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The Competitiveness of Small Baltic Container Terminals. The PROMETHEE II Multi-criteria Analysis

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The article examines the competitiveness of small Baltic container terminals. In order to conduct the research, thirty terminals, whose annual maximum throughput capacity does not exceed 150,000 TEU, have been examined taking into consideration a number of criteria which are: length of the quay (C1), number of RTG (C2) and STS (C3) cranes, number of shortsea shipping connections (C4), maximum (technical) depth at the quay (C5), distance from motorways and expressways/national roads (C6), distance from the national railway station (C7). Selected k=7 criteria were used to perform PROMETHEE II (Preference Ranking Organization Method for Enrichment Evaluations II) multi-criteria ranking that enabled specifying those Baltic Sea container nodes which are in the area of strategic benefits for the analysed market sector.

Keywords: maritime container terminals, Baltic Sea, competitiveness, PROMETHEE II.

1. INTRODUCTION

The region of the Baltic Sea is the location of fifty-five container terminals operating in the territory of nine countries: Denmark, Estonia, Finland, Lithuania, Latvia, Germany, Poland, Russia and Sweden [1]. The annual maximum throughput capacity of thirty of them does not exceed 150,000 TEU[2] (Table 1). The presented article examines the competitiveness of small Baltic container terminals, and on the basis of the final PROMETHEE II ranking determines which of them occupy the dominant position in the analysed region.

Table 1 presents nine Swedish bases, six Finnish, five German, four Danish, three Russian, two Polish and one Latvian. In the group there is no terminal from Lithuania and Estonia. At the same time, the absolute market shares of the largest player (BCT Baltiysk) do not exceed 8%, and for over 1/3 of the nodes (exactly for 36.7% of them) – they are lower than 2%.

[1] The study includes those terminals, which belong to the body of the Baltic Sea due to its location. In the list presented in Table 1, there are no terminals that do not lie on the Baltic Sea, but only use trade routes running through its waters.

[2] TEU (*Twenty-foot Equivalent Unit*) is a unit of capacity equivalent to a container volume of 20-ft.

Table 1. Absolute market shares in the group of thirty small container terminals (%).

Country	Place	Name of the terminal (code)	Shares
Denmark (D)	Aalborg	Aalborg Container Terminal (ACT)	6.05
	Fredericia	Fredericia Container Terminal (FCT Fredericia)	5.15
	Kalundborg	Kalundborg Container Terminal (Kalundborg CT)	0.73
	Skagen	Skagen Container Terminal (SCT)	3.03
Finland (FIN)	Hanko	Hangö Stevedoring (Hangö Stevedoring)	1.21
	Kemi	Ajos (Ajos)	1.82
	Kokkola	All Weather Terminal (AWT)	1.82
	Oulu	Oritkari (Oritkari)	6.05
	Pori	Hacklin Terminal (Hacklin)	3.03
	Tornio	Röyttä (Röyttä)	0.91
Latvia (LV)	Riga	Riga Container Terminal (RCT)	6.05
Germany (D)	Lubeck	CTL Cargo–Terminal Lehmann (CTL)	3.03
		LHG Skandinavienkai (LHG Skandinavienkai)	3.03
		LHG Nordlandkai (LHG Nordlandkai)	3.03
		LHG Schlutup (LHG Schlutup)	3.03
		LHG Seelandkai (LHG Seelandkai)	3.03
Poland (PL)	Świnoujście	OT Port Świnoujście (OT Port)	4.24
	Gdańsk	Gdańsk Container Terminal (GKT)	4.24
Russia (RUS)	Baltiysk/Kaliningrad	Baltiysk Container Terminal (BCT Baltiysk)	7.26
		Kaliningrad Sea Commercial Port (KSCP)	1.82
	St Petersburg	Rusmarine Forwarding Terminal (RFT)	3.63
Sweden (S)	Åhus	Åhus Container Terminal (ÅCT)	6.05
	Halland	Halmstadt (Halmstadt)	6.05
	Karlshamn	Karlshamn Container Terminal (Karlshamn CT)	1.82
	Piteå	Haraholmen (Haraholmen)	1.82
	Södertälje	Sydhamnen (Sydhamnen)	2.72
	Stockholm	Container Terminal Frihamnen (CTF)	4.24
	Sundsvall	SCA Logistics Sundsvall (SCA Logistics Sundsvall)	1.51
	Umeå	SCA Logistics Umeå (SCA Logistics Umeå)	1.82
	Varberg	Varberg Container Terminal (VCT)	1.82

Source: own elaboration.

