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SOME ASPECTS OF SITE SELECTION FOR THE DRY PORT TERMINALS

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Abstract: *The choice of the location of a dry port is a very complex process of the multicriteria decision making. The port should be located next to the larger city that has a high-quality rail and/or road connection to the port, enough qualified workers, to possess a proper intermodal technology, etc. The basis of the selection of a location consists of six key requirements that determine it: the distances and the amount of flow in transportation, a level of the economic development of priority areas, the state of the infrastructure, the degree of the trade development, the required level of environmental protection, and the minimum cost. This paper analyzes some of the factors determining the choice and the importance of the logistics center, and the problems that occur when making decisions. It points to the need to use multi-criteria analysis. There are shown some of the models for the choosing of the location of dry port terminals, and allocation of users to new dry ports. Into the focus, there are placed the problems of the single allocation dry port median with unlimited capacity, and problems of the single allocation dry port median with limited capacity. Also, here is presented a proposal of one allocation model of dry port concept establishing. The model is tested in the case of the port of Bar.*

INTRODUCTION

Dry port terminals are a relatively new concept which in practice gives very positive results. A basis of the complex process of site selection consists of six key requirements:

- the distance and the amount of flow in transport,
- economic development level of priority areas (GDP, commercial and industrial growth),
- state of the infrastructure (security, number, and distribution of the logistics centers),
- the level of development of trade (condition of complementary activities, the level of import-export),
- the required level of environmental protection (regional, and local along the route),
- minimum costs (costs of transport, lease of land, and taxes).

There are many methods and different approaches to solving the problem of location of dry ports, as it is shown in [1]. The most commonly are used: non-parametric DEA (*Data Envelopment Analysis*), ANP (*Analytic Network Process*), Fuzzy C-clustering, Genetic fuzzy clustering etc. In the continuous location-allocation problems, one or more optimal locations are places in continuous space that are considered. In the discreet location problems, there is a fixed list of possible locations, and the task is confined to the selection of one or more locations from the final or discrete set of possible locations [2], [3]. In networked location problems, a mathematical structure is used: weighted graph or a network, and the task of site selection comes down to treating the network and the selection of one or more sites in the discrete network hub locations problems, or a place(s) in the continuous network hub location problems.

Models of Dry Port Terminal Site Selection

Location theory reliably solves the problems of selecting the location of the terminal, and the allocation of customers to new dry ports. In certain cases, the objects can be located at any point of the region (continuous location problems). Another group of location problems means that objects can be located only in some predefined points (discrete location problems). If there is a pre-set number of dry ports (p) to be located, we are talking about the problems of *p-Median Problem* to minimize the sum of the cost of transport from the initial port to the dry port, from the dry port to the dry port, and from the dry port to the customers. In the case that the number of dry ports is not already defined, it is necessary to plan fixed costs for their establishing.

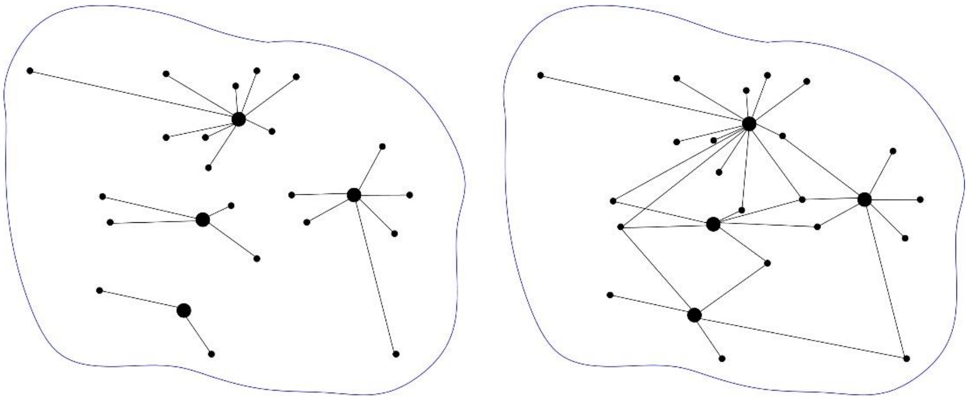

Fig.1. Examples of single and multiple allocation p-dry port median problems of 25 end users and the four dry ports

If the number of medians with which the customers can be connected is not limited, it gives the problem of multiple allocations. On the other hand, if each end user is connected to only one dry port, this is a single allocation problem. Figure 1, shows the solution of the problem of four dry ports with 25 customers in the forms of a single (the left image), and the multiple allocations (the right image) [4]. Basically, there are two basic concepts:

- The dry port single allocation scheme median with the incapacitated hub location problems, and
- The dry port single allocation scheme median with the limited capacity.

