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Inland waterway ports nodal attraction indices relevant in development strategies on regional level

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Abstract. Present paper aims to propose a set of ranking indices and related criteria, concerning mainly spatial analysis, for the inland waterway port, with special view on inland ports of Danube. Commonly, the attraction potential of a certain transport node is assessed by its spatial accessibility indices considering both spatial features of the location provided by the networks that connect into that node and its economic potential defining the level of traffic flows depending on the economic centers of its hinterland. Paper starts with a overview of the critical needs that are required for potential sites to become inland waterway ports and presents nodal functions that coexist at different levels, leading to a port hierarchy from the points of view of: capacity, connection to hinterland, traffic structure and volume. After a brief review of the key inland waterway port ranking criterion, a selection of nodal attraction measures is made. Particular considerations for the Danube inland port case follows proposed methodology concerning indices of performance for network scale and centrality. As expected, the shorter the distance from an inland port to the nearest access point the greater accessibility. Major differences in ranking, dependent on selected criterion, were registered.

1. Regional development context

Literature review highlights that some critical needs are required for potential inland waterway ports sites to be candidates for development strategies on regional level. In the perspective of regional or national actions, in order to support the successful operation of inland waterway ports, these critical needs can be identified from the point of view of some of the main actors and their functions at inland waterway ports [1], [2]. These, in turn, impact the modal corridors (rail, waterway and highway) along which they are located. Since the operations of traditional ports are assumed at some inland waterway ports, the critical needs of traditional ports can be expected to provide a list of critical needs at an inland port. From the point of view of a community public authority (planning agency) a list of assets necessary for a site to become an inland waterway port can be provided [3]. This asset list comprehensively describes what communities can concentrate on to develop into an inland waterway port and can be considered the critical needs:

- Intermodal transportation capacity: rail, highway, deep water access;
- Demographic advantage: large percent of national population;
- Geographic advantage: access to markets;
- Presence of shippers: demand already exists;
- Information technologie infrastructure: infrastructure in place;
- Public/Private cooperation: an established working relationship.



From an inland port point of view, a well-functioning and efficient transport infrastructure is fundamental. Inland ports are a lot more than entrance and exit gates on the waterway. Inland ports are important nodes in the inland transport network. Their success depends on their efficient transport links with the seaports and with the different economic centers. At the same time, seaports and inland ports can be considered as very important “feeders” of rail freight trains and their lines in the European Union.

Transport corridors development increases the polarization and zoning of logistics sites in transport nodes (inland waterway ports) and along the axes between them and inland centers [4]. Logistics poles exercise a location pull by combining a strong intermodal orientation with cluster advantages. Conventional location theories support the tendency towards polarization. The geographical concentration of logistics companies creates synergies and economies of scale which make some of the potential sites even more attractive and further encourages concentration of distribution companies in a particular area [5]. Geographical differences in labor costs, land costs, availability of land, level of congestion, the location near the service markets, labor mentality and productivity and government policy are among the many factors determining observed development of inland waterway ports.

2. Inland waterway port insertion within region

Inland waterway ports main regional economic role is to link a region to global supply chains. Functional relations between inland waterway port and its region, mainly within a port authority can be best represented in a three layers system [6], with the first layer representing the port terminal itself, notably in terms of volume, capacity and performance, the second layer the logistics activities related to the inland terminal, often in co-location, and the third layer represented by an array of retailing and manufacturing activities which inputs or outputs are handled or managed by the logistics activities of the second tier (Figure 1).

