Feasibility Study on the Logistic Competitiveness of Commercial Seaports in Southern Baltic Sea Region

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Summary:

This paper describes a feasibility study designed to determine the competitiveness of a seaport. The content presents a wholly unique approach to the examination and evaluation of the seaport competitiveness level based on the multi-criteria assessment model of their unique logistical characteristics. The research area is limited to the selected seaports located in the Southern BSR. This is the first stage of an international research programme using multi criteria logistics capabilities analysis combined with an adaptation of the Analytic Hierarchy Process (AHP) method for seaports competition level assessment. The paper also identifies unique criteria, sub-criteria and evaluated diagnostic features (parts of the logistic capabilities chart) of selected Southern Baltic Sea ports facilities taken from an analysis of the main processes and commercial profiles in the seaports of Gdańsk, Gdynia, Szczecin and Świnoujście (Poland) and Rostock, Lübeck (Germany). A specific decision-making model for practical assessment of the hypothesised seaport logistics potential has been proposed as well as a group of speculative ventures designed to verify the proposed solutions in subsequent field research.

Key words: seaport logistic capabilities; seaport competition; seaport facilities; seaport processes; shipping

JEL Classification: F 190, M 210

1. Introduction

Commercial Seaports (CSPs) are key links of the transportation processes taking part in the global logistics chain of supply. In inter-organizational and inter-subjective scope their activity is complementary to other links in the transport system. Their technical and logistic features make them multi-functional transport hubs that connect different systems between two

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distinctly different surface sectors - sea and land. The multi-functional aspect of CSPs is demonstrated by their ability to deliver comprehensive services related to transport and trans-shipment storage and handling, forwarding and related commercial activities as well as city-genic and region-generating demands. Often there is a close integration of logistics and industrial zones related to the shipbuilding and processing industries, light manufacturing and warehousing, and other industries within the context of the aforementioned multi-functionality (Acosta *et al*, 2010).

The economic importance of seaports for the local economy is recognised by their ability to function in relation to cargo handling as well as the ability to cooperate with other links in the supply chain. It is facilitated by applying logistics standards, the proper structure oriented to the service of various transport streams and the possession of necessary resources to do so (Hidekazu, 2002). Dependent on the seaport's ability to perform the above identified tasks (such as the exploitation of its' logistics capabilities), its level of competition in the selected region may be assessed.

2. Conceptual background – research problem and task

The main goal of this paper is to identify the unique logistics capabilities criteria of the Southern Baltic Sea Regions' (Southern BSR) commercial seaports: Gdańsk, Gdynia, Szczecin, awinoujście (Poland) and Rostock, Lübeck (Germany) necessary for the further multi criteria assessment of their competition levels based on the AHP method.

This requires the need to identify the seaports' logistics capabilities criteria, which are unique for the Southern BSR.

The research problem that needed to be resolved concerns the method of evaluation of a seaport's logistic potential. The Logistic Capabilities Chart that was drawn up and utilized in this research can become a universal and practical tool for the evaluation of competition levels between selected seaports located in the particular area (Southern BSR). In order to resolve the research problem the following tasks were identified:

- Define the area of knowledge necessary to solve the research problem;
- Determine the criteria groups, sub-criteria related to them and the diagnostic features which would enable the team to assess the logistics potential of a sea port in the Southern BSR;
- Propose a model for the logistics capabilities assessment together with the accompanying mathematical formula;
- Recommend further development and a model for verification.

3. Measuring seaport competitiveness

3.1. The organization, main operations and key processes of a seaport

A contemporary commercial seaport is a collection of logistics systems integrating several branches of transport depending on its location (Bozarth and Handfirld 2007). This collection includes the following subsystems (Grzelakowski and Matczak, 2012):

- The system of port infrastructure;
- The system of port superstructure;
- The system of logistics information exchange;

These systems facilitate the logistics processes, of which different branches of transport in the seaport are the constituents (Haralambides *et al*, 2010). The seaport infrastructure in the logistics aspect is the combination of such elements that allow receiving and providing services for ships, operational activities related to them and comprehensive services of the exported and imported cargo (Misztal, 2010) (fig. 1).