2. COMPETITIVENESS OF BALTIC CONTAINER TERMINALS

Competitiveness can be defined as a measure of efficiency in the past [2]. The competitiveness of the maritime container terminal is influenced primarily by factors such as: technical infrastructure, work organization of the terminal, use of advanced information technologies, as well as provision of comprehensive logistic services [13].

Due to the fact that technical infrastructure is the basic factor conditioning right functioning of each container terminal, in the research the focus was placed on those elements of the terminal which need to be correctly constructed and laid out to determine its effectiveness. The length of the quay, the maximum depth at the quay and the distance from the nearest motorways, expressways/national roads and the national railway station can be described as such. The study also took into account super-structural (number of STS quay cranes and RTG yard cranes) as well as service (number of shortsea shipping connections that each terminal supports) factors. This set of criteria, along with their weight and direction in which each should follow, is presented in Table 2[3].
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[3] The analysis does not include the criteria for which reliable and comparable data could not be found for all of the terminals analysed in the study. The omitted criteria include the number of marinas, the number of ocean connections, the number of reefer plugs, the length of tracks on the rail siding, or the size of the yard and warehouse space.

Table 2. Criteria selected for the analysis of competitiveness along with their weights and desired direction.

Name of criterion	C1 Length of the quay (m)	C2 Number of RTGs	C3 Number of STS	C4 Number of shortsea connections	C5 Max depth at the quay (m)	C6 Distance from motorways and expressways/ national roads (m)	C7 Distance from the national railway station (m)
Direction of criterion	max	max	max	max	max	min	min
Weight of criterion	8	4	5	8	7	6	6

Source: own elaboration.

Data for the first five criteria was acquired either from websites of individual terminals or from various types of aggregate studies. All of these criteria should be maximized. The biggest weight (8) was assigned to the criteria "length of the quay" and "number of shortsea connections" because these two parameters significantly affect the efficiency and accessibility of marine container bases. A slightly lower weight (7) has been given the maximum water depth at the quay, as this is a parameter determining the size of ships that can call at a given port, and thus affecting the ability to maintain ocean connections. The parameters "number of STS" (weight 5) and "number of RTGs" (weight 4) were considered least important due to the fact that some container terminals use a different type of equipment for quay and yard operations[4] . Nevertheless, both mentioned criteria have been included in the analysis because the use of specialized handling equipment significantly improves the efficiency of container bases. On the other hand, distances from motorways and expressways/national roads, as well as the national railway station were determined on the basis of own calculations using navigation programmes and digital maps. These distances have been calculated regarding the nearest road of a given type or railway station where the train can change the route. In both cases, the parameters should be minimized, and their weight is 6.

3. OVERVIEW OF SMALL BALTIC CONTAINER TERMINALS

Separate analysis of each of the seven criteria selected for the study can be the basis for a conclusion that the best terminals are located in Fredericia (C5, C6), Lubeck (LHG Skandinavienkai, C1, C4) and Świnoujście (C3, C7) (Table 3). OT Port is next to the ACT, Oritkari, RCT, FCT, LHG Seelandkai, SCA Logistics Umeå and Kalundborg CT, one of eight Baltic container bases that support two regular shortsea connections. Only two of all analysed terminals use RTGs for yard operations (BCT Baltiysk, GKT), and as many as 18 bases do not have any STS cranes. In addition, four terminals do not support any regular line connections (RCT, GKT[5] , Haraholmen, Hangö Stevedoring). With reference to the first criterion (length of the quay), AWT's location can be considered as the least favourable, while the base in Åhus got the worst result when the fifth criterion is considered (maximum depth at the quay). Finally, BCT Baltiysk and Hacklin are the furthest offshore locations from the Baltic Sea roads and railways.

