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A Contribution to Analysis of the Space Productivity in a Seaport

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Abstract: *After the general theoretical introduction on port development trends, space productivity is taken into consideration in this paper. As an object of research is selected open storage area at the Dry Bulk Cargo Terminal in the Port of Bar (Montenegro). Some of the group of basic operational features of the Dry Bulk Cargo Terminal are taken into consideration. Based on data series on cargo quantities stored within the open storage area at the Dry Bulk Cargo Terminal, from the period from January 2014 to July 2022, related utilization rates are calculated. In that context, the intensity of the influence of different subjects (port terminal operator, exporter/importer, etc.) on port space productivity is analyzed. The principal direction of actions aiming to increase space productivity at the Dry Bulk Cargo Terminal in the Port of Bar (Montenegro) is identified, too.*

1. INTRODUCTION

Seaports play a role of utmost importance and act as an incentive for the development of the national economy in general (Nguyen, 2020).

The importance of seaports for countries cannot be underestimated. Ports work to encourage all industries so that they can export them to countries abroad and also works to open new businesses and projects (https://tijaratuna.com/en/importance-of-seaports/).

Ports must be agile and flexible to be able to quickly respond to rapidly changing economic, geopolitical and environmental realities (ESPO, 2022). Also, ports are important for the support of economic activities in the hinterland since they act as a crucial connection between sea and land transport (https://www.vliz.be/projects/sail/fiches/10.pdf).

According to Deloitte Global Port Advisory (2020), key development trends in the port sector in the time horizon to 2030 are Space productivity; Waterfront redevelopment; Reshoring of industries; Port infrastructure; Changes in supply and demand; Impact on trade; More technological solutions; More cyber risk; Less focus on physical infrastructure investments; Overcapacity; Niche markets; Shift from big, bigger, biggest to green, greener, greenest; Sustainability; Shorter trade routes; Increased trade; New resources; A physical trade platform; Impact on Maritime trade; Technology as a competitive advantage; Sustainability as a competitive advantage; Collaboration between carriers; Collaboration at ports.

Ports are crucial for the European transport business, for Europe's competitiveness, and have a huge potential for job creation and investment. There is a forecast: a 50% growth of cargo handled in European Union ports is predicted by 2030. The European Commission has estimated that by 2030 between 110 000 and 165 000 new jobs can be created in ports (European Commission, 2013).

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The major challenges facing ports are (European Commission, 2013): High predicted growth, a structural performance gap in Europe, the changing nature of shipping (the size and the complexity of the fleet are increasing, deployment of bigger vessels for short sea shipping and feeder services, recent trends in logistics and distribution systems attract more value-added services within a port's area, energy trades are changing).

Pre-existing megatrends – generators of port development – are (UNCTAD, 2021): geopolitical, technological, and environmental.

In addition, in references (PTI, 2021; Piernext, 2022) is stated that the starting point of the maritime traffic study in Europe in the 2040 Horizon has been to identify the trends which have the highest degree of consensus: economic trends, environmental trends, social trends, trends linked to supply chains, such as the increasing appearance of global disruptions; the development of electronic commerce and circular economy or the role additive printing or autonomous transport can take, trends in maritime transport, mainly the development of mega-ships.

2. SPACE PRODUCTIVITY

Space productivity, according to Deloitte Global Port Advisory (2020), is related to the shortage of space in the existing urban ports. Innovation and automation can contribute to increasing efficiency, i.e. by raising berth and terminal occupancy. It is therefore expected that technological developments will increasingly be used to tackle the challenges of space scarcity.

On the other hand, in (ESPO, 2022) is recognized that the scarcity of available port land enlarges the case for port cooperation. In considering how best to accommodate increasing trade demand, in (https://www.portvancouver.com/projects/) is given an example of a business objective: Making the best and most efficient use of existing land and facilities.