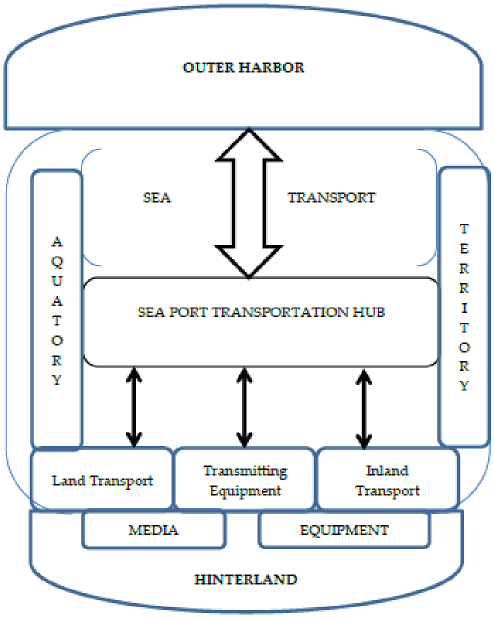

Fig. 1. Seaport infrastructure

The next critical element of a commercial sea port is its superstructure which is comprised of such elements of technical equipment as port trans-shipment systems, specialized warehouses and port storage areas as well as a supporting harbour fleet assigned to a particular port installation (Sanchez et al 2003) (fig. 2).

The superstructure determines the quality and efficiency of the logistic processes. It has an effect on the competition level of a seaport as an element of logistic operations. Misztal (2010) states the superstructure of a seaport is composed of elements such as:

- Cargo transhipment and transmitting equipment;

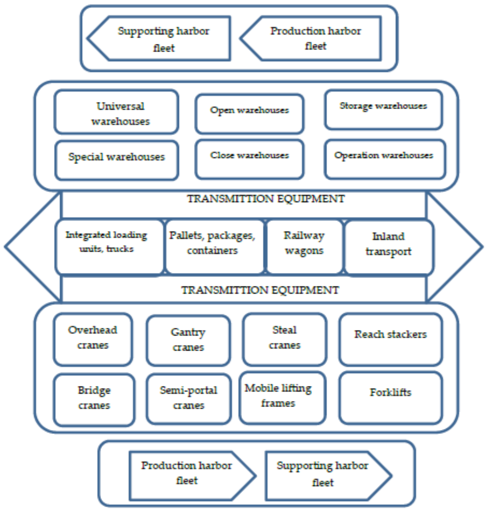

Fig. 2. Superstructure in the internal chain of supply of commercial seaport (Markusik, 2009)

- Operating harbour vessels providing navigation services for ships (e.g. piloting, towing, fuel bunkering, environmental safety);
- Supporting harbour vessels dedicated to ensuring ship's fire safety (firefighting units) and the maintenance of fairways and water basins that ensures safety of navigation (ice-breakers, dredgers, scows, hydrographic vessels);
- Warehouses and storage areas with complimentary equipment;
- Technical installations and equipment that maintains the durability and technical readiness of a port infrastructure and superstructure (e.g. repair shops).

The key process in a seaport can be divided into following operations (Peng-Hong *et al*, 2004, Esmer, 2008):

- Berth operations – based on the schedules of arriving vessels, allocation of the wharf space and the cargo handling resources (e.g. a quay crane availability and efficiency).

- Ship operations - involve synchronized sub processes of discharging from and loading cargo on board a vessel.
- Yard operations - consist of sub processes of discharging, loading as well as redistribution of cargo (yard shifting) involving (when necessary) inter-terminal haulage for further handling and loading onto another vessel or another means of transportation.
- Gate operations – sub processes which deal with freight forwarders (mostly external) involved in the import-export activities.
- Scheduling - the function (a part of seaport operations management system) that utilizes the various resource pools (e.g. prime mover, yard crane) in an efficient, synchronized and optimal way.