Table 3 presents the values for thirty analysed Baltic container terminals within k=7 criteria. The best results, considering each of the criteria, are bolded, and the worst – highlighted in grey boxes.

Sweden is the country, which has the largest number of small container terminals in the Baltic Sea region, of which the largest market shares are held by ÅCT and Halmstadt (see Table 1). None of the Swedish terminals use RTG cranes, and more than half do not use STS cranes. Taking into account the distance from the nearest motorways and expressways/national roads, the best location is the SCA Logistics base in the Umeå port (0.9 km), and the worst – the container terminal in Piteå (12.4 km). The ÅCT is, in turn, the furthest from the national railways (15.9 km), while the station for the national railway is closest to VCT (0.7 km).

[4] Not all marine container terminals use STS (Ship to Shore) and RTG (Rubber Tyred Gantry) cranes. Their technical equipment may include other devices, such as e.g. RMG (Rail Mounted Gantry) cranes, gantry carriers, fork lifts or reach stackers.

[5] In an article by W. Krakowska-Mehring [4] investments planned in GTK are mentioned, while the National Court Register [10] contains information about the liquidation of the Gdańsk Container Terminal partnership. This can be the reason why it currently does not maintain any regular shortsea connections.

There are six Baltic container bases in the analysed group in Finland. The smallest Finnish terminal is Röyttä in Tornio, while Hangö Stevedoring has the deepest waterfront. The AWT of Port of Kokkola is the only terminal in the Nordic Countries where vessels can be loaded and discharged under roof. Regardless of the size of terminals, in Finland no RTG cranes are used for yard operations. Finally, taking into account the location of the analysed bases, the terminal located farthest from motorways and expressways/national roads is the Ajos in the port of Kemi (7.1 km), while the Hacklin in the Tornio port is located at the greatest distance from the nearest national railway station (24.9 km).

Of the five German terminals, only one (LHG Seelandkai) uses specialized equipment on the quay (two STS cranes). However, none of the terminals in question uses yard RTGs. Taking into account all the nodes described, the port in Lubeck maintains regular line connections with each of the Baltic countries except Poland. Moreover, the most distant from motorways, expressways/national roads is the second largest terminal of the Lubeck port, LHG Nordlandkai (3.1 km), and the CTL (10.4 km) is the farthest from the national railway station.

In Denmark there are located four small Baltic container terminals, the smallest of which is situated at Kalundborg (only 12,000 TEU of annual turnover). Bases in Aalborg and Copenhagen can serve up to 100,000 and 150,000 20-ft containers per year. The first of these is a direct link to the container route Rotterdam – Aalborg – Gothenburg, and the second – to Hamburg, Rotterdam and Bremerhaven. The FCT Fredericia is, in turn, the deepest Danish terminal with a water depth at the quay up to 15 m. None of the Danish terminals use RTG cranes for yard operations.

Three small Baltic container terminals are located in Russia. Their maximum annual throughput capacity does not exceed 150,000 TEU (RFT and terminals in Kaliningrad and Baltiysk). The information contained in Table 3 shows that two out of three Russian terminals use no quay nor yard cranes (KSCP, RFT). Finally, the BCT Baltiysk's location is definitely the least advantageous as it is located 13.1 km away from the nearest motorways and expressways/national roads.

Both terminals operating in Poland use STS cranes, and one (GKT) also RTGs. The OT Port has a better location, as it is located just 0.85 km and 0.6 km from the nearest roads and the national railway station, respectively.

As the RCT's annual throughput expressed in 20-ft containers does not exceed 150,000, the terminal in question is the only Latvian base (in Latvia there are three Baltic container terminals in total) that is listed in Table 3. The terminal has a relatively short (195 m) and deep (10.5 m) quay, but does not maintain any regular shortsea connection. Although two STS cranes are used on its quay, similarly to most of the analysed bases no RTGs are used in RCT's yard.

Table 3. Criteria values for small Baltic container terminals.

