Location of an intermediate hub for port activities

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Location of an intermediate hub for port activities

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Abstract. An intermediate hub might increase the accessibility level of ports but also hinterland and so it can be considered more than a facility with a transhipment role. These hubs might lead to the development of other transport services and enhance their role in gathering and covering economic centres within hinterlands and also getting the part of logistic facility for the ports, with effects on port utilization and its connectivity to global economy. A new location for a hub terminal leads to reduced transport distances within hinterland, with decreased transport costs and external effects, so with gains in people's life quality. Because the production and distribution systems are relatively fixed on short and medium term and the location decisions are strategic and on long term, the logistic chains activities location models have to consider the uncertainties regarding the possible future situations. In most models, production costs are considered equal, the location problem reducing itself to a problem that aims to minimize the total transport costs, meaning the transport problem. The main objective of the paper is to locate a hub terminal that links the producers of cereals that are going to be exported by naval transportation with the Romanian fluvial-maritime ports (Galaţi, Brăila). GIS environment can be used to integrate and analyse a great amount of data and has the ability of using functions as location - allocation models necessary both to private and public sector, being able to determine the optimal location for services like factories, warehouses, logistic platforms and other public services.

1. Introduction

In order to distinguish the need for facility location actions one must foresee the material flows that they would generate, the ”inputs” and the ”exits” brought by the new locations, so, the products that would be transported (raw materials and products). The essential role of transportation is to reduce distance and allow people and economic agents to put aside space. In a continuous space, in theory, all relations are possible but, in reality, defining the transport system takes into account different restrictions like time, transport cost and space itself that might be ameliorated or overcame by certain conditions and in favour of space continuity (law cost and split-able infrastructures, high quality services etc.).

Literature regarding economic activities location has evolved from classical, descriptive modelling to mathematical and probabilistically modelling. In the 18th century, Turgot established the fundaments of commercial location theory and Von Thunen [1], at the beginning of the 19th century, explained that ”the optimal location for agricultural activities is represented by the points where the land rent is maximum”. In 1909, Weber [2] has developed the first industrial location model that has the objective of minimizing the transport costs and that was updated later by authors like Hoover, Lösh and more recent, based on rectangular distances, by Huriot and Smith [3]. August Losch and

Walter Christaller, based the central point theory [4] that supposes that a consumer will always search to buy a product or a service by travelling the shortest possible distance. Owen et al. [5] has grouped network location models (discrete space) in three major categories: covering problems, where serving a client depends on the distance from him to the production facility that he is allocated to, distance lower than a pre-established limit, satisfying all needs with minimum total costs; Church and ReVelle [6], based on the covering concept, underlie the maximum covering problem (Maximum Covering Location Problem - MCLP), trying to maximize the served demand with a limited number of new production centres; the p-central problem that aims establishing p production centres and allocating each client to the closest of them so that the maximum distance between demand points and production centres would by minimum; the p-median problem [7], where locating the p production centres must be realised so that all demands are covered and the total costs are minimum, in the following hypothesis: the number of facilities is apriority known, the costs of establishing new facilities are the same no matter the potential location and the facilities have no capacity restrictions. The Uncapacitated Facility Location Problem (UFLP) is derived from the p-median problem, by endogenous determination of the number of facilities to be located and was followed by the Capacitated Facility Location Problem (CFLP) [8].

Recent development of the location-allocation models took into account integrating these models within the geographical information systems (GIS) by generating GIS data and by structuring the objective functions of the different models like software modules in GIS [9]. By this integration, decidents might limit the search area of new locations based on well fundament decisions.

2. The location-allocation model

The location-allocation models select optimal locations from a set of possible locations in the most efficient manner and allocate demand for a certain service to these facilities, depending on the demand distribution. The main objective of the location models is assuring the covering of all demand within a specific area for a certain length of the route, predefined, within a standard response time, also predefined.

Location-allocation models have three base components:

- the distribution of the demand points and of the raw material supply points;
- candidate production centres` position;
- distances/travel times matrix from the points of demand/raw materials to consumption.

The study within the paper integrates GIS models and geo-spatial analyse based on location-allocation models with the main objectives:

- evaluation of the existing locations of the silos and their territory covering;
- necessity of locating new silos in order to reduce costs and realise a better coverage of the territory;
- examining the way that these models are sensitive to the change of location for different points on the network.

