Parametric Assessment of Competitiveness of Commercial Sea Ports Based on Their Logistic Potential with the Use of the AHP Method

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The article comes as a summary presenting one of the stages in the realisation of a project carried out at the Chair of Logistics at Gdańsk School of Banking (WSB Gdańsk) in the cooperation with Fachschule in Stralsund. The project concerns the use of multi-criteria decision models for assessing competitiveness of commercial sea ports based on their logistic potential. The project team, whose members have a lot of experience in the field of sea logistics gained during their long professional practice, has verified a preliminary concept representing a logistic model of a commercial sea port. The project team has also provided the analysis of the use of multi-criteria decision models for the assessment of the suggested model, in terms of the competitiveness of the analysed entities. The suggested model of the logistic potential of a commercial sea port is graphically interpreted and described with the use of a multi-criteria assessment sheet. It refers strictly to the factors which determine the macro-, micro-, and mezzo-economic levels of competitiveness presented by such an economic entity as a commercial sea port. The logistic potential of a commercial sea port is presented as a hierarchical set of criteria, sub-criteria and diagnostic features assessed at the level of the analysed installation, which is directly compared with other competitive installations. During the research and in the course of analyses, it has been decided that further assessment shall be performed with the use of the following method: the analytic hierarchy process of decision making. This method comes as an optimal instrument to provide mutual assessment of logistic potentials of the analysed entities which operate in particular sea areas. An adequate methodology has been also selected to comply with the suggested solution – it allows the authors to quantify the logistic potential of a commercial sea port in terms of its competitiveness.

Keywords: seaport competitiveness, logistic potential, AHP.

1. INTRODUCTION

Competitiveness is a basic economic mechanism of market economy. It is oriented towards maximisation of income obtained from sales, maximisation of benefits obtained from purchase or services offered by business entities. This phenomenon characterises some relations between business entities which participate in it. These relations can be defined as competition, that is namely: pursuing objectives set by organisational entities and competing with other entities, since achieving these objectives by some entities is impossible without making it difficult for other entities to realise these goals (Christowa-Dobrowolska 2007, 36). Hence, competitiveness may be – on one hand - defined as a tool used to achieve maximal efficiency in business, which is exercised by enterprises in their market competition. The main aim of that competition is survival on the market and it results in a natural selection of weak business entities. On the other hand, however, it is also a fight between business entities which is realised in two dimensions: the value of obtained profit and sales.

The relations between the level of sales and the obtained profit depend on costs connected with the assumed customer service. These costs can be optimized by particular decisions in the logistic field. It should be noted that the decision making process has a permanent character, irrespective of the area of business operation. Most problems which are considered have small strategic significance, therefore, when we consider some really important questions, we think which decision will result in the greatest advantage or will prevent the biggest loss.

The reflection on a decision comes when it is connected with a success that goes beyond our expectations, or with a failure. In both cases the most important thing is to define some rules that should be followed in similar situations. In logistics the decision making process may refer to many aspects of supply chain functioning. It may refer to the choice of raw material suppliers, logistic service providers, transportation routes, the modes and means of transport, transport operators or a logistic hub - a storage and cargo handling centre which integrates transport modes. One of such hubs is a commercial sea port (CSP) which is always situated at the border of two environments, and which naturally integrates sea and land, inland or air transport. In economy, the essence of such a hub may be described on the basis of its competitiveness in relation to other, similar logistic installations in a particular area. A CSP is not only an object of logistic infrastructure. Apart from transportation services, it is also a provider of logistic services which have a complex, consolidated character, they present different levels of integration and are offered at one location. It may be assumed that it is an integrator of transport, forwarding and logistic services offered by various operators functioning within the frames of a CSP. Considering the significant role of a CSP in the national logistic system, in a Euro-logistic system or global logistic system, it is impossible to omit the question of competitiveness of such a business entity in a particular geographic area.

Competitiveness may be defined as an attribute, which determines possibilities of an enterprise to create some developmental tendencies constantly, to increase its productivity and to develop its markets efficiently in a situation when competitors offer new, better and cheaper goods or services (Adamkiewicz 1998, 61). When discussing competitiveness of a CSP, we understand it as competitiveness of an enterprise in a macro-, mezzo- and micro-economic scale. The basic determinants of competitiveness in the macro-economic scale are broadly defined resources, that is namely: natural resources, labour force, capital resources, technological resources and their sophistication level, and also economic infrastructure (Gorynia 2009, 69). The conditions of competitiveness in the mezzo-economic scale can be defined as access to production factors and demand factors, proper configuration of sectors (supporting and related sectors) and, finally, conditions for creation, organisation and administration of economic entities (Gorynia 2009, 72). In the micro-economic scale, we shall define the conditions, which determine the competitiveness of a particular economic entity as its market share, service quality, good reputation in its sector, the time of service realisation, the use of advanced technology skills, and availability of the products which are offered (Adamkiewicz 1998, 62-63). At this level, the potential of competitiveness is connected with a competitive position of a business entity which involves such elements as (Gorynia 2009, 79):

- market position of a business entity;
- cost position of a business entity;
- brand and how well it is established in the market
- technical competences and the use of advanced technology skills
- profitability and financial power

The measurement of competitiveness of a CSP, based on its logistic potential seems well-grounded, as logistics decides about the effectiveness and efficiency of the realised economic processes for which the existing logistic system comes as the reference basis. It also affects the brand of a business entity in terms of its service offer, customer service level and reduction of logistic costs. It is proportional to minimisation of the customer's costs which also affects the price levels.

The measurement of competitiveness should be expressed in appropriate indicators or measures. Therefore, it has been decided to apply a particular decision model that allows us to express this value for a CSP in a particular numerical value. Applying the AHP method (analytical hierarchy process) allows us to define competitiveness of an analysed business entity in the reference to the levels presented by the competitive entities.

This article comes as the next stage in the realisation of a research project ***The Construction and Verification of an Original Model of the Logistic Potential of a Commercial Sea Port as a Tool for the Assessment of Competitiveness of Ports in the Southern Baltic Basin, with the Use of Analytic Hierarchy Process (the AHP Method)*** carried out at the Chair of Logistics at Gdańsk School of Banking (WSB Gdańsk) in the cooperation with Fachschule in Stralsund in 2014/2015. The article aims at the selection of a multi-criteria decision model and adaptation of its use – in this particular case: the AHP method – for the assessment of competitiveness of commercial

sea ports, based on their logistic potential. The research problem which the authors of the article have decided to solve is: in what way should the logistic potential of a commercial sea port be presented to give us a possibility to assess its competitiveness in comparison to other business entities, with the use of the AHP method? The working hypothesis which the authors have decided to prove is: applying a decision model, such as the AHP method, to evaluate competitiveness of a commercial sea port, based on its logistic potential, allows us to provide a comprehensive assessment of effectiveness and efficiency presented by the logistic installation in a land-sea supply chain.