One of the key components of the space in a port is an open storage area, for different cargo types (dry bulk cargoes, general cargoes, containers, ...). Taking open storage area for dry bulks as a topic of further consideration, it can be said that, in general, the capacity of an open storage area for storing dry bulk cargoes, C (t), is a function of the following parameters: net size of the area, P_n (m^2), storing height, h_i (m), the specific density of dry bulk cargo stored, ρ (t/m^3), coefficient of the storage volume utilization, k. It can be interpreted by the following relation:

$$C = f(P_n, h_i, \rho, k) \tag{1}$$

Quantity of cargo stored at any moment, v, on the open storage area, Q_t (t), can be defined based on the following equation:

$$Q_v = q_0 + [(\Sigma q_{jt} + \Sigma q_{kw} + \Sigma q_{ls}) - (\Sigma \delta_{mt} + \Sigma \delta_{nw} + \Sigma \delta_{os}) \tag{2}$$

Where:

- q_0 (t) – initial cargo quantity stored;
- q (t) – quantities transported to an open storage area by trucks, wagons, ships, in a certain period;
- δ (t) – quantities delivered from an open storage area by trucks, wagons, ships, in a certain period;

Maximal dry bulk cargo quantity stored, Q_{max} (t), in open storage area is a maximum of quantities of stored cargo, Q_v (t) (according to equation (2)), which can be interpreted as follows:

$$Q_{max} = g(Q_{v1}, Q_{v2}, ..., Q_{vp}, ..., Q_{vr}) \quad (3)$$

Space productivity of an open storage area, S_p (t), related to dry bulk cargoes, in one of possible variants, could be defined as dry bulk cargoes quantities passed through that area for a certain period, V (h), as given by the relation (4):

$$S_p \text{ (t/period of time)} = f[\Sigma(q - \delta)_v, Y_x) \quad (4)$$

Where:

$\Sigma(q - \delta)_v$ – cargo quantities stored (for all cargo types);
Y_x (h) – storing period of each cargo type, x;

3. A RESEARCH ON THE SPACE PRODUCTIVITY OF THE OPEN STORAGE AREA AT A DRY BULK CARGO TERMINAL

In this paper segment are shown results of research on space productivity of the open storage area at the Dry bulk cargo terminal in the Port of Bar (Montenegro).

3.1. Object of Research

The object of research is the open storage area (its space productivity) at the Dry bulk cargo terminal in the Port of Bar. Some of the group of basic operational features of the Dry Bulk Cargo Terminal in the Port of Bar are systematized in Table 1. The total size of the open storage area is area: 27,845.1 m^2 (length x width (m) = 556,90 x 50 m); the dimension of 26 m corresponds to the maximum outreach of the gantry cranes towards the open storage area, as well as the outreach of the mobile harbour cranes in relation to their optimal positions towards the line of the key.

3.2. Objective of Research

The objective of the research has the following components: **to define** the utilization rate of the open storage area at the Dry bulk cargo terminal in the Port of Bar (related to storing volume); **to define** parameters that determine space productivity of the open storage area at the Dry bulk cargo terminal and analyzing their variations over the time; **to identify** the intensity of influence of different subjects (port terminal operator, exporter/importer, ...), participating in the supply chain realization, on space productivity; **to define** principal directions of actions aiming to increase space productivity at the Dry bulk cargo terminal in the Port of Bar;

3.3. Research Methodology

Basic elements of the research methodology, adjusted to the object of research, are given in Table 2.

Results of the Research

Due to the limited volume of this paper, in further parts will be shown results of the research R_2 and R_4 (as per elements of Table 2.).