The minimum impedance problem of the ArcGIS software tries to find new locations so that the weighted costs sum between production and consumption points would be minimum, with certain restrictions. The first set of restrictions says that the demands outside the impedance limit will be considered unallocated and the second set imply that the demands outside the impedance limit will be allocated to the closest centre [11]. This type of problem is similar to the p-median problem of Hakimi but further restriction regarding the capacity of the silos has to be taken into consideration.

The p-median problem consists in finding the locations of p centres on a network so that the total cost is minimized, supposing the situation where the cost of covering the demands of node i is given by the product of the demand of node i and the distance from node i to warehouse/silo j [7]. It can be formalised like an integer linear programming problem:

$$v(P) = \min \sum_{i=1}^{n} \sum_{j=1}^{n} h_i d_{ij} x_{ij} \tag{1}$$

with the restrictions assuring that every *j* node is allocated to just one *i* node that has to be a median and that determine the exact number of medians to be located. Church and Reveille [6] introduced the maximum covering condition (MCLP – Maximum Covering Location Problem) that puts aside the condition of serving all clients and implies a limited number of new facilities, with the formulation:

$$\max \sum_{i \in I} h_i y_i \qquad (2)$$

and with restrictions regarding the fact that *i* client's demand is covered if there is at least one facility situated at most the service distance and that the total number of facilities is limited.

For the case study the area chosen was the one of Brăila and Galați counties as major cereals flows pass through this area to be shipped abroad. The existing silos of the two ports have capacities of 25000 tones, the one in Brăila and 31000 tones, the one in Galați. The silos taken into consideration were the ones with capacity exceeding 10000 tonnes in order to be able to realise a complete train to the destination (table 1) [12,13]

Table 1. Silos in the two counties analysed.

Silos	County	Capacity [t]
Vădeni	Brăila	14000
Traian	Brăila	60000
Ianca	Brăila	29000
Făurei	Brăila	10000
Dudești	Brăila	44100
Jirlău	Brăila	10300
Tecuci	Galați	10000
Independența	Galați	59000
Ivești	Galați	13000

3. Data handling and modelling

The data set in GIS format has been realised by grouping the data-bases used in network formalisation in a structure of network geo-database type within ArcCatalog. The attributes of the links and nodes of the network were taken into consideration, length and capacity. Then, the layers with the necessary data were built in order to analyse the different location-allocation models (figure 1). From the multitude of models offered by ArcGIS, the Maximize Capacitated Coverage model was chosen as the facilities are located such that as many demand points as possible are allocated to solution facilities within the impedance cut-off; additionally, the weighted demand allocated to a facility can't exceed the facility's capacity.

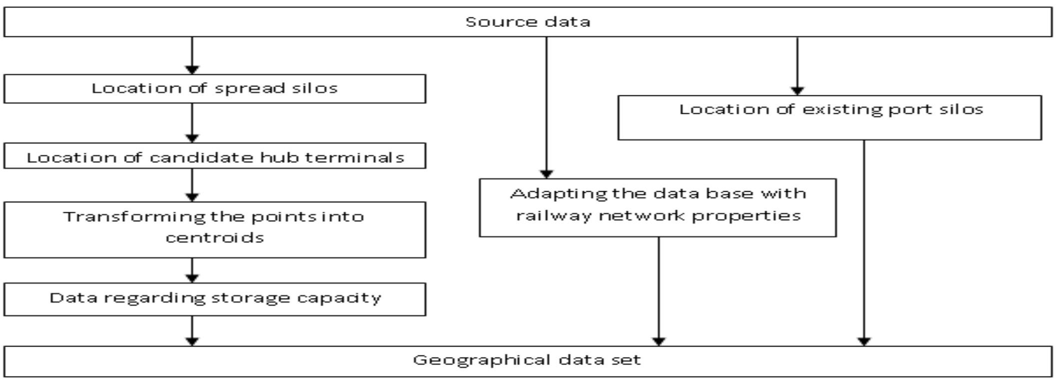

Figure 1. The process of data integration within GIS environment.