3.2. Seaport competition level assessment methods review

The competitiveness of a seaport is defined as an ability of a seaport to offer services that meet the quality standards of the local and world markets at prices that are competitive and provide adequate returns on the resources employed in all processes. This definition is closely linked to the performance indicators. For the port industry, being permanently under competitive pressure, measuring its performance is a matter of great importance. However, according to statistics and literature (Marlow and Casaca, 2003) such a measurement has been mainly focused on productivity indicators. The productivity of a seaport depends on its performance (especially in the logistics processes). According to Mentzer and Konrad (1991), performance is defined as an investigation of effectiveness and efficiency in the accomplishment of a given activity, where the assessment is carried out in relation to how well the objectives have been met.

UNCTAD (2009), supported by a paper from Bichou and Gray (2004) suggests two categories of seaport performance indicators:

- Macro performance indicators (which quantify an aggregate seaport impact on economic activity), and
- Micro performance indicators (which evaluate input/output ratio measurements of seaport operations).

Due to the complexity of seaport operations and crucial for further analysis process differentiation there are three main groups of indicators (Esmer, 2008), these are:

- Comparing actual throughput with an optimum level of attainment (mainly over a specific time period e.g. month, year)
- Calculating cargo-handling productivity (mainly at berth, seldom at quay, yard, terminal)
- Measuring single factors/processes in productivity.

In recent years significant progress has been made in the field of the availability of more complex tools. Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA), representing more comprehensive approaches have been increasingly employed to analyse seaport production and performance ratios (Tongzon, 2001).

As a consequence of the synthesis of the previously outlined seaport performance indicators, two broad categories, financial and operational (Esmer, 2008), have been introduced (table 1).

Table 1. Seaport broad performance indicators characteristic

Financial indicators	Operational indicators
labor expenditure	service time
tonnage worked	waiting time
capital equipment expenditure [per ton of cargo]	turn-around time
total contribution	tonnage per ship
contribution [per ton of cargo]	fraction of time berthed ships worked
cargo handling revenue [per ton of cargo]	number of gangs employed [per ship/ shift]
berth occupancy revenue [per ton of cargo]	tons per ship-hour in port/terminal
	tons per ship hour at berth
	tons per gang hours
	fraction of time gangs idle

Source: Esmer, 2008, p. 239

Financial analysts often look on seaports as business organizations. In such cases a seaport's performance measurement is based on profits. As a result analyses of a seaport performance and seaport comparisons from a value-added perspective are made. 'Value-added' in this context is defined as the difference between port revenues and port costs, which varies according to ship, cargo and operational types (Cullinane and Wang, 2006).

However, in the most aggregated way (Esmer, 2008) the competition level of a seaport is regulated only by two major factors:

1. The optimization in utilization of all available resources, and
2. The efficiency in management of all operations.

Using these two factors (which can be treated as the main goals to be achieved when considering effectiveness many objectives can be considered (Tu-Chang, 1992), such as:

- Increasing the port throughput,
- Increasing the level of utilization of resources (yards, quays, berths, cranes, etc.),
- Minimizing port congestion,
- Minimizing any possible disruptions,
- Optimizing demurrage and operating costs,
- Reducing handling time, etc.

Conceptual and organizational differences explain the variety of measures, but also expose the difficulty and complexity of measuring port performance and comparing seaports especially in terms of their regional economic impact (Notteboom and Rodrigue, 2005). As long as there is no widely-accepted approach to the roles and functions of seaports, the subject of what and how to measure performance, logistics process efficiency and competition levels will remain a debatable issue (Bichou and Gray, 2004).

4. The assessment of the logistic capabilities criteria of a commercial seaport (CSP) – the process approach

The activity of a CSP is recognized as the implementation of particular processes based on its logistics systems this can be presented as a transfer of materials, taking into account the feedback between the input/output system and the transferral system (fig. 3).