In the first group, it has been shown that these problems belong to the *NP-hard problems*, even when the dry ports' locations are fixed. Here is defined a mathematical formulation of the problem together with the given constraints while minimizing the total cost of transportation between the port and the dry port, between two dry ports, and between the dry port and the end user [5].

In the second group of problems, it is about dry ports locations selection and the allocation of customers, when there are restrictions in the form of capacities of all, the dry ports and roads. The goal is to choose a set of the dry port terminals and to join the end-users to them so that the sum of the transport and other costs of establishing of the terminal is minimal. It is possible to define a mathematical formulation of the problem together with the given limitations, and, also, NP-completeness of this problem has been proven, while the total cost of the transport on the network and the fixed costs of establishing of the dry ports are minimized. [6].

A PROPOSAL OF AN ALLOCATION MODEL IN ESTABLISHING OF THE DRY PORT CONCEPT

Allocation problems belong to NP-hard problems. If even a dry port location is fixed, the allocation part of the problem remains NP-hard. For a fixed set of dry ports, the sub problem of determining of multiple allocations can be solved in polynomial time, while single allocation sub problem remains NP-hard. Single allocation problems, especially problems of 2-Hub and 3-Hub median. In the case of two hubs, the problem is solvable in polynomial time, for the fixed location of hubs. For the number of hubs greater and equal to three, the problem is NP-hard. The concept of solving the location selection is shown in figure 2.

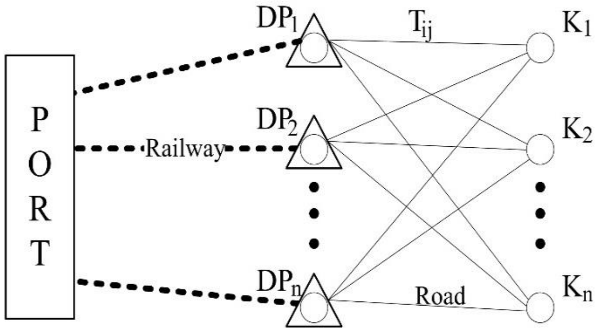

Fig.2. The concept of the proposed allocation model

The following variables can be introduced:

Q_{ij} - The amount of the cargo;

α - Relational coefficient;

L_{ij} - Euclidean distance between the established dry port *i* and the end user *j*;

C_{ij} - Pure transport price (without reloading costs) according to the current rate of road transport between the established dry port *i* and end user j [1];

X_{ij} - 1 if the end user *j* is served over the established dry port *i*. Otherwise, 0.

Relational coefficient α takes values between 0 and 1. Its value decreases with increasing size of L_{ij}. This way it is achieved reducing the cost on long distances. The model predicts that for the mileage of up to 60 km coefficient takes the value 1; for mileage from 60 to 100 km, 0.9; for the mileage of 100 to 140 km value is 0.8, while for mileage over 140 kilometers the value of this ratio is chosen to 0.7. The aim is to achieve cost reduction (T), and a mathematical formulation of the analyzed problem has the following form:

(1) $\min \sum T_{ij}$

under restrictions:

(2) $\sum_j X_{ij} = 1$

The cost function has the base form:

(3) $T = Q_{ij} \cdot \alpha \cdot L_{ij} \cdot C_{ij} \cdot X_{ij}$,

while a single allocation achieves by the restrictions, i.e. each user is served by a single dry port.

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[1] 1,1 € per kilometer according to the applicable rates in road transport..

If there are established two or less dry port terminals, based on this work, the problem can be solved in polynomial time of the work of computers. If there are established three or more dry port terminals, it is to assume that the problem belongs to the group of NP-hard problems and that must resort to heuristics and metaheuristics algorithms. To solve the problem in polynomial time, as appropriate methods are proposed optimization algorithms (e.g. integer programming), while for NP-hard problem solving, as a method GA metaheuristics is suggested.