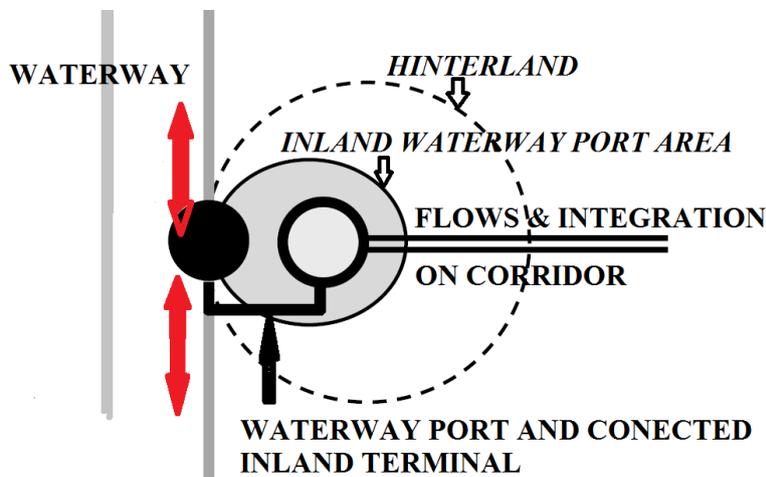


Figure 1. Functional relations waterway port – region
Adaptation [7]

In this context, the hinterland can be considered the summation of all the flows of the three layers. Although the hinterland represented on Figure 1 is continuous, it can be discontinuous as well, particularly if the inland waterway port is a node within a global supply chain. Many actors are involved in an inland port, each having its own strategy depending on its core business even if vertical integration could lead to some overlapping. At the same time, various functions could be developed in an inland port depending on the actors involved (Table 1). The most basic inland port is an inland terminal allowing the modal shift of the containers from barges or trains to trucks or vice versa. The warehousing function is almost non-existent. In this case, the inland terminal is a node in a transport

chain, with an increasing level of integration due to containerization, but without a direct intervention on the goods being transshipped. Door to door services are provided mostly by freight forwarders through merchant haulage or by shipping lines through carrier haulage. Trucking companies, rail or barge operators could also theoretically develop door-to-door services even if in fact they are the most basic transport providers, being subcontractors of freight forwarders or shipping lines.

Table 1. Main function at inland waterway ports according to different studies

Rodrigue & al 2010	Notteboom 2000	Bavoux 2005
<i>Transport functions:</i>	<i>First generation ports</i> (before 1960s)	<i>Connecting function</i>
Terminal function	<i>functions</i>	
Load center	Transshipment (1)	<i>Shelter function</i>
Transmodal center	Storage (2)	
	Trade (3)	<i>Deconsolidation function</i>
<i>Logistic functions</i>		
Consolidation /	<i>Second generation ports</i> (after 1960s)	<i>Transmodal function</i>
Deconsolidation	<i>functions</i>	
Transloading	(1) to (3) + Industry (4)	<i>Feeder function</i>
Postponement		
<i>Land use</i>	<i>Third generation ports</i> (after 1980s)	
The inland port handles	<i>functions</i>	
and/or processes freight flows	(1) to (4) + Distribution (5)	
related to the		
hinterland/region	<i>Fourth generation ports</i> (after 2000s)	
	<i>functions</i>	
	(1) to (5) + Logistic control	

Source: Author's elaboration

All presented nodal functions coexist at different levels [7], [8], [9] and lead to a port hierarchy from the points of view of: capacity (equipment quantity, structure and performance), connection to hinterland, traffic structure and volume.

3. Ranking methodology

3.1. Criterion for inland waterway ports ranking

In order to be able to differentiate inland waterway ports, criteria for classification methodology are necessary (Table 2). Criterion used for port importance ranking, also quite interdependent, can be placed into two different categories:

- First category regards nodal attraction, expresses through accessibility as a result of spatial characteristics (connectivity and nodal position in hinterland on regional level), indexes associated to this criteria are quite difficult to quantify due to significant spatial and temporal variation).
- Second category regards port activity level expressed through traffic volume and structure, traffic flow origin and destinations, area of territory they serve and multimodality parameters. A criterion for classification can be found in infrastructure availability. Inland ports (and/or inland terminals) can be accessible by rail, inland waterways or a combination of both (in addition to road). Secondly, inland ports can be classified according to type of activity: freight, passenger or both and type of ownership: public ownership, private ownership, or a public private partnership where public and private entities cooperate. A third criterion for classification is the array of technical parameters of inland waterway port: area, water

chamber lock and port terminals. Another criterion lies in the importance of transportation and logistics activities (transshipment facilities for intermodal transport, production, logistics, and supply chain management). Passenger and freight traffic flows values are directly dependent of the criterions presented before.