Table 1. Operational features of the Dry Bulk Cargo Terminal in the Port of Bar

Berth		(1)	01
Berth length (m)		(2)	185,63
Water depth (m)		(3)	14,00
Ship draft (m)		(4)	12,80
Availability of the shore port machinery	Yes	(5)-1	*
	No	(5)-2	
Type of the port machinery		(6)	Ship to shore gantry cranes (3 pcs.), SWL: 12 t, rail mounted, movable by all three berths; outreach to open storage area: 26 m;
Cargo types which can be handled (LB – Liquid bulks; DB – Dry bulks; G – Lo-Lo - General Lo-Lo; C – containers Lo-Lo; G - Ro-Ro – General Ro-Ro;	LB	(7)-1	
	DB	(7)-2	*
	G Lo-Lo	(7)-3	*
	C	(7)-4	
	G Ro-Ro	(7)-5	
Cargo handling operations – ship to shore (and vice versa) (sum of possible handling operations)		(8)	Dry bulks: Ship to shore-open storage area/truck/wagon (and vice versa); ship to silo (and vice versa) (8); General Lo-Lo: ship to shore-open storage area-distant close warehouse/truck/ wagon (and vice versa) (8);
Availability of open storage area behind the berth		(9)	Yes. Dimensions: 185,63 x 50,00 m

Table 1. - continuation

Berth		(1)	02	03
Berth length (m)		(2)	185,63	185,63
Water depth (m)		(3)	14,00	14,00
Ship draft (m)		(4)	12,80	12,80
Availability of the shore port machinery	Yes	(5)-1	*	*
	No	(5)-2		
Type of the port machinery		(6)	Mobile harbour crane Liebherr LHM420 (on rubber tyres); SWL: 124 t; maximal outreach: 48 m; Mobile harbour crane Liebherr LHM550 (on rubber tyres); SWL: 144 t, maximal outreach: 54 m; Remark: by these two berths can be used and gantry cranes installed by the berth 01.	
Cargo types which can be handled (LB – Liquid bulks; DB – Dry bulks; G – Lo-Lo - General Lo-Lo; C – containers Lo-Lo; G - Ro-Ro – General Ro-Ro;	LB	(7)-1		*
	DB	(7)-2	*	*
	G Lo-Lo	(7)-3	*	*
	C	(7)-4	*	*
	G Ro-Ro	(7)-5		
Cargo handling operations – ship to shore (and vice versa) (sum of possible handling operations)		(8)	Containers: ship to shore-open storage area/truck/wagon (and vice versa) (6) Liquid bulks: Ship – reservoir (1); Dry bulks: Ship to shore-open storage are/ truck/ wagon (and vice versa) (6); General Lo-Lo: ship to shore-open storage area-distant close warehouse/truck/wagon (and vice versa) (8);	
Availability of open storage area behind the berth		(9)	Yes. Dimensions: 185,63 x 50,00 m	Yes. Dimensions: 185,63 x 50,00 m

Source: Author, based on Port of Bar, 2022.

Table 2. Elements of the research methodology

Methodology phase, PH_i	Expected result, R_j
PH_1: An analysis of cargo quantities stored within open storage area at the Dry bulk cargo terminal for the period from January 2014 to July 2022, per cargoes types and in total;	R_1: Quantities (data series) of cargoes stored within open storage area at the Dry bulk cargo terminal , per cargoes types and in total, for the period from January 2014 to July 2022;
PH_2: Calculation of utilization rate of the open storage area at the Dry bulk cargo terminal for the period from January 2014 to July 2022; identifying principal influential factors on the utilization rate values;	R_2: Utilization rate of the open storage area at the Dry bulk cargo terminal for the period from January 2014 to July 2022; influential factors on the utilization rate;
PH_3: Identifying intensity of influence of different subjects (port terminal operators, exporter/importer, ...), participating in the supply chain realization, on space productivity at the Dry bulk cargo terminal;	R_3: Intensity of influence of different subjects, participating in the supply chain realization, on space productivity at the Dry bulk cargo terminal;
PH_4: Defining principal directions of increasing space productivity at the Dry bulk cargo terminal;	R_4: Principal directions for increasing space productivity at the Dry bulk cargo terminal;

Source: Author

Result 2 – A) Utilization rate of the open storage area at the Dry bulk cargo terminal for the period from January 2014 to July 2022

In table 3 are given the results of analyses of the utilization rate of the open storage area at the Dry bulk cargo terminal for the period from January 2014 to July 2022 – it's variant related to the utilization of available storing volume. Basic values of the utilization rate, k_1, are calculated based on the input parameters recognized in the process of analyzing performances of the open storage area at the Dry bulk cargo terminal (Table 1).