TESTING OF THE MODEL IN THE CASE OF THE PORT OF BAR

The proposed allocation model will be tested in the case of the port of Bar. In accordance with the schedule of potential beneficiaries and the geographic and demographic constraints, there are proposed locations of potential dry ports in the cities of Virpazar, Podgorica and Bijelo Polje. All these towns have a rail link with the port of Bar and they are considered to be the most appropriate given the disposition of the customers to be served, as well as in terms of the conceptual development of the dry port terminals.

Table 1 Test data for the network

Link (DP-K)	Q_{ij} (t)	α	L_{ij} (km)	C_{ij} (€/tkm)	T (€)
1-1	90	1	37	1.10	3663
1-2	83	0.9	78	1.10	6409
1-3	115	1	34	1.10	4301
1-4	94	0.8	129	1.10	10671
1-5	88	0.8	111	1.10	8596
2-1	78	1	36	1.10	3089
2-2	106	1	52	1.10	6063
2-3	92	1	18	1.10	1822
2-4	74	0.9	86	1.10	6300
2-5	90	0.9	95	1.10	8465
2-6	83	0.8	127	1.10	9276
2-7	94	0.9	70	1.10	6514
2-8	88	0.9	90	1.10	7841
2-9	78	0.8	115	1.10	7894
2-10	106	0.8	177	1.10	16511
3-4	92	0.9	74	1.10	6740
3-5	74	1	54	1.10	4396
3-6	80	1	52	1.10	4576
3-7	103	1	51	1.10	5778
3-8	93	1	30	1.10	3069
3-9	82	1	51	1.10	4600
3-10	115	0.9	83	1.10	9450

Customers are located in the following cities: Cetinje, Niksic, Danilovgrad, Pluzine, Savnik, Zabljak, Kolasin, Mojkovac, Andrijevica, and Pljevlja. The input data for the network are given in Table 1. Data on the amount of cargo were adopted for practical reasons as hypothetical, while the location of customers in 10 cities of Montenegro are real. Euclidean distance between the established Dry ports and end-user was calculated using the software Google Earth, i.e. by means of its application to calculate the lengths according to the planned path.

The mathematical form of the problem in the given case has the following form:

(4) min: $3663\cdot X_{11} + 6409\cdot X_{12} + 4301\cdot X_{13} + 10671\cdot X_{14} + 8596\cdot X_{15} + 3089\cdot X_{21} + 6063\cdot X_{22} + 1822\cdot X_{23} + 6300\cdot X_{24} + 8465\cdot X_{25} + 9276\cdot X_{26} + 6514\cdot X_{27} + 7841\cdot X_{28} + 7894\cdot$

$X_{29} + 16511 \cdot X_{210} + 6740 \cdot X_{34} + 4396 \cdot X_{35} + 4576 \cdot X_{36} + 5778 \cdot X_{37} + 3069 \cdot X_{38} + 4600 \cdot X_{39} + 9450 \cdot X_{310}$

under restrictions:

(5) $X_{11} + X_{21} = 1,$

(6) $X_{12} + X_{22} = 1,$

(7) $X_{13} + X_{23} = 1,$

(8) $X_{14} + X_{24} + X_{34} = 1,$

(9) $X_{15} + X_{25} + X_{35} = 1,$

(10) $X_{26} + X_{36} = 1,$

(11) $X_{27} + X_{37} = 1,$

(12) $X_{28} + X_{38} = 1,$

(13) $X_{29} + X_{39} = 1,$

(14) $X_{210} + X_{310} = 1$

The problem was solved by using binary integer programming in the program WINQSB (*Windows Quantitative Systems for Business*). Results were as follows:

Variables X_{21}, X_{22}, X_{23}, X_{24}, X_{35}, X_{36}, X_{37}, X_{38}, X_{39}, X_{310}, they have value 1, which means that these branches of the network are associated to established dry port terminals for each customer. The value of the goal function is: 49143.