Name of the terminal	Length of the quay (m)	Number of RTGs	Number of STS	Number of shortsea connections	Max depth at the quay (m)	Distance from motorways and expressways/ national roads (m)	Distance from the national railway station (m)
Denmark							
ACT	870	0	**2**	4	9.4	5 600	10 300
FCT Fredericia	330	0	0	5	**15.0**	**300**	2 300
Kalundborg CT	250	0	**2**	2	11.9	500	1500
SCT	580	0	0	1	11.0	850	950
Finland							
Hangö Stevedoring	**245**	**0**	**0**	**0**	**14.0**	**850**	**1 000**
Ajos	**178**	**0**	**0**	**2**	**10.0**	**7 100**	**10 200**
AWT	**122**	**0**	**0**	**1**	**8.3**	**5 600**	**7 100**
Oritkari	**345**	**0**	**2**	**2**	**10.0**	**4 000**	**4 100**
Hacklin	**850**	**0**	**1**	**1**	**12.0**	**3 800**	**24 900**
Röyttä	**225**	**0**	**0**	**1**	**8.0**	**3 900**	**11 600**
Latvia							
RCT	195	0	**2**	0	10.5	8 100	3 800
Germany							
CTL	300	0	0	2	9.0	500	10 400
LHG Skandinavienkai	**2 065**	0	0	**10**	9.5	1 100	4 300
LHG Nordlandkai	1 550	0	0	4	9.5	3 100	3 700
LHG Schlutup	230	0	0	1	8.5	1 400	9 500
LHG Seelandkai	400	0	**2**	5	9.0	500	10 000
Poland							
OT Port	660	0	**2**	2	13.2	850	**600**
GKT	365	2	1	0	9.8	1 200	6 300
Russia							
BCT Baltiysk	205	**4**	0	1	9.5	13 100	3 400
KSCP	420	0	0	2	9.6	2 500	3 100
RFT	150	0	0	3	7.4	1 000	4 100
Sweden							
ÅCT	400	0	0	2	7.0	1 500	15 900
Halmstadt	500	0	1	1	8.5	3 700	1 200
Karlshamn CT	200	0	0	1	10.5	2 300	4 900
Haraholmen	600	0	0	0	7.5	12 400	13 500
Sydhamnen	320	0	0	2	10.0	1 200	2 500
CTF	240	0	**2**	3	10.4	2 400	4 800
SCA Logistics Sundsvall	800	0	1	1	12.3	2 400	6 700
SCA Logistics Umeå	185	0	**2**	1	11.0	900	14 000
VCT	400	0	0	1	7.5	1 700	700

Source: own elaboration.

4. DESCRIPTION AND CHARACTERISTICS OF THE PROMETHEE II METHOD

In the PROMETHEE II method *(Preference Ranking Organization Method for Enrichment Evaluations II)* for each decision-making variant *K* a number of criteria is distinguished, for which $m_i^{(k)}$ measures, directions of optimization (minimum or maximum) and wk weights are determined. The procedure for this method consists of five stages:

1. Setting the value of the preference function for all object pairs within each criterion;
2. Designation of individual preference indexes for each and every object pairs within each criterion (normalization of preference function values);
3. Determination of multi-criteria preference indexes for all object pairs;
4. Determination of dominance flows (input, exit, net) for each of the objects;
5. Determination of the ranking of objects on the basis of net dominance flows [7].

Let the assessment of the i^{th} object relative to the k^{th} criterion be denoted as $m_i^{(k)}$. In order to compare pairs of variants (i, j) within criterion k, the non-binding function of preferences $r^{(k)}(i,j)$ is calculated using formula (1):

$$r^{(k)}(i,j)=\begin{cases} 0\,if\, m_i^{(k)}-m_j^{(k)}<0 \\ m_i^{(k)}-m_j^{(k)}\,if\, m_i^{(k)}-m_j^{(k)}\geq 0 \end{cases} \quad (1)$$

The next step of the procedure is the determination of individual indexes of preferences $H^{(k)}(i,j)$ for each pair of objects (i, j) within a single criterion k depending on the selected generalized criterion, which allows to normalize relations between particular decision variants. The selection of a generalized criterion is of significant importance, as to some extent, it represents the real preferences of the decision maker within the given situation the preference indexes are calculated linearly and are related to the value of the preference function.

