia and Cernavoda on the other hand. Although the problem is local, the optimal determined solution is important both due to the geographical site of these ports (Rhine-Main-Danube and Danube-Black Sea Canal) and to their significance and share of the transit of goods to inland Europe.

Taking into account these aspects, we will seek the best location of a dry port.

The analysed problem can solve both of the following situations simultaneously:

- **Situation 1**: For general goods arriving to Romanian seaports, the question of building a dry port arises from where the goods to proceed towards the three river ports (Murfatlar, Medgidia and Cernavoda) to serve their entire hinterland area.

Table 1. Data related to the first situation

City	Population	Distance to (km):		
		Constanta	Midia	Mangalia
Murfatlar	10,746	18	41	55
Medgidia	43,841	40	47	76
Cernavodă	20,105	62	86	102

- **Situation 2**: Various agricultural, industrial or mineral products obtained in different parts of Dobrudja, arrive to three river ports, where they are stored for a period of time and then are transported to the three sea ports (Constanta, Midia and Mangalia).

Table 2. Data related to the second situation

City	Population	Distance to (km):		
		Murfatlar	Medgidia	Cernavodă
Constanta	319,168	18	40	62
Midia	32,300*	41	47	86
Mangalia	33,434	55	76	102

* The data is for the population of Navodari, the closest city to Port of Midia.

The network made between the seaports/river ports and possible dry port locations is shown in the figure below.

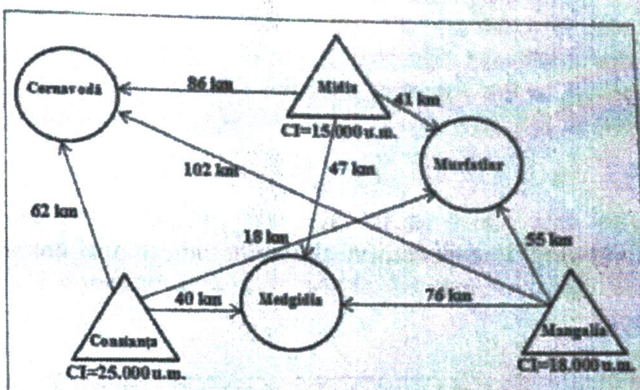

Figure 1. The network made among possible locations of the dry port and potential distributors

4.1 *Method I: The genetic algorithm method*

This search and optimization method was presented and analysed by Carp and Stinga (2016). The genetic algorithm method differs from other conventional search techniques due to its mechanism of natural selection and genetic inheritance.

The objective function used was:

$$min\left(\sum_{i\in I} x_i \cdot CI_i + \sum_{j=1}^{m} \min_{i\in I_1}(d_{ij} \cdot \frac{P_j}{100}\right))$$

where:

- J={1, 2, ..., m}, is the set indexed by *j*, consists of potential providers;
- I={1, 2, ..., n}, is the set indexed by *i*, made up of possible locations for intermediate storage platform;

- $I_1 = \{ i \in I \,/\, x_i = 1 \}$;
- $x_i = \begin{cases} 1, \textit{ if there is a platform on "i"} \\ 0, \textit{if there is not a platform on "i"} \end{cases}$
- CI_i, represents the installation costs associated with each possible location of the platform;
- $d_{i,j}$, is the distance between the storage platform and the distributors;
- P_j, is the existing population in every city where the storage platform can be placed.

The table below shows the results obtained using genetic algorithms using the MATLAB software.

Table 3. The results obtained by using genetic algorithms

The running time of the algorithm	Number of iterations	Value of the objective function	The structure of the solution chromosome
0.624989	100	43,316.16	(011000)
0.569121	100	29,243	(000100)
0.573037	100	23,910.3	(001000)
0.563188	100	36,181	(000010)
0.604099	100	26,934.28	(100000)
0.621351	100	19,405.86	(010000)
0.600968	100	36,181	(000010)
0.544985	100	26,934.28	(100000)

Comparing the results obtained by using the Matlab software, for the objective function values we concluded that the dry port will be located at Midia, as the objective function value is 19,405.86.

4.2 *Method II: Linear programming method*

The data allow us to take into consideration the following transportation problem, where the costs are direct connected to the distances between the ports:

	Murfatlar cost	Medgidia cost	Cernavoda cost	Demand Value $*10^3$
Constanta	36	80	124	3194
Midia	82	94	172	5833
Mangalia	110	152	204	5974
Offer Value$*10^3$	1225	7146	5026	

Since the total demand isn't equaled to the total offer, the problem is not balanced and we have to consider a virtual consumer as follows:

	Murfatlar cost	Medgidia cost	Cernavoda cost	Virtual consumer	Demand Value$*10^3$
Constanta	1225	1969	-	-	3194
	36	80	124	-	
Midia	-	5177	656	-	5833
	82	94	172	-	
Mangalia	-	-	4360	1604	5974
	110	152	204	-	
Offer Value$*10^3$	1225	7146	5026	1604	

Initial solution is: $x_{11}=1225$, $x_{12}=1969$, $x_{22}=5177$, $x_{23}=656$, $x_{33}=4360$, $x_{34}=1604$. The significance of $x_{34}=1604$ is that the quantity 1604 offered at Mangalia will not be distributed.

The cost associated to the initial solution is $C=1225*36+1969*80+5177*94+656*172+4360*204$ or $C=1,690,530$.

Since the optimum criteria aren't satisfied, the initial solution was transformed as follows:

	Murfatlar cost	Medgidia cost	Cernavoda cost	Virtual consumer	Demand Value$*10^3$
Constanta	1225	1313	656	-	3194
	36	80	124	-	
Midia	-	5833	-	-	5833
	82	94	172	-	
Mangalia	-	-	4360	1604	5974
	110	152	204	-	
Offer Value $*10^3$	1225	7146	5026	1604	

The cost associated to the second solution decreased, being $C=1,667,226$,

Since the optimum criteria aren't satisfied again, the solution was transformed as follows:

	Murfatlar cost	Medgidia cost	Cernavoda cost	Virtual consumer	Demand Value$*10^3$
Constanta	1225		1969	-	3194
	36	80	124	-	
Midia	-	5833	-	-	5833
	82	94	172	-	
Mangalia	-	1313	3047	1604	5974
	110	152	204	-	
Offer Value $*10^3$	1225	7146	5026	1604	

The cost associated to the third solution decreased, being $C=1,657,722$.

The solution is not optim, so we transformed it in:

	Murfatlar cost	Medgidia cost	Cernavoda cost	Virtual consumer	Demand Value$*10^3$
Constanta	-		3194	-	3194
	36	80	124	-	
Midia	-	5833	-	-	5833
	82	94	172	-	
Mangalia	1225	1313	1822	1604	5974
	110	152	204	-	
Offer Value $*10^3$	1225	7146	5026	1604	

The set of dual variables are solutions of the system:

$U_1+v_3=124$ $U_2+v_2=94$ $U_3+v_1=110$ $U_3+v_2=152$ $U_3+v_3=204$

A particular solution of it is the following: $U_1=0$ $U_2=22$ $U_3=80$ $v_1=30$ $v_2=72$ $v_3=124$ and now the criteria of optimum are completed, so this solution is the optimal one. The minimum cost is C=1,650,372.

Since the best connection and distribution is done from Mangalia, we can conclude that a dry port could locate there.

5 CONCLUSIONS

The two methods presented are not at all similar, or equivalent. Their conclusion are not identically because the objective functions are different: the genetic algorithm was related to the minimization of the total cost of installation and allocation of the consumption and the objective function of the transportation problem is the minimization of the transportation cost only. The best location could be established using the two complementary methods.

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