To solve the research problem and to prove the working hypothesis, the following research objectives have been realised:

- description of applying the AHP method for the assessment of competitiveness of various phenomena and objects;
- identification of the potential presented by a commercial sea port
- analysis of possibilities to use the AHP method for the assessment of competitiveness of a commercial sea port, based on a determined logistic potential of a particular installation.

2. THE AHP METHOD IN THE ASSESSMENT OF COMPETITIVENESS PRESENTED BY PHENOMENA OR OBJECTS

The assessment of competitiveness presented by a business entity can refer to customers' preferences connected with the expected level of customer service and its financial aspect, and also with the comparison of the abovementioned parameters with an offer presented by potential competitors. The AHP method can be such a method as it is a commonly accepted and applied tool in decision making, based on a significant number of criteria. This method is applied in everyday economic life and in logistic management to make decisions concerning the selection of broadly defined suppliers in the transport-forwarding-logistics sector.

Considering the fact that ports can play various roles in sea-land supply chains, that is namely: transportation hubs, feeder service providers, it is possible to see them as enterprises of the transportation-forwarding-logistics sector. These enterprises are characterised by a wide range of logistic functions, which are realised there and which are located at one place, and are mutually strongly integrated. Therefore, applying this method to assess competitiveness of a CSP based on its logistic potential is fully justified.

Applying the AHP analysis in the process of decision-making consists in comparing pairs of the obtained data. The solution to a decision problem follows the algorithm presented in Fig., 1 and the following stages can be distinguished there:

Stage 1 – the construction of a hierarchical model consists in creating a decision tree. At its top the main objective is located which comes as the final solution, the ultimate state or condition that is being pursued. In our case, solving the analysed problem means defining the ultimate condition that is the logistic potential of the CSP. The next stage is to define factors which appear at the lower level of the hierarchical model, and which strongly affect achieving the ultimate condition, namely: defining the logistic potential of the CSP. At the particular levels these factors are referred to as so called global preferences, that is the criteria, their relevant sub-criteria, and finally, diagnostic features assigned to these sub-criteria. On the basis of the diagnostic features, the assumed decision variants shall be assessed, for example the analysed CSP. The general structure of the hierarchical scheme is presented in Fig. 2.

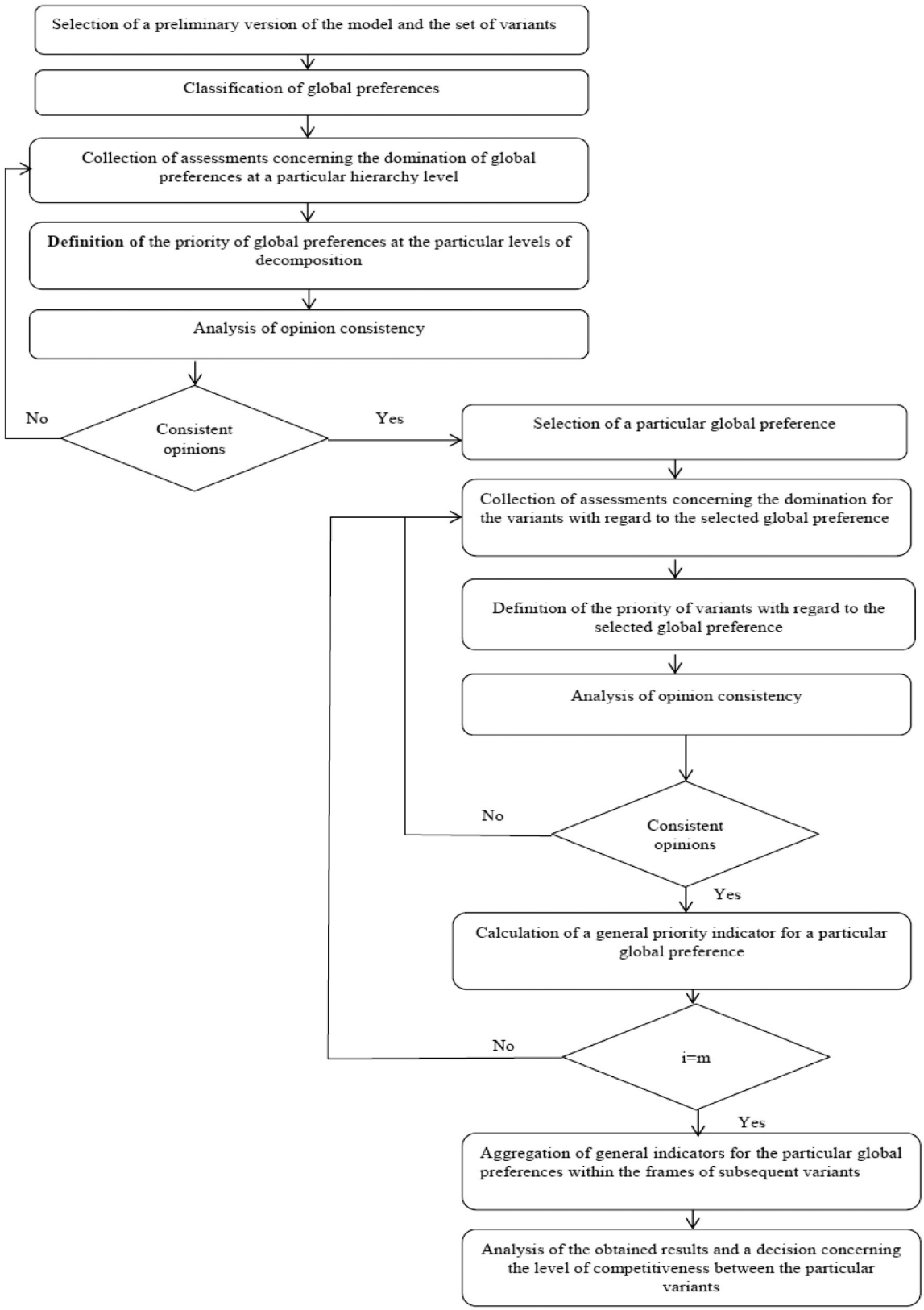

Fig. 1. The stages of decision problem solving with the use of the AHP method.
Source: the authors' own study based on G. Rogowski, *Metody i oceny działalności banku na potrzeby zarządzania strategicznego*, Publishing of Poznań School of Banking, Poznań 1998.