The difficulty met when quantifying port activity level lies in dissociation of direct added value (activities strictly concerning port regarded as a node), indirect (industry using port facilities) and induced (socio economical influences in served territory).

Table 2. Overview of inland waterway port ranking criterion

Criterion	Selected parameter name	Clarifications
Nodal attraction	Connectivity Nodal position	Accessibility measures
Port activity level	Activity Scale Area Water chamber lock Port terminals Passenger or cruise terminal Passenger traffic flow Freight traffic flow Connection with rail Length of rail connection Road connection Transshipment facilities for intermodal transport	Freight/ Passenger/ Freight and passenger Number of sailings All land and water area that belongs to the port Wide and length dimensions Quays length Quays area Passengers per year Tons per year YES/NO Available tracks length Distance to the nearest highway YES/NO

Source: Author's elaboration

In present analysis, the focus in classifying inland ports is on accessibility as a result of spatial characteristics, connectivity and nodal position in hinterland on regional level. Proposed methodology assimilates inland waterway port with a complex transport node that represents an interface between „micro“-transport networks and the „macro“-networks and consequently it functions as a multiple role player in intermodal transport context. When analysts attempt to measure accessibility of an inland waterway port/ transport node, they try to measure the connection to its hinterland [10], [11]. The accessibility evaluation is useful, for example, when assessing connectivity or centrality of single transport mode but is insufficient in the assessment of intermodal transport and in cases where a port has multiple transport networks in close proximity so, a measurement and index can be more effective when considering and assessing the intermodal roles of an inland waterway port. Therefore the accessibility evaluation cannot be used as an integral indicator for the node status of an inland waterway port in the same way as the port accessibility index can be used to assess a single transport mode [12].

In this context, two indexes are chosen for nodal attraction ranking purpose: modal networks scale index and centrality classification index.

3.2. Port inland network scale performance index

Inland modal networks connected to inland waterway port can be placed into three categories: road, rail and logistics/ transshipment facilities for intermodal transport. The same weight is considered for each inland modal network, as shown in Table 3, as in the cases of evaluation of transport infrastructure and service of each country by the World Economic Forum and the case of logistics performance evaluation by the World Bank [13].

In Table 3 we can observe different types of inland transport modes around an inland waterway port and their scales.

Table 3. Modal networks scale index for inland waterway ports

Port/ Item	Rail network	Road network	Logistics/ transshipment	Total/ Inland network
<i>Scale</i>	<i>1/3</i>	<i>1/3</i>	<i>1/3</i>	<i>1</i>
Port A	YES	YES	YES	1
Port B	YES	YES	NO	2/3
...
Port P	NO	YES	NO	1/3

Source [14]

3.3. Port centrality performance index

When nodal attraction is concerned, the geographical location of an inland waterway port gives the basic information on spatial accessibility. Proposed centrality index gives a measure of nodal accessibility considering the proximity of central places in the ports hinterland.

It is assumed that the distance between considered origin – destination nodes (in present paper the set of inland waterway ports and the set of chosen central places) has a negative influence on the mutual attraction potential as time and cost directly depends on distance (the so called ‘distance hypothesis’) [8]. Therefore, centrality index is directly dependent on the provision of transport network infrastructure and, at some extent of transport services.

Table 4. Central places characteristics used for inland waterway port ranking

Central places parameters	Characteristics
Number of central places in the hinterland	Western Europe studies were conducted for places ranging from > 200000 to > 400000 inhabitants
Level of localization analysis for central places	Local Regional International
Measure for “scale” of central places	Population
Measure for “distance” from inland waterway port to central place	Distance (by road or rail) Travel time

Source: Author’s elaboration

Major differences in ranking, resulting from variations in the measure for distance on considered infrastructure network and the regions that are taken into consideration (Tab. 4) will always be relative because a location can only be more or less central when referred to a central area or a center place [8].