Three hypothesis were taken into account, the first were the demand had to be covered by the existing silos in the three ports, were the lack of capacity played a major role, the second considering establishing two new silos of higher capacities in the two ports and the third were only one silo had to be put in place, with a capacity necessary to cover all demand (figure 2).

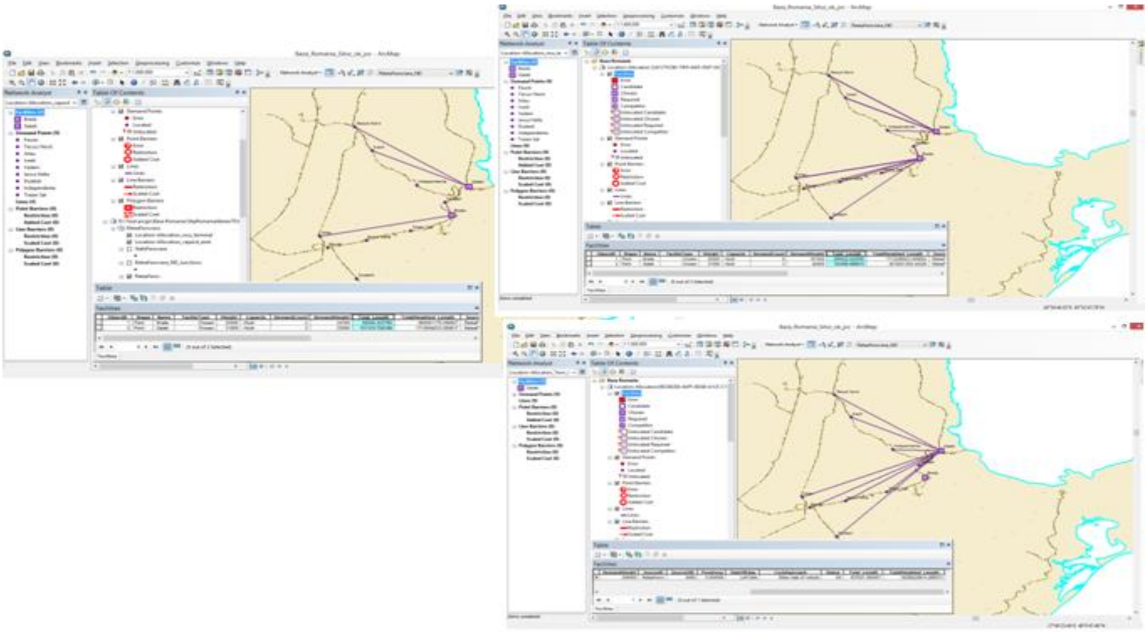

Figure 2. Result of the simulation of the three hypotheses.

4. Results and discussions

After running the three models the logistic parameters regarding the transport process were determined (table 2).

Table 2. Transport parameters in the three hypotheses

Considered model \ Transport parameters	Total length [km]	Total weighted length [t·km]
Existing port silos with limited capacity	233835	10658480409
Two new port silos with the necessary capacity	463911	11323218123
One new silo with the necessary capacity (Galați)	637021	16209229914

Among them [10]:
- total length covered by the transport means:

$$D_{\hat{\imath}} = \sum_{p=1}^{\theta} \sum_{w_t=1}^{\Omega_t} \frac{Q_p^{(w_t)}}{q_{o/p}^{(w_t)}} \times \frac{1}{l_{o/p}^{(w_t)}} \times d_{\hat{\imath}/p}^{(w_t)} \tag{1}$$

- total weighted length:

$$P_u = \sum_{p=1}^{\theta} \sum_{w_t=1}^{\Omega_t} v_p^{(w_t)} \times d_{\hat{\imath}/p}^{(w_t)} \times q_{o/p}^{(w_t)} \times \frac{l_{o/p}^{(w_t)} + 1}{2} \tag{1}$$

where: $D_{\hat{\imath}}$ is the loaded trip for all transport means, during θ time interval,

$Q_p^{(w_t)}$ – transport flow for the covered area with $w_t\left(w_t = \overline{1,\Omega_t}\right)$type transport vehicles in a $p\left(p = \overline{1,\theta}\right)$ period,

$q_{o/p}^{(w_t)}$ – average size of a delivery,

$l_{0/p}^{(w_t)}$ – average number of deliveries in a trip,

$d_{\hat{\imath}/p}^{(w_t)}$ – length of the average loaded trip.