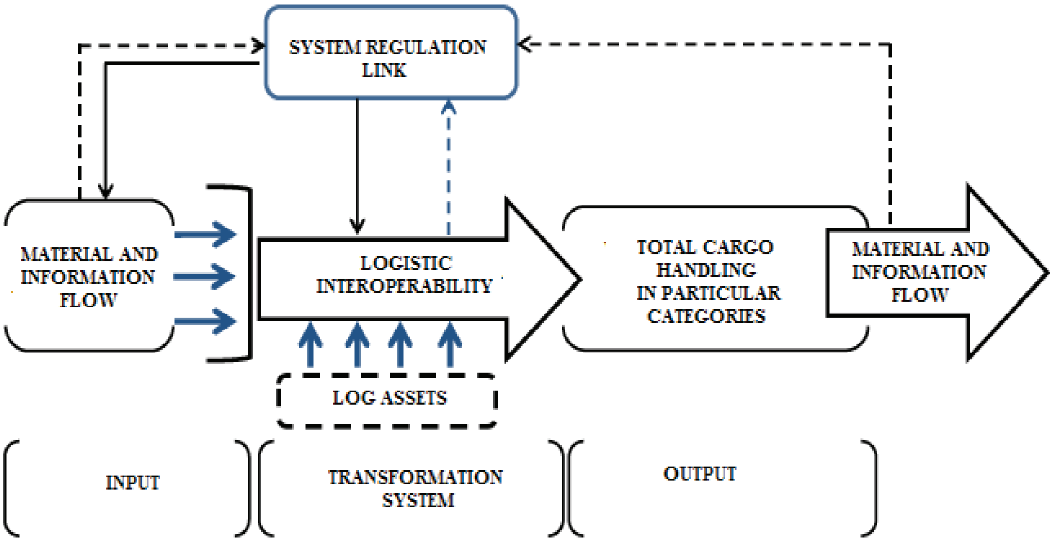

Fig. 3. Transfer of materials in a CSP, taking into account the feedback between the input/output (I/O) system and the transformation system

With regard to the above figure, the concept of the logistic capabilities assessment of a CSP has been based on the three main criteria, which include (Nejder, 2013):

- Economic results that are reflected in the turnover volume in various cargo categories (bulk cargo, conventional break bulk, break bulk in containers, ferry cargo, Ro - Ro cargo both self- and non-self-propelled) and the port charges (handling charges, tonnage dues, berth charges, pilotage, towage and moorage charges).
- Logistic interoperability as the ability to integrate systems in a fully advantageous way is the ability to provide an anticipated level of logistics and port services;
- Assets, which are the means by which the above-mentioned ability in accordance with the demand for such services from the market is determined.

5. The proposed model of multi criteria assessment of a CSP based on logistics capabilities in the Southern BSR

Based on extensive statistical analysis of the Southern BSR seaborne trade (including standard models: binomial, Poisson, normal) and levels of competition (judged from seaport handbooks data) as well as specific features of the logistics characteristic of the main Southern BSR seaports (achieved directly from selected seaport authorities – in-depth questionnaire) a model for multi criteria assessment for the logistics capabilities of selected CSPs has been established (fig. 4).

It is a tool designed originally to evaluate competition levels of installations of this type in the particular sea area (Southern BSR). By dividing criteria into sub-criteria and then into diagnostic features, and by using figure 4, it is possible to produce an