4. Romanian Danube inland ports analysis

4.1. Examined area

Recent analysis concerning transport flows on Romania level [15] shows that 72% from total is transported by road, 21% by rail and only 6% on waterway (Danube river).

From total flows, 17% is born from three main origin regions [16]:

- Constanta (NUTS – II Sud - Est / Region RO 22) - important industrial and commercial centre, maritime port handling an increased traffic flow - 17.7 million tones;
- București-Ilfov (NUTS – II Bucuresti- Ilfov/ Region RO 32), countries most industrialized region – 18.2 million tones;
- Gorj (NUTS – II Sud Vest – Oltenia / Region RO41) concentrating most of the countries mining and extraction activities – 19.5 million tones.

The same three regions named before proved to be main destination for traffic flows, attracting 14.5% from total traffic goods flow at country level.

The dataset of Romanian Danube inland ports of international importance (Figure 2) is largely based on data provided by port authorities.



Figure 2. Romanian Danube inland ports of international importance (*Source:* Author's elaboration)

If we consider two main types of ports [17]: maritime feeders (A, B, C) and inland waterway (1 to 11), then we can identify selected ports according to this classification (Table 5).

Table 5. Region examined and site identification overview of Romanian Danube inland ports

NUTS – II/ Regions	Counties	Area covered [mln km ²]	Population in region [mln inhabitants]	GDP - Total gross domestic product [mln Euro]	Ports involved/ Simbol used in figure 2
Sud - Est RO22	Braila Buzau Constanta Galati	35.7	2.54	6800	A - Braila B - Galati C - Tulcea 1 - Murfatlar

	Tulcea				2 - Medgidia
	Vrancea				3 - Cernavoda
Sud – Muntenia RO31	Arges				
Bucuresti- Ilfov RO32	Calarasi				
	Dambovita				
	Giurgiu				4 - Calarasi
	Ialomita	34.5	3.13	5900	5 - Giurgiu
	Prahova				6 - Oltenita
	Teleorman				
	Bucuresti- Ilfov				
Sud Vest – Oltenia RO41	Dolj				7 - Corabia
	Gorj				8 - Bechet
	Mehedinti	29.21	2.07	5600	9 - Calafat
	Olt				10 - Drobeta
	Valcea				T. Severin
					11 - Orsova

Data source: [18], [19]

4.2. Inland waterway classification indices for selected ports

For selected ports presented in Table 5 inland waterway modal network scale indices were calculated (Table 6) and port sites were accordingly ranked. Results show that sites with rail link and placed in the immediate proximity of A2 Bucuresti - Constanta highway ranked better.

Presented data only takes into consideration inland network and not shipping network that can, in some extent, affect the economic role of a port. The range of economic effects is, in fact, decided by different components of shipping and inland networks.

Table 6. Modal networks scale indices for inland considered waterway ports

Port symbol (*)	Rail network	Road network/ distance to the nearest highway in km	Logistic network	Total/ Inland network	Rank
Scale	1/3	1/3	1/3	1	
A - Braila	YES	YES/120	YES	1	(6)
B - Galati	YES	YES/ 1	YES	1	(1)
C - Tulcea	YES	YES/100	YES	1	(5)
1 - Murfatlar	NO	YES/ 36	NO	1/3	(12)
2 - Medgidia	YES	YES/29	YES	1	(3)
3 - Cernavoda	YES	YES/ 2	YES	1	(2)
4 - Calarasi	YES	YES/55	NO	2/3	(8)
5 - Giurgiu	YES	YES/63	NO	2/3	(9)
6 - Oltenita	YES	YES/50	NO	2/3	(7)
7 - Corabia	NO	YES/68	NO	1/3	(13)
8 - Bechet	NO	YES/ 75	NO	1/3	(14)
9 - Calafat	YES	YES/87	NO	2/3	(10)
10 - Drobeta	YES	YES/98	YES	1	(4)
11 - Orsova	YES	YES/100	NO	2/3	(11)

*According to Figure 2

Source: Author's elaboration

For ports centrality classification index calculation, even if Danube side Romanian waterway ports have the advantage of geo-strategic location [20] it is already established that major differences in ranking derives from variations in the measure for distance and the hinterland regions considered.