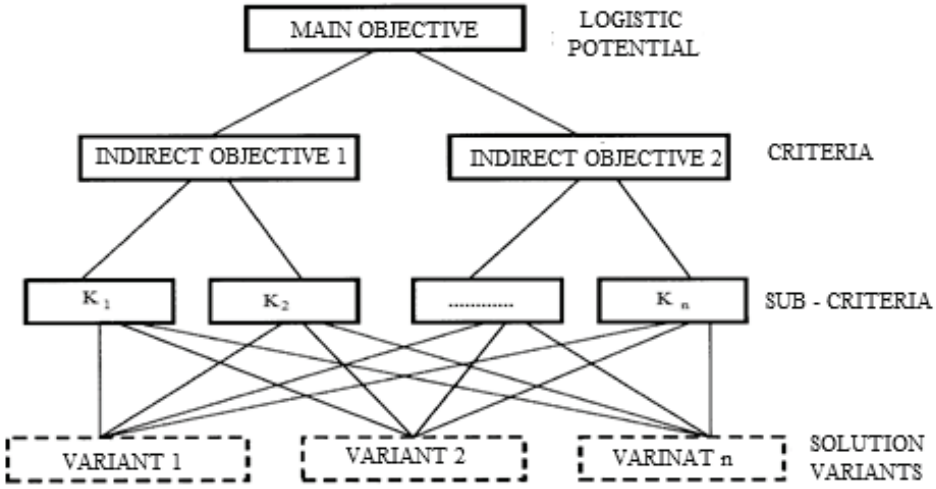

Fig. 2. The Hierarchy scheme used in the AHP method.
Source: the authors' own study based on B. Skowron Grabowska, *Centra logistyczne w łańcuchach dostaw*, PWE, Warszawa 2010.

Stage 2 – defining the priority of global preferences at the particular levels of the hierarchical model is performed by a series of comparisons done between the pairs of the particular factors at the same hierarchical level. It is done to determine their influence, based on the assumed priority scale (Table 1).

Table 1. An exemplary priority scale for defining preference indicators for the criteria, sub-criteria and diagnostic features..

The global preference has no priority or is noted higher in the hierarchy of priorities	The global preference has no priority or is noted lower in the hierarchy of priorities
1 – lack of priority	1 – lack of priority
2 - little priority	1/2 - little priority
3 – considerable priority	1/3 – considerable priority
4 – very considerable priority	1/4 – very considerable priority
5 – unquestionable priority	1/5 – unquestionable priority

Source: the authors' own study based on Bozarth C., Handfirld R., *Wprowadzenie do zarządzania operacjami i łańcuchem dostaw,* Helion, Gliwice 2007

The comparison results in a priority matrix. An exemplary priority matrix performed at all the levels of the hierarchical scheme is presented in Table 2.

Table 2. An exemplary priority matrix for global preferences.

Criterion	K_1	K_2	K_3	K_4
K_1	K_{11}	K_{12}	K_{13}	K_{14}
K_2	K_{21}	K_{22}	K_{23}	K_{24}
K_3	K_{31}	K_{32}	K_{33}	K_{34}
K_4	K_{41}	K_{42}	K_{43}	K_{44}

Source: the authors' own study, based on Bozarth C., Handfirld R., *Wprowadzenie do zarządzania operacjami I łańcuchem dostaw,* Helion, Gliwice 2007

When the point-based scale from Table 1 is applied, the following regularity appears:

If $K_{12} = n \rightarrow K_{21} = \frac{1}{n}$ etc, for all the compared global preferences.

The preferences are compared in accordance with Table 1 by a specially selected group of experts.

Determining the importance of global preferences, or in other words, their priority indicators at the subsequent levels of the hierarchical scheme is realised by constructing a matrix of the standardised values (Table 3). Table 3 presents the formulas for which the values of the subsequent priority indicators of global preferences W_{K_i} have been calculated.

Table 3. The matrix of the standardized values and the values of the priority indicators of global preferences.

	K_1	K_2	K_3	.....	K_4	**Priority indicators of global preferences**
K_1	K_{11}	K_{12}	K_{13}	.....	K_{1m}	$W_{K_i} = \frac{\frac{K_{11}}{\sum_{i=1}^{m} K_{i1}} + \frac{K_{12}}{\sum_{i=1}^{m} K_{i2}} + \frac{K_{13}}{\sum_{i=1}^{m} K_{i3}} + ... + \frac{K_{1i}}{\sum_{i=1}^{m} K_{mm}}}{m}$
K_2	K_{21}	K_{22}	K_{23}	.....	K_{2m}	$W_{K_2} = \frac{\frac{K_{21}}{\sum_{i=1}^{m} K_{i1}} + \frac{K_{22}}{\sum_{i=1}^{m} K_{i2}} + \frac{K_{23}}{\sum_{i=1}^{m} K_{i3}} + ... + \frac{K_{2i}}{\sum_{i=1}^{m} K_{mm}}}{m}$
K_3	K_{31}	K_{32}	K_{33}	.....	K_{3m}	$W_{K_3} = \frac{\frac{K_{31}}{\sum_{i=1}^{m} K_{i1}} + \frac{K_{32}}{\sum_{i=1}^{m} K_{i2}} + \frac{K_{33}}{\sum_{i=1}^{m} K_{i3}} + ... + \frac{K_{3i}}{\sum_{i=1}^{m} K_{mm}}}{m}$
.....	.....	.....	.....	.....	.....	.....
K_m	K_{m1}	K_{m2}	K_{m3}	.....	K_{mm}	$W_{K_i} = \frac{\frac{K_{mi}}{\sum_{i=1}^{m} K_{i1}} + \frac{K_{m2}}{\sum_{i=1}^{m} K_{i2}} + \frac{K_{m3}}{\sum_{i=1}^{m} K_{i3}} + ... + \frac{K_{mi}}{\sum_{i=1}^{m} K_{mm}}}{m}$
	$\sum_{i=1}^{4} K_{i1}$	$\sum_{i=1}^{4} K_{i2}$	$\sum_{i=1}^{4} K_{i3}$	....	$\sum_{i=1}^{4} K_{im}$	

Legend: K_i – global preferences, where i=1,2,3…m, W_{K_i} - the priority indicator of a global preference.

Source: the authors' own study based on Bozarth C., Handfirld R., *Wprowadzenie do zarządzania operacjami i łańcuchem dostaw,* Helion, Gliwice 2007

At the stage of defining the standardised values for the priority indicators of global preferences, there is a significant element: calculating the consistency of the experts' assessments by calculating the value of so called consistency index CI_i *and* consistency ratio CR_i on the basis of the following relation:

$$ICI_i = \frac{\lambda_{\max} - 1}{m - 1} \quad \text{and} \quad CR_i = \frac{CI_i}{R_i} \leq 0{,}1 \qquad (1)$$

Where $\lambda_{\max}$ - maximum matrix value, m – the number of global preferences at the particular level of the hierarchy, R.I. – Random Index.

Stage 3. Defining the domination (priority) of the analysed variants. In order to do this, it is necessary to construct a priority matrix of the analysed variants, considering the stage of the realisation of the particular global preferences by the analysed variants. The variants referred to the particular factors at the subsequent levels of the hierarchical scheme are compared in pairs, and the quantification of their values is also based on the priority point-based scale, in accordance with Table 1. The priority matrix of the variants and the standardised values (Table 4) for variant preferences is constructed analogically to the priority matrix and the standardised value matrix for global preferences at the particular levels of the hierarchical scheme.

Table 4. The standardised matrix of the variant priority with regard to the criterion K_i.