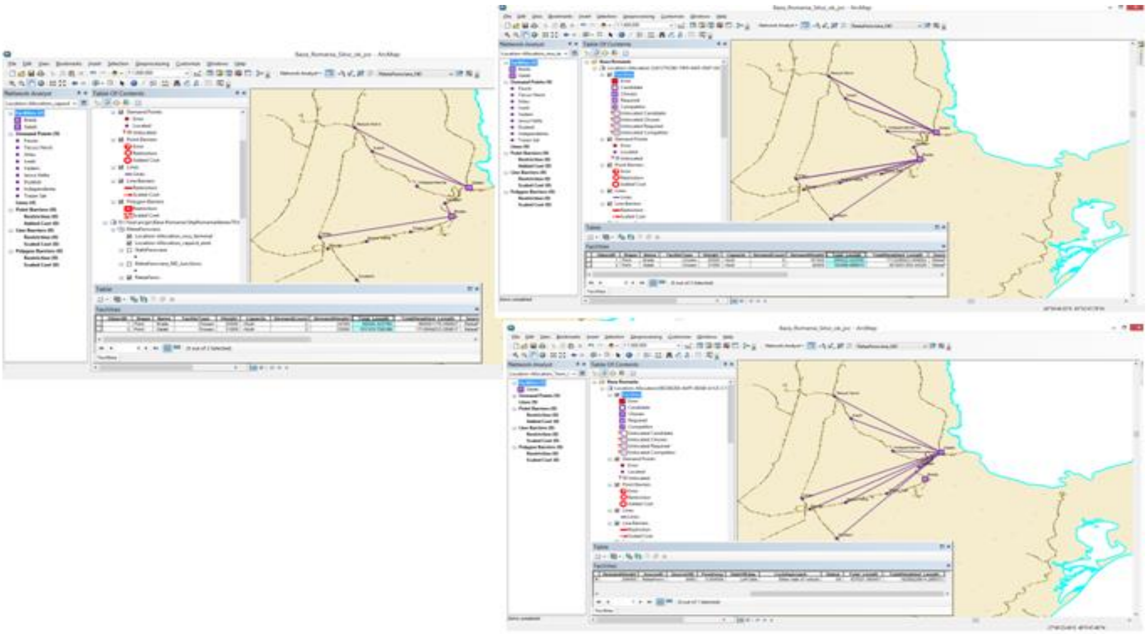

Figure 3. Result of the simulation of the three hypotheses.

The existing situation is not able to cover all demand at the right time, bringing up major waiting times and so, relevant costs increase. In the second hypothesis the demand could be covered but with major strategically decisions necessary as establishing two facilities is a hard thing to do and not feasible as the Port of Galați has an on-going project for building an intermodal terminal. In the third hypothesis, even though the total length increased by 34%, the total weighted length, the one bringing incomes to the transport operators, increased by 43%.

5. Conclusions

In order to discern the need for location/relocation actions we must know the transport flows that would be generated and that would eventually become transport processes together with the set of points regarding production areas and possible locations. Location decisions are critical in realising the logistic chains and for their operation. Misplaced facilities might lead to costs increase and low service quality no matter stock, transport or information politics. As the number of located facilities increases they become closer to users and determine transport cost diminishing with higher operational costs. As location decisions are strategic and long term decisions, the facility location models must take into account uncertainties regarding possible future situations. One might see that most models consider equal production/storage costs, the location problem becoming a problem with the objective of minimising the total transport costs, the so called transport problem, with a solution that might be perceived as the determination of the set of market and production areas [11].

Optimization of the multitude of the logistic activities supposes accepting lower performances for some activities so that the whole logistic chain efficiency would increase. By comparing the transport indicators of the models even though the total length increased by 34%, the total weighted length, the one bringing incomes to the transport operators, increased by 43% and so, the facilities were able to be used almost at their full capacity, bringing up benefits to the port and to the storage and handling operators within. GIS might be used to integrate and analyse a great amount of data and has the capacity of using functions like the location-allocation models, so necessary to the private and public sector by being able to determine optimal locations for private and public services.

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