Port symbol (*)	Aggregate distance on road infrastructure [km]	Aggregate distance on rail infrastructure [km]	Weighted aggregate distance	Rank
<i>Weight</i>	<i>0.7</i>	<i>0.3</i>		
A - Braila	2451	2680	2519.7	(11)
B - Galati	2330	2538	2392.4	(10)
C - Tulcea	2852	3175	2948.9	(13)
1 - Murfatlar	2387	2256	2347.7	(8)
2 - Medgidia	2337	2373	2347.8	(9)
3 - Cernavoda	2193	2253	2211	(5)
4 - Calarasi	2084	2236	2129.6	(4)
5 - Giurgiu	1743	1840	1772.1	(2)
6 - Oltenita	1693	1788	1721.5	(1)
7 - Corabia	1769	1922	1814.9	(3)
8 - Bechet	1919	No rail connection		(14)
9 - Calafat	2147	2482	2247.5	(6)
10 - Drobeta	2265	2291	2272.8	(7)
11 - Orsova	2716	3216	2866	(12)

*According to Figure 2

Source: Author's elaboration

Main economic region in the hinterland of selected ports considered for this case study is South region of Romania (Figure 2) and selected central places range is of more than 200000 inhabitants, namely cities of Bucuresti, Brasov, Constanta, Ploiesti, Pitesti, Craiova and Timisoara. Data in table 6 lead to a measure for the centrality towards the selected South region of Romania hinterland in terms of the aggregate distance in km by road and by rail. Weighted aggregate distance is calculated considering that 70% from total traffic flow from inland waterway ports is split on road and 30% on rail consequent to data presented in section 4.1.

5. Conclusions

Romania has extensive inland waterways which in all cases underperform in terms of utilizing their potential capacities for freight transportation. The major reason for the unsatisfactory role inland navigation plays in coping with ever growing freight volumes in Central Europe is the lack of functional integration of the ports with their potential hinterland, and also with other ports. Likewise, the functionality of multimodal transport infrastructures is rather limited.

As expected, major differences in ranking dependent to the selected criterion (network scale and centrality) were registered. Each actor involved in the selection process can aggregate the results, according to the weight they impose on each criterion.

Results concerning inland waterway modal network scale show that sites with rail link and placed in the immediate proximity of A2 Bucuresti - Constanta highway are better ranked. As expected, the shorter the distance from an inland port to the nearest access point to a main road or highway the greater accessibility of the inland port, which can attract higher levels of transport flows and generate further growth in demand.

Inland waterway ports of relatively low importance (small ports), some of them with very low handling capacity, ranked first when centrality indices were considered.

Ports of Murfatlar and Corabia have no rail terminal and therefore no direct rail network connection and Bechet has no rail link, the nearest rail node is 15 km away. In the perspective of regional development strategies the value of financial public investment necessary for completing the missing infrastructure link is to be taken into consideration [21]. Port managers, national, regional authorities and municipalities cooperation is the only dimension that can provide the framework for the effective coordination of the different national and local transport and logistics policies towards increased the strategic function of multimodal transport infrastructure in handling traffic flows in the region and environmental sustainability.

In the context of a multi-level approach to land accessibility [8], present paper only addresses the basic two layers: the geographical location layer, characterized by centrality index (Table 6) and the provision of infrastructure layer, characterized by network scale index (Table 5). For further study, the upper layers, consisting in transport and logistics services, are to be taken into consideration and integrated into analysis.

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