Variant	WAR_{1Ki}	WAR_{2Ki}	.....	WAR_{nKi}	Priority indicators of the analysed variants for the particular global preference K_i
WAR_{1K1}	WAR_{11Ki}	WAR_{12Ki}	.....	WAR_{1nKi}	$WWAR_{1Ki} = \frac{\frac{WAR_{11Ki}}{\sum_{j=1}^{n} WAR_{j1K_1}} + \frac{WAR_{12ki}}{\sum_{j=1}^{n} WAR_{j2K_1}} + ... + \frac{WAR_{1JKi}}{\sum_{j=1}^{n} WAR_{jnK_1}}}{n}$
WAR_{2K1}	WAR_{21Ki}	WAR_{22Ki}	……..	WAR_{2nKi}	$WWAR_{2Ki} = \frac{\frac{WAR_{21Ki}}{\sum_{j=1}^{n} WAR_{j1K_1}} + \frac{WAR_{22Ki}}{\sum_{j=1}^{n} WAR_{j2K_1}} + ... + \frac{WAR_{2j}}{\sum_{j=1}^{n} WAR_{jnK_1}}}{n}$
.....	.....	.....	.....	.....	…….
WAR_{nKi}	WAR_{n1Ki}	WAR_{n2Ki}	……..	WAR_{njKi}	$WWAR_{nKi} = \frac{\frac{WAR_{n1K1}}{\sum_{j=1}^{n} WAR_{j1K_1}} + \frac{WAR_{n2Ki}}{\sum_{j=1}^{n} WAR_{j2K_1}} + ... + \frac{WAR_{njKi}}{\sum_{j=1}^{n} WAR_{jnK_1}}}{m}$
	$\sum_{j=1}^{n} WAR_{j1K_1}$	$\sum_{j=1}^{n} WAR_{j2K_1}$	……..	$\sum_{j=1}^{n} WAR_{jnK_1}$	

Source: the authors' own study based on Bozarth C., Handfirld R., *Wprowadzenie do zarządzania operacjami i łańcuchem dostaw,* Helion, Gliwice 2007

At this stage, it is also advisable to calculate the consistency of the criteria concerning the preference values of the ICI_j variants, based on the following relation:

$$ICI_j = \frac{\lambda_{\max} - 1}{n - 1} \leq 0{,}1 \qquad (2)$$

Where: $\lambda_{max} = n \bullet \sum_{j=1}^{m} WWAR_{jK_i}$, n – a number of the analysed variants.

If this relation is met, the priority of the variants has been correctly quantified.

Stage 4. Organising the decision variants with the use of a general priority indicator for all the analysed variants, in accordance with the following equation:

$$W_O = \sum_{j=1}^{m} \sum_{i=1}^{n} WWAR_{JK_i} \bullet W_{K_i} \qquad (3)$$

Stage 5. The analysis and interpretation of the results, based on the value of a general indicator of the variant preferences W_O.

3. THE LOGISTIC POTENTIAL OF A COMMERCIAL SEA PORT

Before we define the notion of the logistic potential of a commercial sea port, we should refer to the classical definition of potential stating that it is a resource of possibilities, power and productive skills presented by an entity; also: efficiency, capability, possibility (Jacyna 2012, 34). The logistic potential comes as a defined resource of possibilities (abilities) concerning supply, services or production, which are used for the realisation of particular productive, commercial, service or public activities. In other words, on one hand, the logistic potential is a measure of effectiveness and efficiency of a logistic system which can be defined in two ways, namely (Ficoń 2004, 361):

- as a set of sub-systems, such as supply, production, transport, storage and sales, with the relations between them and between their characteristics, with a constant pursuit to achieve higher levels of system organisation;
- as an intended and organised physical flow of goods that is joined within a defined economic system and accompanied by the flow of financial resources and information.

On the other hand, however, a logistic system is used to maintain and to support the logistic potential in all the aspects of logistic support (Jacyna 2012, 36).

Considering a CSP which has its own logistic system necessary to realise port and logistic services, the logistic potential shall be a measure of abilities presented by this system to realise the abovementioned services. Considering the strategic aims of logistic business operation that is intended to maximize the added value, to reduce the company's own costs (its logistic costs) and to maintain a high level of customer service, including timely realisation, quantitative and qualitative consistency of customers' orders and the realisation of deliveries or services, and the level of information exchange between the customer and the service provider, it is possible to state that the size of the logistic potential of a particular business entity affects its competitiveness in the market in a directly proportional way. It is so in the case of a CSP. The operation of a CSP is based on the realisation of particular processes with the use of its logistic system. Therefore, it is possible to consider them as a flow of materials with the consideration of the feedback between input, output and the transformation system. (Fig. 3).

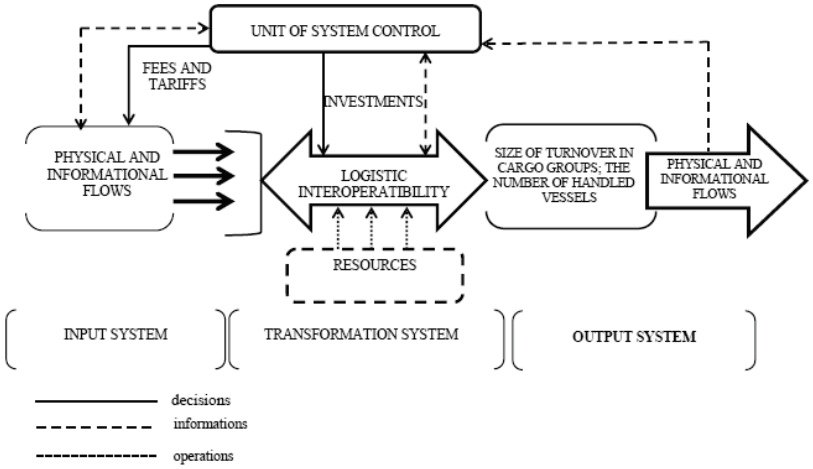

Fig. 3. The flow of materials in a CSP with the consideration of the feedback between the input, output and the transformation system.

Source: the authors' own study based on B. Pac, *Koncepcja wielokryterialnej oceny potencjału logistycznego jako narzędzia do badania konkurencyjności morskich portów handlowych*, InfoGlobmar conference 2014, *Porty morskie, i żegluga w systemach transportowych*, The Institute of Maritime Transport and Seaborne Trade at the University of Gdańsk, Gdańsk 2014.

The result of Fig. 3 analysis allows us to base the concept of assessing the potential of a commercial sea port on three essential criteria (Fig. 4). These are namely (Pac 2014, 59):

– the economic criterion which is expressed by the effectiveness and efficiency of a commercial sea port. These are reflected in the size of turnovers in particular categories of cargo, the number of handled vessels and the financial aspect connected with tariffs and port fees;
– the logistic interoperability understood as an ability to cooperate, that is: an ability to provide an expected range of logistic and port services with the use of own resources and applied procedures;
– the resources or means which come as a condition for the abovementioned ability, following the demand for such services reported in the market, including logistic infrastructure and supra-structure and the size of the installation area, with the consideration of possibilities concerning further development.