These criteria require determining in advance whether the objects are inert to each other or whether one dominates over the other. Alternatively, they introduce certain thresholds of indifference or preferences that can be transformed with a given function. These thresholds are set in the form of a dialogue with the user. In order to establish the threshold of equivalence, an answer to the question to which extent the differences between the measures for a given criterion are not of great significance for the user needs to be provided. The preference threshold is set, in turn,

Table 4. Types of generalized criteria used in the study and the corresponding preference functions.

Name of the criterion	Preference function	Parameters
Criterion with linear preference	$H^{(k)}(i,j)=\begin{cases} 0\,if\, r^{(k)}(i,j)\leq 0 \\ \frac{r^{(k)}(i,j)}{p}\,if\, 0<r^{(k)}(i,j)\leq p \\ 1\,if\, r^{(k)}(i,j)>p \end{cases}$	p
Pseudo-criterion (linear with indifference area)	$H^{(k)}(i,j)=\begin{cases} 0\,if\, r^{(k)}(i,j)\leq q \\ \frac{(r(k)(i,j)-q)}{(p-q)}\,if\, q<r^{(k)}(i,j)\leq p\,1\,if\, r^{(k)}(i,j)>p \end{cases}$	q , p

Source: own elaboration.

criterion. Two of the six basic types of generalized criteria were used in the study[6] :

1. *The criterion with linear preference* (also known as the *V-shape criterion*), in which the value of the individual index of variant preference i with respect to the variant j is linearly correlated with the value of the preference function $r^{(k)}(i,j)$ (the value of the preference index increases linearly as the value of the preference function increases) until the value of $r^{(k)}(i,j)$ exceeds a certain $p>0$ threshold, known as the preference indicator. The p level is the limit above which object i strictly dominates the j^{th} object;
2. The with linear preference and indifference area (also known as the V-shape with indifference criterion) which can be seen as, to some extent, similar to the criterion based on the p level. The main differences can be witnessed, when the value of the preference function is in the range of . In the described

thanks to the answer to the same question, but in this case the differences between the measures for a given criterion start to gain importance for the user [6, 9]. The list of generalized criteria used in the study and the method of their calculation are presented in Table 4.

The next step in the proceedings is the determination of multi-criteria preference indexes πij for each pair of objects in accordance with the formula:

$$\pi(i,j)=\frac{\sum_{k=1}^{K} w_k H^{(k)}(i,j)}{\sum_{k=1}^{K} w_k} \quad (2)$$

where:

w_k – the weight of the k criterion, which represents its significance for the decision maker with consideration of the other criterions.

[6] A description of all generalized criteria can be found, among others, in an article by A. Kucharski [5].

The last step of the procedure is to calculate the dominance flows for each pair *(i, j)*:

1) domination of output (positive): $\varphi^{+}(i)=\sum_{j=1}^{N}\pi(i,j)$;
2) input domination flow (negative): $\varphi^{-}(i)=\sum_{j=1}^{N}\pi(i,j)$;
3) net domination flow: $\varphi(i)=\varphi^{+}(i)-\varphi^{-}(i)$.

The value of φ+*(i)* is an assessment of the extent to which the variant is better than the other options. The value of φ-*(i)* is an assessment of the extent to which the variant is worse than the other options. The final ranking is obtained by arranging the objects in a descending manner with regards to the value of net dominance flows. A positive value of the net dominance flow means that the variant is in the group of dominant variants, while the negative one assigns the variant to the group of dominated variants.

5. MULTI-CRITERIA RANKING OF SMALL CONTAINER TERMINALS OF THE BALTIC SEA

In the presented study, the type of generalized criterion and the values of appropriate preference and indifference thresholds were selected in accordance with the grades for the given criterion. The model of linear preference (criteria C2, C3, C4) and the model with linear preference and indifference area (criteria C1, C5, C6 and C7) proved to be the best for determining copliance rates. Both models provide a linear increase in assessment measures between set thresholds. The second model was used when the small difference between the values when comparing two alternatives with a given criterion was not relevant to the decision maker (the difference was considered negligible). Table 5 presents adopted types of generalized criteria and values of *p* and *q* parameters, while Table 6 presents the final results.