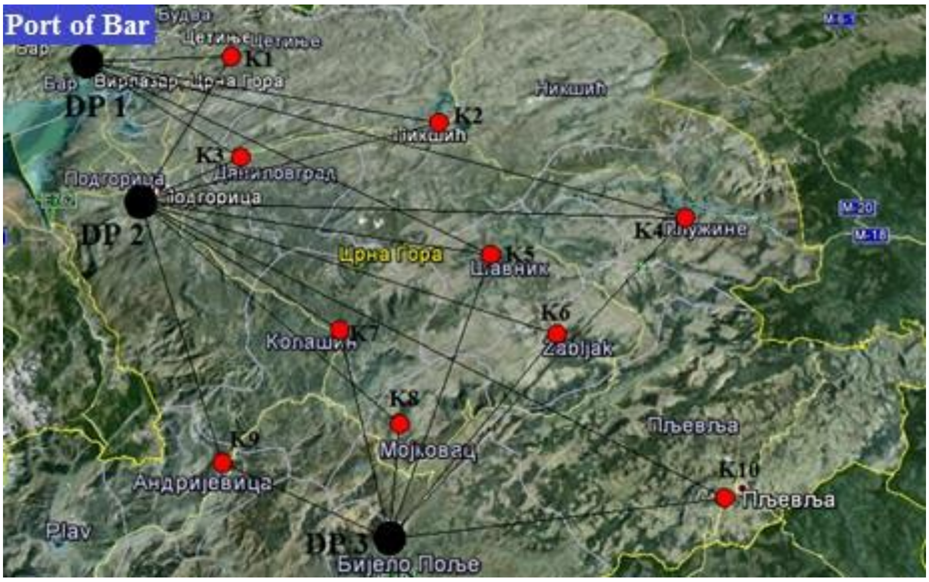

Fig. 3. Output of the model - Layout of the users after modeling

As from DP_1 no one end user is served, a closure of DP_1 is proposed. Figure 3 shows the allocation of end users in the dry ports DP_2 and DP_3).

CONCLUSIONS

The mathematical problem for solving the problem of dry port location selection is done according to two reliable models. Based on the analysis of existing dry ports and the available literature it can be concluded that the dry ports should be a part of transport policy, as they can offer significant advantages for the majority of stakeholders. In further research, each potential dry port location needs to be considered individually because they all differ in terms of available infrastructure, the stakeholders, a number of orders, available operators, etc. It would be important to establish a set of rules and regulations that could be applied to all dry port issues in intermodal transport, in the various local communities, the region, and beyond.

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НЯКОИ АСПЕКТИ ПРИ ОПРЕДЕЛЯНЕ МЕСТОПОЛОЖЕНИЕТО НА ПРИСТАНИЩНИ ТЕРМИНАЛИ ЗА ОБРАБОТКА НА НАСИПНИ ТОВАРИ

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СЪРБИЯ

Ключови думи: *пристанищен терминал за обработка на насипни товари, проблеми при определяне на местоположението, моделиране*

Резюме: *Определянето на местоположението на пристанищен терминал за обработване на насипни товари е сложен проблем, който изисква вземането на определен набор от мултикритериални решения. Пристанището трябва да бъде разположено в близост до по-голям град, който е осигурен с железопътна и пътно-шосейна инфраструктура, в който да работят добре квалифицирани служители, да разполага с подходящи съоръжения за интермодални превози и пр. Основно, изборът на подходящо разположение на пристанището се определя от шест ключови изисквания: направление и количество на товаропотоците; равнище на икономическо развитие на приоритетния регион; състояние на инфраструктурата; развитие на търговията в региона; изискуемо ниво на опазване на околната среда и минимални разходи. В настоящия доклад са анализирани някои от основните фактори, които определят избора и важността на логистичния център, както и проблемите, които възникват при този избор. Особено внимание в доклада е отделено на необходимостта от приложението на мултикритериен анализ. Представени са някои модели за избор на подходящо местоположение на пристанищните терминали за обработване на насипни товари, както и избор на потенциалните товародатели. Във фокуса на изследването попада също така и анализът на проблемите, които възникват при определяне на местоположението на пристанище с неограничен капацитет, както и на такова с ограничен капацитет. Предложен е модел за определяне на местоположението на пристанищен терминал за обработване на насипни товари, като този модел е апробиран в пристанище Бар.*