The economic criterion includes the set of sub-criteria which can be listed as follows:

- the real and estimated cargo handling capacity - it reflects the extent to which the logistic potential of a commercial sea port is used;
- turnovers of particular cargo groups, in accordance with the classification presented by Statistical Yearbook of Maritime Economy 2013 (Rocznik statystyczny gospodarki morskiej 2013, 99);
- turnovers of particular cargo groups in transit;
- port incoming vessels, including port incoming vessels with cargo;
- port incoming vessels by type;
- port tariffs: tonnage fees, wharfage fees, passenger fees;

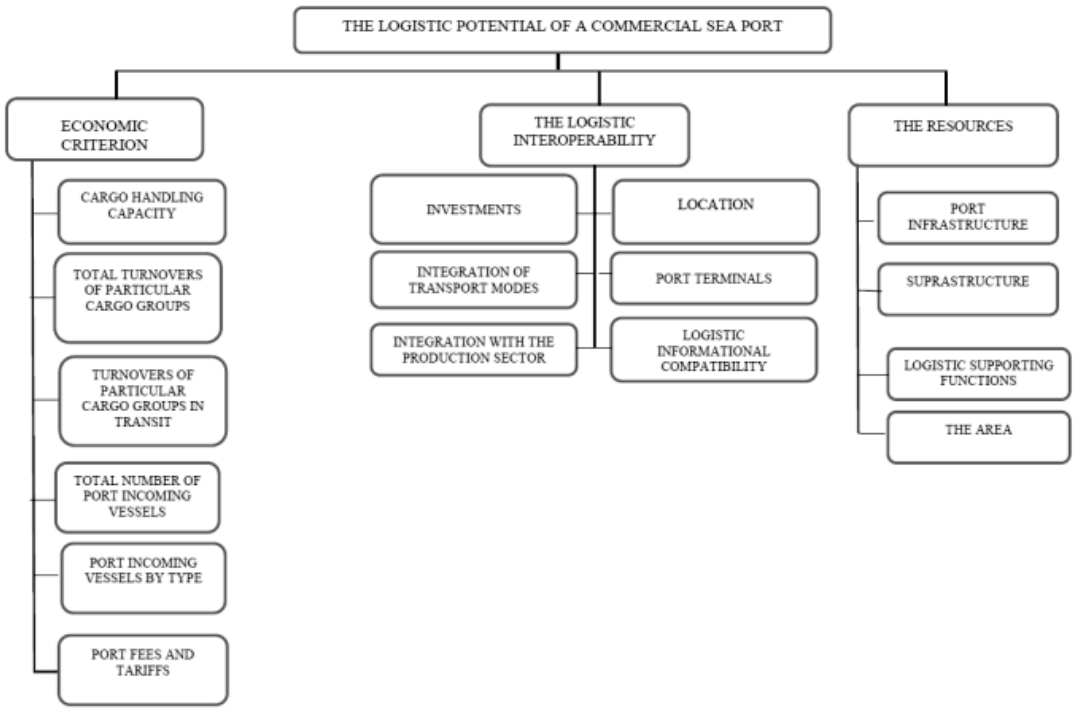

Fig. 4. The logistic potential of a commercial sea port.
Source: the authors' own study based on B. Pac, *Koncepcja wielokryterialnej oceny potencjału logistycznego jako narzędzia do badania konkurencyjności morskich portów handlowych*, InfoGlobmar conference 2014, *Porty morskie, i żegluga w systemach transportowych*, The Institute of Transport and Seaborne Trade at the University of Gdańsk, Gdańsk 2014.

It should be noticed that information concerning cargo turnovers, passenger and vessel traffic comes from the representatives of vessels incoming sea ports, and it is often obtained from the maritime offices – harbour master's offices, boatswain's offices. The range of the information usually complies with the Directive of the EU Parliament and Council 2009/42/WE of 6th May 2009 concerning statistical reports about transportation of goods and people by sea (Journal of Laws WE L 141 of 6th June 2009). These data do not include:

- vessels of gross tonnage (GT) smaller than 100.
- bunkering (loading fuel for vessels).
- national turnover, except for cabotage, that is: cargo transported by sea between Polish sea ports.
- the weight of empty and loaded containers and ro-ro vessels used for cargo transportation.

The data concerning turnover of transit cargo at sea ports are obtained from sea port authorities and business entities which handle cargo loading and unloading operations at sea ports.

Taken from the military sector, the notion of logistic interoperability means the ability of a logistic installation or a logistic object to cooperate with any other logistic installation or object. In other words, it means the ability to offer logistic services to other objects or installations, or the ability to accept such services. Logistic interoperability is the objective of standardisation which, in this case, is to be understood as using procedures, technical and technological solutions which make it possible to achieve logistic interoperability. Logistic interoperability also results in the optimisation of the use of resources and means in the administrative, informational, operational and material fields (NATO Logistics Handbook 1997, 188).

Logistic interoperability of a CSP is defined as a synergic ability of all the installations and port facilities to provide complex handling of goods and cargo, irrespective of their traffic direction, kind of volume, flow intensity and the operational range of particular supply chains (handling cargo in a region or in transit). The level of interoperability and the size of the involved resources directly affect the size of the total turnover and in the particular cargo groups. They also determine achieving the assumed level of

customer service, the competitiveness of a CSP in the transportation market and the level of total costs of a sea port as a business enterprise.

This criterion includes the following sub-criteria of the port assessment (Pac 2014, 60-61):

- location, that is: its geographical position in the communication routes, the function performed in the global and continental system of maritime transport and the range of handled connections;
- logistic installations, that is: cargo handling terminals functioning at a CSP: container terminals, bulk terminals, mixed cargo terminals, passenger and ro-ro terminals and also LPG and petroleum terminals;
- integration of various transportation modes in the area of the CSP;
- logistic informational compatibility expressed by using the GS 1 system or warehouse management systems (WMS);
- integration with the production sector, that is: vicinity of production plants typical for maritime economy, or any other plants which affect the town- and region-shaping role of a sea port; processing the transported materials into final products;
- investments into infrastructure and supra-structure which improve the accessibility of the port from the land side and the sea side, and a general level of the logistic interoperability of a CSP.

The last criterion is the criterion of resources which quantity and quality affect and condition the level of logistic interoperability. The resources include:

- port infrastructure which comes as the basis of port production and the material and technical basis of port business operations. The quantity and quality of these operations significantly affect the functioning and development of the whole installation;
- port supra-structure, that is namely: the factor created on the infrastructure basis;
- supporting logistic functions connected with forwarding, ship agency, towage, mooring and pilotage services;
- the area, that is: the size of the surface administered by the port authority, potential areas for further development of the port and their location in relation to residential areas and their environmental impact.