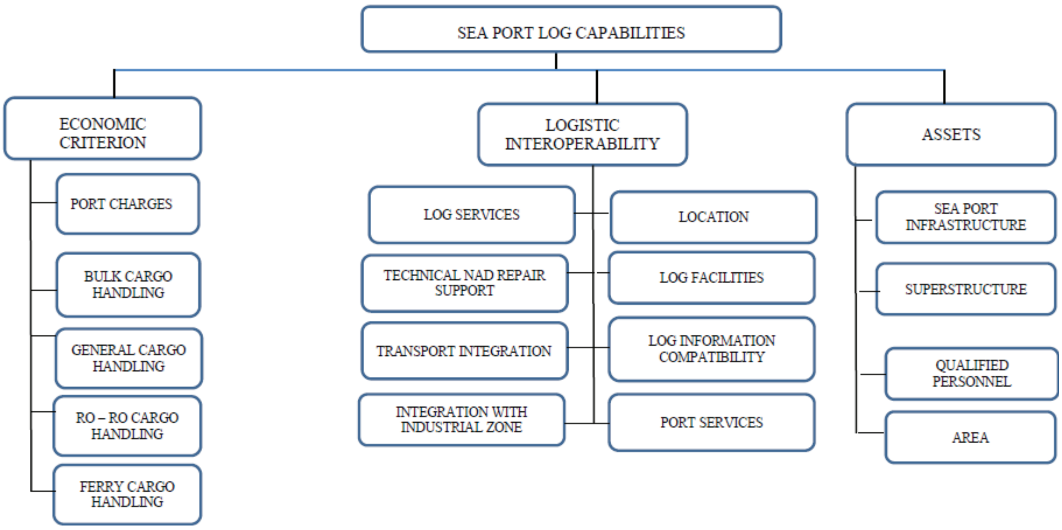

Fig. 4. Diagram of the Logistic capabilities of a Commercial Sea Port

accurate assessment chart of the logistics capabilities of a CSP within the Southern BSR (table 2).

Table 2. Chart of the logistic capabilities of Commercial Sea Port in Southern BSR

Criterion	Sub-criterion	Diagnostic feature
C_1 - Economic	S_{11} - Bulk handling	D_{111} - Coal and coke
		D_{112} - Ore
		D_{113} - Grain and feed
		D_{114} - Crude oil and petroleum products
		D_{115} - Wood
		D_{116} - Other bulk
	S_{12} - General cargo handling	D_{121} – Freight dry cargo
		D_{122} – General cargo in containers
	S_{13} - Ro - Ro cargo handling	D_{131} - Mobile non-self-propelled
		D_{132} - Mobile self-propelled
	S_{14} - Ferry cargo handling	D_{141} - Passengers
		D_{142} - Vehicles
	S_{15} - Port charges	D_{151} – tonnage dues
		D_{152} - berth charge
		D_{153} – passenger charge

		D_{154} – pilotage charge
		D_{155}- towage charge
		D_{156} – mooring charge
		D_{157} – Terminal handling charge
		D_{158} –Heavy lift charge
		D_{1569}– Extra length charge
		D_{1510} – bulk cargo handling charge
		D_{1118} –dry freight cargo handling charge
C_2 – Logistic interoperability	S_{21} - Logistic installations	D_{211} - Bulk terminal
		D_{212} - General bulk terminal
		D_{213} - Ferry terminal
		D_{214} - Container terminal
		D_{215} - Oil terminal
		D_{216} - LNG terminal
	S_{22} - Location	D_{221} - Transport corridor
		D_{222} - Sea motorway
		D_{223} - Transportation hub
		D_{224} - Port of delivery
		D_{225} - Continental connections
		D_{226} - Intercontinental connections
	S_{23} - Integration of transport branches	D_{231} - Sea - Road
		D_{232} - Sea - Railway
		D_{233} - Sea - Inland
		D_{234} - Sea - Pipelines
		D_{235} - Sea - Air
	S_{24} - Integration with industrial zone	D_{241} - Construction shipyard
		D_{242} - Ship repair yard
		D_{243} - Processing industry
		D_{244} - Light manufacturing
		D_{245} - Other
	S_{25} - Technical and repair support	D_{251} – Power plant and propulsion system repairs