The value of φ+ determines the extent to which the considered variant is better than all the others, while the value of φ- is an assessment of the extent to which it is worse than the rest of the variants. The final ranking was made by arranging the terminals in question according to the descending value of net dominance flows. In the analysed group of thirty Baltic container terminals with annual maximum throughput less than 150,000 TEU, 40% of the objects should be assigned to the dominating group (positive value φ), and 18 terminals – to the dominated one (negative value φ). The top three positions in the final ranking were taken by Lubeck's LHG Skandinavienkai, the Danish FCT Fredericia and the Polish OT Port. The worst in the analysed group were the Swedish (Haraholmen, ÅCT) and the Finnish (Röyttä, AWT, Ajos) terminals. The group of dominating objects included the German LHG Nordlandkai and LHG Seelandkai, Danish terminals in Kalundborg and Aalborg, the Polish GKT and four Scandinavian bases (CTF, Oritkari, Hangö Stevedoring, SCA Logistics Sundsvall). At the same time, the largest shareholder in the market in question, BCT Baltiysk, took a distant, 24th place in the ranking presented in Table 5.

6. CONCLUSIONS

The results of the competitive analysis of small Baltic container terminals reflect the dependencies on this market. Characteristic features of the analysed terminals are small differences between the characteristics values within each of the chosen criteria (especially in the second criterion – the number of RTGs, and the third – the number of STS). Due to small differences in absolute market shares, it seems that there is a real threat of a competitive struggle within the examined group, especially as the considered maritime container bases direct their offer to the same group of recipients.

Table 5. Generalized criteria and values of p and q parameters adopted in the PROMETHEE II method.

	C1	C2	C3	C4	C5	C6	C7
Name of criterion	**Length of the quay (m)**	**Number of RTGs**	**Number of STS**	**Number of shortsea connections**	**Max depth at the quay (m)**	**Distance from motorways and expressways/ national roads (m)**	**Distance from the national railway station (m)**
Generalized criterion	LPI	LP	LP	LP	LPI	LPI	LPI
p value	842.85	1.46	1.78	4.05	3.86	6 595.44	11 095.92
q value	454.78	–	–	–	1.68	3 325.67	5 143.16

Source: own elaboration.

In the discussed group, the best results were achieved by terminals from Denmark, Germany and Poland, which positioned themselves in the area of strategic benefits for individual criteria. These are FCT Fredericia (C5 – maximum depth at the quay, C6 – distance from motorways, expressways/national roads), LHG Skandinavienkai (C1 – length of the quay, C4 – number of shortsea connections) and OT Port (C3 – number of STS, C7 – distance from the national railway station). The advantage of the latter can be further increased if a deep-water container terminal in Świnoujście (located east of the LNP terminal) is opened. Currently, however, it cannot be predicted what will be the outcome of public consultations on the matter and if the investment planned for 2025–27 (with the value of 2 billion PLN) will be carried out [3].

In the final multi-criteria ranking, the worst performers were Scandinavian terminals: Swedish Haraholmen and ÅCT, and Finnish Röyttä, as well as AWT. At this point, however, it is worth noting that the Scandinavian bases may, in the near future, build their competitive advantage by striving, according to the mission of the latest generation of marine container terminals, to reach the rank of the so-called "Green ports". This is confirmed by the activities currently undertaken by the Scandinavians to reduce CO2 emissions, use alternative energy sources or systems that reduce the impact of congestion [1].

Finally, the results of the conducted research (especially the analysis of regular shortsea routes offered (C4)) confirm the conclusion that the Baltic container market is of a feeder character[7] , where most of the connections are communicated by large North Sea ports, where oceanic vessels call – Hamburg, Bremerhaven, Rotterdam, Antwerp, with Baltic ports[8] .

[7] This has been confirmed by the ranking of the 15 largest container ports in Europe of 2018 [11], in which only Gdańsk may be found as one and the only Baltic Sea port in the last, 15th position.

[8] The few exceptions include Maersk Line connection reaching the DCT terminal in Gdańsk and, more recently, BCT in Gdynia [12].

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