4. THE ANALYSIS OF A POSSIBILITY TO APPLY THE AHP METHOD FOR THE ASSESSMENT OF THE COMPETITIVENESS OF COMMERCIAL SEA PORTS, BASED ON THEIR LOGISTIC POTENTIAL

Applying the AHP analysis requires some development of a hierarchical structure of the logistic potential of a CSP. It can be achieved by decomposition of global preferences. Based on the analysis of expert literature and business practice, a sheet presenting the logistic potential of a CSP has been constructed. It shall be used for the assessment of competitiveness (Table 5).

A graphical representation of the sheet presented above is a decision tree of the logistic potential of a CSP (Fig. 5), which comes as the first stage of the AHP analysis.

The second stage of applying the AHP method to define the potential of a commercial sea port is the construction of a preference matrix of global preferences. The criteria, sub-criteria and diagnostic features shall be compared within the frames of this matrix. It is recommended that the assessment of the abovementioned elements and determination of the appropriate preference indicators should be based on the results of expert research, in the form of a questionnaire survey, realised in a group of "competent arbiters".

After that, a priority matrix is constructed for the diagnostic features within the frames of a particular sub-criterion.

The next step is constructing a matrix of the standardised values, in accordance with Table 3, for the criteria, sub-criteria and diagnostic features; calculating proper inconsistency indices and then the values of the priority indicators for the listed global preferences (Table 6).

Table 5. The sheet of the logistic capabilities of a commercial seaport in BSR.

C_1^{log} - ***ECONOMIC CRITERIA***			
S_{11}	***CARGO HANDLING CAPACITY (sub-criteria)***		***Parameter***
Diagnostic Feature D_{111}	***Estimated Cargo Handling Capacity***	Total	[thousands of tonnes]
D_{112}	***Real Cargo Handling Capacity***	Total annual turnover/Total international sea turnover/Total national sea turnover	[thousands of tonnes]
S_{12}	***TURNOVER OF PARTICULAR CARGO GROUPS***		
D_{121}	***Dry Bulk Cargo*** (coal, coke, ores, scrap metal, agricultural products, others)	Total cargo turnover/Total international sea turnover/Total national sea turnover	[thousands of tonnes]
D_{122}	***Liquid Bulk Cargo*** (liquefied gas, crude petroleum, petroleum products, other liquid bulk cargo)	Total cargo turnover/Total international sea turnover/Total national sea turnover	[thousands of tonnes]
D_{123}	***Container Cargo*** (big containers)	Total cargo turnover/Total international sea turnover/Total national sea turnover	[thousands of tonnes/ TEU]
D_{124}	***Ro-Ro Self-propelled Cargo*** (trucks, cars and other vehicles for trade, other vehicles)	Total cargo turnover/Total international sea turnover/Total national sea turnover	[thousands of tonnes]
D_{125}	***Ro-Ro Non self-propelled Cargo*** (goods trailers, semi-trailers, railway carriages)	Total cargo turnover/Total international sea turnover/Total national sea turnover	[thousands of tonnes]
D_{126}	***Other General Cargo*** (iron and steel, forest products, cargo in small containers, others)	Total cargo turnover/Total international sea turnover/Total national sea turnover	[thousands of tonnes]
D_{127}	***International Passenger Carriage*** (ferry and other passenger carriage).	Total number of people [in thousands of passengers]	[thousands of passengers]
S_{13}	***TURNOVER OF PARTICULAR CARGO GROUPS IN TRANSIT***		
D_{131}	***Dry Bulk Cargo*** (coal, coke, ores, scrap metal, agricultural products, others)	Total transit/Total sea transit/ Total sea-land and land-sea transit	[thousands of tonnes]
D_{132}	***Liquid Bulk Cargo*** (liquefied gas, crude petroleum, petroleum products, other liquid bulk cargo)	Total transit/Total sea transit/ Total sea-land and land-sea transit	[thousands of tonnes]
D_{133}	***Container Cargo*** (big containers)	Total transit/Total sea transit/ Total sea-land and land-sea transit [	[thousands of tonnes/ TEU]
D_{134}	***Ro-Ro Self-propelled Cargo*** (trucks, cars and other vehicles for trade, other vehicles)	Total transit/Total sea transit/ Total sea-land and land-sea transit	[thousands of tonnes]
D_{135}	***Ro-Ro Non self-propelled Cargo*** (goods trailers, semi-trailers, railway carriages)	Total transit/Total sea transit/ Total sea-land and land-sea transit	[thousands of tonnes]
D_{136}	***Other General Cargo*** (iron and steel, forest products, cargo in small containers, others)	Total transit/Total sea transit/ Total sea-land and land-sea transit	[thousands of tonnes]
S_{14}	***PORT INCOMING VESSELS***		
D_{141}	Total number of incoming vessels	Number of vessels/ net tonnage/gross tonnage	-/NT/GT
D_{142}	Incoming vessels with cargo	Number of vessels /net tonnage/gross tonnage	-/NT/GT
S_{15}	***PORT INCOMING VESSELS BY TYPE***		
D_{151}	Tankers	Number of vessels /net tonnage/gross tonnage	-/NT/GT
D_{152}	Bulk carriers	Number of vessels /net tonnage/gross tonnage	-/NT/GT
D_{153}	Container ships	Number of vessels /net tonnage/gross tonnage	-/NT/GT
D_{154}	General cargo ships	Number of vessels /net tonnage/gross tonnage	-/NT/GT
D_{155}	Barges (dry cargo)	Number of vessels /net tonnage/gross tonnage	-/NT/GT
D_{156}	Passenger ships	Number of vessels /net tonnage/gross tonnage	-/NT/GT
D_{157}	Other vessels	Number of vessels /net tonnage/gross tonnage	-/NT/GT
S_{16}	***PORT FEES AND TARIFFS (FOR SEAGOING VESSELS)***		
D_{161}	Tonnage fee	Average rate in Euro/1 GT for the selected types of seagoing vessels	(including the discount for liner shipping)
D_{162}	Wharfage fee	Average rate in Euro/1 GT for the selected types of seagoing vessels	(including the discount for liner shipping)
D_{163}	Passenger fee	Rate in Euro/1 passenger for ferries, passenger vessels, passenger and cargo vessels and other seagoing vessels	
C_2^{LOG} - ***LOGISTIC INTEROPERABILITY***			
S_{21}	***PORT TERMINALS***		
D_{211}	Specialised terminals	Number and purpose. Estimated annual cargo handling capacity, length of quays, vessel draught. Warehouse area and capacity. Open store area. Main cargo handling equipment	detailed information to be obtained
D_{212}	Multi-purpose terminals	Number and purpose. Estimated annual cargo handling capacity, length of quays, vessel draught. Warehouse area and capacity. Open store area. Main cargo handling equipment	detailed information to be obtained
S_{22}	***LOCATION***		
D_{221}	Location in relation to the handled sea area	Direct (there is a direct access to the sea area) Non-direct (no direct access to the sea area)	Y/N
D_{222}	Related land area	The size of the area which is economically related to a particular sea port	[sq. km]
D_{223}	Location in a transport corridor	Location in the transport corridor of TENT	Y/N, no. of corridor
D_{224}	Location on a motorway of the sea (MoS)	Location on a motorway of the sea (MoS)	Y/N
D_{225}	Continental sea line connections	The number of connections and destinations	detailed information to be obtained
D_{226}	Intercontinental sea line connections	The number of connections and destinations	detailed information to be obtained