		D_{252} –Stability, unsinkability and floating power sustainment
		D_{253} – navigational system repairs
		D_{254} –communication system repairs
		D_{255} – other deck system repairs
	S_{26} - Logistic information compatibility	D_{261} - The use of GS 1 standards
		D_{262} - WMS systems in sea port warehouses
		D_{263} - Container terminal management system
	S_{27} - Logistics and sea port services	D_{271} - Ship to land transhipment
		D_{272} - Land transhipment
		D_{273} - Storage and warehousing of goods
		D_{274} - Intra-port transportation
		D_{275} - Port cargo handling
		D_{276} - Cargo packaging
		D_{277} - Container stuffing and stripping
		D_{278} - Cargo stevedoring
		D_{279} - Cargo Trimming
		D_{2710} - Sorting, assembling and packing of cargo
		D_{2711} - Forwarding
		D_{2712} - Rail transport service in the hinterland
		D_{2713} - Traffic management and railway cargo handling in the sea port area
		D_{2714} - Pilot
		D_{2715} - Towing
		D_{2716} - Mooring
		D_{2717} - Supply of utilities (water, electricity)
		D_{2718} - Supply of food, fuel and spare parts
		D_{2719} - Reception of waste from ships
		D_{2720} - Container depot for ship-owners
		D_{2721} - Fire protection and rescue
		D_{2722} - Telecommunication and IT services
		D_{2723} – containers consolidation and deconsolidation operations
		D_{2724} – container tracking

		D_{2725} – container cards
		D_{2726} - container priority operations
		D_{2727} – custom service
		D_{2728} – agent service
C_3 - Assets	S_{31} - Sea port infrastructure	D_{311} - Aquatory
		D_{312} - Territory
		D_{313} - Sea port transportation hub
		D_{314} - Media and networks
	S_{32} - Superstructure	D_{321} - Transmission equipment
		D_{322} - Lifting equipment
		D_{323} - Warehouses and storage yards
		D_{324} - Production harbor fleet
		D_{325} - Supporting harbor fleet
	S_{33} - Qualified personnel	D_{331} – Management (incl. Corporate Social Responsibility (CSR) aspects)
		D_{332} - Seafarers
		D_{333} - Cargo handling
		D_{334} - Technical personnel
		D_{335} - Forwarding service
	S_{34} - Area	D_{341} - The size of the administrated area
		D_{342} - Potential land assets for further development
		D_{343} - Proximity to human settlements
		D_{344}- Environmental considerations (incl. Particularly Sensitive Sea Area (PSSA) and from January 2015 Sulphur Emission Control Area (S-ECA) impact)

6. Mathematical description of the proposed model

It should be noted that for some of the diagnostic features concerning the infrastructure and superstructure within the assets criterion additional diagnostic elements can be distinguished and which could be subject to assessment as well.

Using the proposed assessment methodology the logistic capabilities of a CSP can be presented in the following way:

$$\partial_{CSP}^{log} = \left\{\partial_i^{log}; i = \overline{1,3}\right\} \qquad (1)$$

where:

∂_{CSP}^{log} - Logistic capabilities of CSP

∂_i^{log} - Logistic capabilities according to i- this assessment criterion where:

- ∂_1^{log} - capabilities within the range of economic criterion;
- ∂_2^{log} - capabilities within the range of the logistic interoperability;
- ∂_3^{log} - capabilities within the range of owned assets;

The overall assessment of the logistic capabilities of a CSP will be derivatives of these capabilities as described by several assessment criteria, which are reflected in the equation:

$$\prod{}_{CSP}^{log} = f\left(P_{i}^{log}; i = \overline{1,3}\right) \quad (2)$$

where:

$\prod{}_{CSP}^{log}$ overall assessment of the logistic capabilities of CSP;

P_{i}^{log} - partial assessment of the logistic capabilities of CSP according to i- this criterion where:

- P_{1}^{log} - partial assessment of the logistic capabilities of CSP according to economic criterion;
- P_{2}^{log} - partial assessment of the logistic capabilities of CSP according to the level the logistic interoperability;
- P_{3}^{log} - partial assessment of the logistic capabilities of CSP according to owned assets;

The multi criteria assessment of the capabilities of a CSP in respect of its' competitiveness will require the application of the decision-making model using the analytic hierarchy process – AHP.