S_{23}	***INTEGRATION WITH THE TRANSPORTATION BRANCH***		
D_{231}	Sea - Road	Access to motorways, expressways, national roads of high traffic capacity	detailed information to be obtained
D_{232}	Sea - Railroad	AGC, AGTC lines, dedicated national connections	detailed information to be obtained
D_{233}	Sea – Inland	Handled waterways, connections with the European inland water system	detailed information to be obtained
D_{234}	Sea -Air	Distance from the airport /passenger carriage/CARGO transport	[km/thousands passengers/thousands tonnes]
D_{235}	Sea - Pipeline	The type of transported raw materials, transit or national turnover. Estimated annual capacity of the pipeline.	detailed information to be obtained
S_{24}	***INTEGRATION WITH THE INDUSTRIAL SECTOR***		
D_{241}	Production shipyards	Number of workshops, specialisation	
D_{242}	Repair shipyards	Number of workshops, specialisation	
D_{243}	Processing industry, power industry	Number of workshops, specialisation	
D_{244}	Port-related industry and light production	Number of workshops, specialisation	
S_{25}	***OWN INVESTMENTS (please, specify EU co-financed investments and state their estimated value)***		
D_{251}	Improving access from the land side	Key investments in 2007-2013	detailed description with costs
D_{252}	Improving access from the sea side	Key investments in 2007-2013	detailed description with costs
D_{253}	Modernising quays	Key investments in 2007-2013	detailed description with costs
D_{254}	Investments in the supra structure	Key investments in 2007-2013	detailed description with costs
S_{26}	***LOGISTIC INFORMATION COMPATIBILITY***		
D_{261}	Applying the GS 1 standards	Using the international system of logistic information exchange GS1(ADC, RFID, EDI, GDSN) in cargo turnover	detailed information to be obtained with type of operational system
D_{262}	Providing port warehouses with the WMS systems	The number of high storage warehouses with the WMS systems	[thousands sq. m]
C_3^{LOG}	***- ASSETS***		
S_{31}	***PORT INFRASTRUCTURE***		
D_{311}	Water area of the port	The number of fairways, width and depth. The surface of the water areas, the number of port basins and canals. The number of anchorage areas, turning circles, passing sidings.	[detailed parameters to be obtained]
D_{312}	Port area	Total length of the quays/ the length of the quays suitable for exploitation/the length of berthing and loading quays	[m]
D_{313}	Maximal parameters of the handled vessels	Cargo-carrying capacity/Length/ Draught	[detailed parameters to be obtained]
D_{314}	Media and networks	The power network (parameters), water and sewage system, telecommunication, IT network, compressed air system, steam, fuel installation	[detailed parameters to be obtained]
S_{32}	***PORT SUPRASTRUCTURE***		
D_{321}	Total surface of the warehouses	Total surface of the warehouses	[in thousands of sq.m]
D_{322}	Total surface of the high storage warehouses	Total surface of the high storage warehouses	[in thousands of sq.m]
D_{323}	Total surface of the open store yards	Total surface of the open store yards	[in thousands of sq.m]
D_{324}	Maximal lifting capacity of cargo handling facilities	Maximal lifting capacity of cargo handling facilities at the port quays (terminals)	[detailed parameters to be obtained]
S_{33}	***SUPPORTING LOGISTIC FEATURES***		
D_{331}	Forwarding functions	number of cooperating companies	(regardless their size)
D_{332}	Towage, mooring and pilotage services	The number of companies handling towage, pilotage and mooring operations	
D_{333}	Shipping agents	The number of shipping agencies handling port operations	
S_{34}	***AREA***		
D_{341}	The size of the administered area	The size of the administered area in km^2	[sq. km]
D_{342}	The potential area assets for further development	The potential possibilities of development	[sq. km]
D_{343}	The distance from residential areas	The straight line distance (in km)	[km]
D_{344}	Environmental conditions	The vicinity of water intakes, wildlife reserves, national parks, sewage treatment plants, etc.,	detailed information to be obtained
D_{345}	Implementation of Directive on Sulphur Emission Control Area (S-ECA) as of 1st January 2015	The plan of counteraction against the results of implementing SECA Directive	detailed information to be obtained

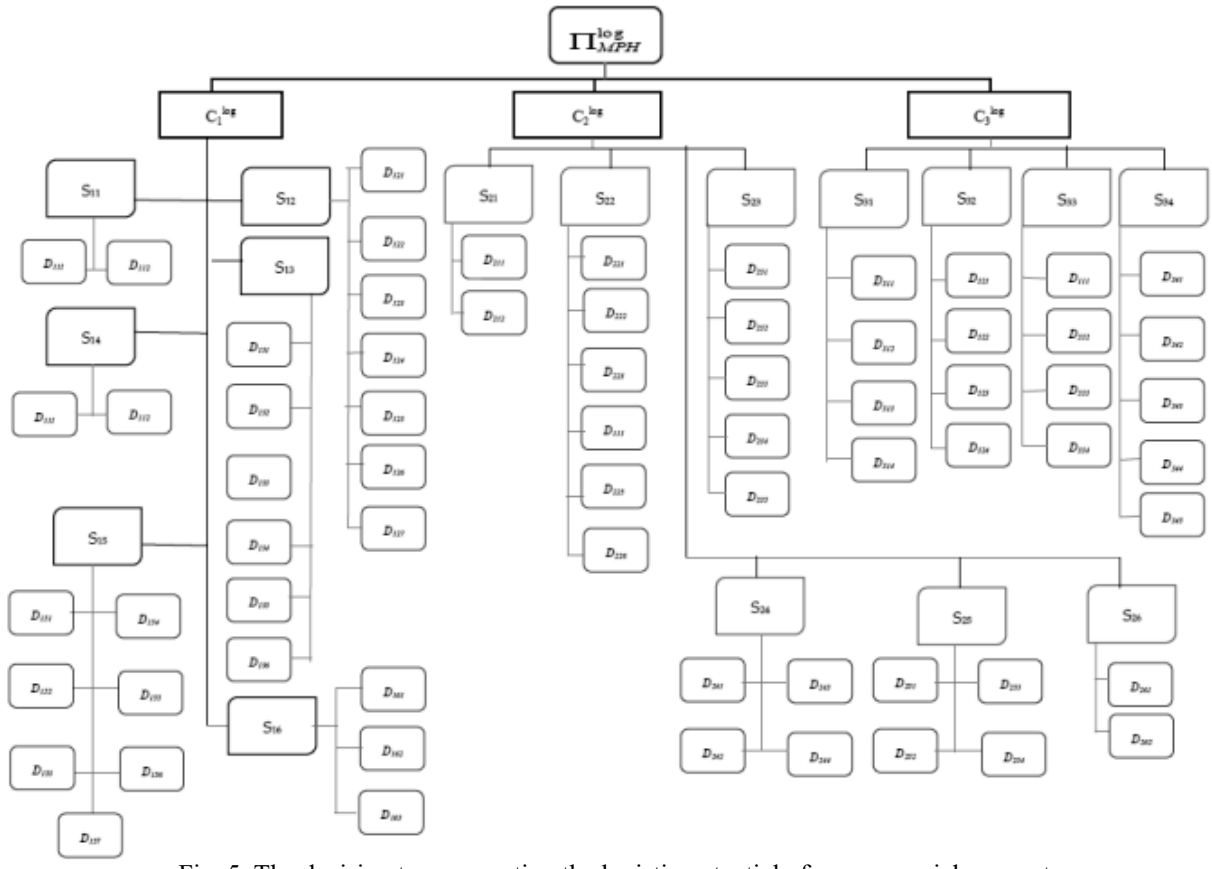

Fig. 5. The decision tree presenting the logistic potential of a commercial sea port.
Source: the authors' own study based on B. Starzyńska, A. Hamrol, M. Grabowska, *Poradnik menedżera jakości, kompendium wiedzy o narzędziach jakości*, Poznań University of Technology, Poznań 2010.

Table 6. The sequence of defining the priority indicators of global preferences.

No.	The stage of the calculations	Formula	Notes
1.	The priority indicator for the diagnostic features	$WD_{ijk} = \frac{\sum_{k=1}^{m} w_{Djk}}{m}$	WD_{ijk} - the priority indicator of the k[th] diagnostic feature of the j[th] sub-criterion in the i[th] criterion; W_{Djk} - the priority sub-indicator of the diagnostic features the calculation of which is based on the matrix of the standardised values; k – the number of the diagnostic features in a particular sub-criterion, , k= $\overline{1,m}$.
2.	The priority indicator for the sub-criteria	$WS_{ij} = \frac{\sum_{j=1}^{n} w_{ij}}{n}$	W_{ij} - the priority indicator of the j[th] sub-criterion in the i[th] criterion. w_{ij} - the priority sub-indicator of the sub-criteria, the calculation of which is based on the matrix of the standardised values; j – the number of the sub-criteria in a particular criterion j= $\overline{1,n}$.
3.	The priority indicator of the criteria	$WC_i = \frac{\sum_{i=1}^{3} w_i}{3}$	W_i - the priority indicator of the j[th] sub-criterion in the i[th] criterion; w_i - the priority sub-indicator of the criteria, the calculation of which is based on the matrix of the standardised values; i – the number of the criteria in the logistic potential CSP,, i= $\overline{1,3}$.
4.	The preference indicator of the analysed CSP in relation to a particular diagnostic feature	$WMPH_{Dijk} = \frac{\sum_{k=1}^{m} wmph_{Dijk}}{m}$	$WMPH_{Dijk}$ - the priority indicator of the analysed CSP (MPH in the equation) in relation to a particular diagnostic feature; $wmph_{Dijk}$ - the preference sub-indicator of the analysed CSP in relations to a particular diagnostic feature, m – the number of the analysed variants (the analysed ports).

Source: the authors' own study based on Bozarth C., Handfield R. *Wprowadzenie do zarządzania operacjami i łańcuchem dostaw*, Helion, Warszawa 2010.

The next steps concerning the calculation of the logistic potential of a CSP as a tool for the assessment of its competitiveness are presented in Table 7.

Table 7. Methodology of the calculation of the logistic potential of a commercial sea port, presented at the particular levels of decomposition of a decision tree.

pos.	The stage of the calculations	Formula	Notes
1.	Calculation of the logistic potential of the particular diagnostic features within the frames of a particular sub-criterion for the analysed sea ports.	$Q_{ijk} = WD_{ijk} \bullet WMPH_{Dijk}$	Q_{ijk}- the logistic potential of a particular diagnostic feature of the analysed CSP; WD_{ijk}- the priority indicator of a particular diagnostic feature; $WMPH_{Dijk}$– the priority indicator of the analysed CSP in relations to a particular feature.
2.	Calculation of the logistic potential by the particular sub-criteria within the frames of a particular criterion for the analysed sea ports	$S_{ij} = WS_{ij} \bullet \sum Q_{ijk}$	S_{ij}- the logistic potential by a particular sub-criterion; W_{ij} - the priority indicator of a particular sub-criterion of the assessment of the logistic potential of a CSP;
3.	Calculation of the logistic potential by a particular criterion:	$C_i^{Log} = W_i \bullet \sum S_{ij}$	W_i- the priority indicator of a particular criterion of the assessment of the logistic potential of a CSP
4.	Calculation of the total logistic potential of the analysed CSP as a general priority indicator.	$\Pi_{MPH}^{LOG} = \sum C_i^{LOG}$	

Source: the authors' own study based on B. Pac, *Koncepcja wielokryterialnej oceny potencjału logistycznego jako narzędzia do badania konkurencyjności morskich portów handlowych*, InfoGlobmar conference 2014, joint publication: *Porty morskie, i żegluga w systemach transportowych*, The Institute of Transport and Seaborne Trade at the University of Gdańsk, Gdańsk 2014,

5. CONCLUSIONS

The considerations presented above clearly suggest that the AHP method may be a proper tool for the assessment of the competitiveness of commercial sea ports. The identified global preferences, that is namely: criteria, sub-criteria and diagnostic features of the logistic potential of a commercial sea port (Table 5) are reflected in the determinants of competitiveness at the macro-economic level, in the conditions of competitiveness at the mezzo-economic level, and in the factors which determine the potential and a competitive position at the micro-economic level. Such a reference makes it possible to verify the reliability of the presented solution to the problem of measuring the competitiveness of a CSP in relation to various levels of the economic and logistic system. Another way to verify the suggested solution is to measure the abovementioned inconsistency indices at the level of general preferences and the analysed variants. Considering the complex model of the logistic potential of a commercial sea port, we obviously realise that it shall be possible to apply the suggested solution at the national logistic system or in a strictly defined region. Because of practical reasons, the number of the compared variants must be limited. Defining the priority indices of global preferences shall be possible by expert research; the priority of the particular variants with regard to global preferences shall be defined on the basis of a detailed analysis of historical data (Table 5, column 3) and then translated into the presented point-based scale of the priority (Table 1). The simultaneous analysis of the importance of two abovementioned characteristics, and the verification of their accuracy, based on appropriate inconsistency indices, makes this method reliable. The next stage in the realisation of the suggested solution by the project team shall be the verification of data availability at the level of the diagnostic features of the potential presented by a commercial sea port, and the appointment of the expert team to define the values of global preferences.

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