Using the proposed tool it is necessary to:

- Identify sub-criteria of capabilities' assessment, appropriate for already identified criteria in this respect;
- Identify diagnostic features within specified sub-criteria;
- Describe dominance relationships on each level of analysis, occurring between the identified criteria, sub-criteria and diagnostic features;
- Calculate on this basis the measurement of preferences for the analysed criteria, sub-criteria and diagnostic features;
- Describe dominance relationships occurring between analysed sea ports in respect of the diagnostic features;
- Calculate on this basis measures of preferences for analysed sea ports in respect of all diagnostic features within individual sub-criteria and criteria;
- Calculate the general measurement of preferences for each analysed seaport by aggregating measurable preferences concerning individual criteria.

On the basis of a general measuring of values for individual CSPs we will be able to reach a conclusion on their mutual competitiveness. This assumption requires the adoption of the following methodology for calculations of the general measurement of preferences/logistic capabilities of the CSP as analysed.

1. The calculation of the logistic capabilities of individual diagnostic features within the given sub-criterion for analysed seaports according to the following parameters:

$$Q_{ijk} \cdot = WD_{ijk} \bullet WCSP_{Dijk} \quad (3)$$

where:

Q_{ijk} - logistic capabilities of the given diagnostic feature of analyzed CSP;

WD_{ijk} - measure of preferences for the given diagnostic feature;

$WCSP_{Dijk}$ - measure of preferences of the analysed CSP in respect to the given feature.

2. The calculation of the logistic capabilities according to individual sub-criteria within the given criterion

for analysed seaports according to the parameters:

$$S_{ij} \cdot = W_{ij} \bullet \Sigma Q_{ijk} \quad (4)$$

where:

S_{ij} - logistic capabilities according to the given sub-criterion;

W_{ij} - measure of preferences for the given sub-criterion of assessment logistic capabilities of CSP;

ΣQ_{ijk} - the total of logistic capabilities of all diagnostic features within the given subcriterion for the given sea port.

3. The calculation of the logistic apabilities according to the given criterion:

$$P_i^{log} \cdot = W_i \bullet \Sigma S_{ij} \quad (5)$$

where:

W_i - measure of preferences for the given criterion of assessment logistic capabilities of CSP;

ΣS_{ij} - the total of logistic capabilities according to sub-criteria for the given sea port;

4. The calculation of the total capabilities of analyzed CSP as the general preference measure:

$$\prod_{Log}^{CSP} \cdot = \sum P_i \quad (6)$$

Conclusions

The material presented in this article offers a unique approach to the examination and evaluation of seaport competitiveness levels based on the multi-criteria assessment model of their unique logistic characteristics. It requires further development and research to determine the optimal preference range of the assessed diagnostic features. However, taking into account the multitude of conditions and differences present in chains of supply that affect Southern BSR seaports' activities, this may turn out to be a challenging task for researchers.

The verification of diagnostic features with regard to quantity and relevance will become an important element in future considerations. Such verification will only be possible after the analysis is made of data from individual ports with regard to the quantity and intensity of loads and for the identification of the individual assets in the operations of each seaport. The proposed solution is not final and can be further adapted depending on the access given to the required data.

The concept of multi criteria assessment can be a practical tool for the analysis of the competition level in a specific time projection, that is within the last 5 years. Changes in the economic criterion concerning the volume of turnover in individual cargo categories will always be associated with the logistic interoperability level and human resources, which can only be determined on the basis of the received and relevant historical data. The proposed formula in this article can be used not only at national (Poland, Germany) and regional (Southern Sea Baltic Region) levels but also (after alteration and adaptation to the different conditions) in any selected region in the world.

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