Volumes per cargoes types are calculated according to the following equation:

$$\text{(volume per cargo type) } [m^3] = \text{(cargo quantity stored) } [t] \,/\, \text{(specific density of cargo) } [t/m^3] \quad (5)$$

Calculated available volume 1 is defined based on the following values of parameters: open storage area dimensions – length x width (m) = 556,90 x 50 m; up to a part of the storage area width of 26 m, storing at a height of 8 m, at the remaining part of the open storage area, of 24 m width, storing at height of 4 m.

In order to establish bases for conclusions on the simultaneous influence of characteristics of open storage area and used port machinery–implemented cargo handling technology, in Table 4. are presented calculated values of utilization rates k_2 and k_3.

Calculated available volume 2 is defined based on the following values of parameters: open storage area dimensions – length x width (m) = 556,90 x 50 m; up to a part of the storage area of 26 m width, storing at height of 10 m (comparing with variant 1, height is increased for 2 m), at the remaining part of the open storage area, of 24 m width, storing at height of 6 m (comparing with variant 1, height is increased for 2 m).

Calculated available volume 3 is defined based on the following values of parameters: open storage area dimensions – length x width (m) = 556,90 x 50 m; up to a part of the storage area of 26 m width, storing at a height of 10 m (storing height remains the same as in variant 2), at the remaining part of the open storage area, of 24 m width, storing at height of 10 m (comparing with variant 2, height is increased for 4 m).

Table 3. Utilization rate of the open storage area for the period from January 2014 to July 2022

date	(1)	2014, 1 January	2014, 1 April	...	2022, 1 July
Volume 1-C1-bauxite;density (t/m3) [18]: 1,7t/m3	(2)	2,223.01	2,223.01		56,343.91
Volume	(3)	1,482.00	1,482.00		37,562.61
Volume	(4)	8,920.18	2,443.33		0.00
Volume 4-C4-salt; density (t/m3) [19]: 1,05t/m3	(5)	0.00	0.00		705.41
Volume 5-C5-petrocoke; density (t/m3) [20]: 0,44t/m3	(6)	0.00	0.00		0.00
Volume 6-C6-iron ore; density (t/m3) [18]: 2,2t/m3	(7)	0.00	0.00		0.00
Total volume (m3)		13818.79	7163.19		63133.56
Calculated available volume (m3)	(9)	169,297.60	169,297.60		169,297.60
Utilization rate, k1	(10)=(8)/(9)	0.08	0.04		0.37

Source: Author

Table 4. Values of utilization rates k_2 and k_3

date	Total volume (m^3)	Calculated available volume 2 (m^3)	Calculated available volume 3 (m^3)	K2	K3
2014, 1 January	13818.79	224,987.60	278,450.00	0.06	0.05
2014, 1 April	7163.19	224,987.60	278,450.00	0.03	0.03
...					
2022, 1 July	63133.56	224,987.60	278,450.00	0.28	0.23

Source: Author

Result 2 – B) influential factors on the utilization rates values

Taking into account the results of analyses shown in tables 3. and 4., the following key groups of influential factors on utilization rates values, k_i, can be defined: **cargo characteristic** (specific density, angle of repose, ...); **parameters which characterize implemented cargo handling and storing technology** (type of port machinery, SWL of used port machinery, positional flexibility of used port machinery, an outreach of used port machinery, etc.); **parameters which characterize open storage area** – the existence of elements which contribute to increasing utilization of available storing volume (e.g. reinforced concrete blocks);

Result 4 - Principal directions for increasing space productivity at the Dry bulk cargo terminal

Respecting previously shown results of research, following principal directions of increasing space productivity of open storage area at the Dry bulk cargo terminal can be defined: **improving implemented cargo handling and storing technology** (introducing new port machinery with an increased level of technological adequacy; here is considered the necessity of analyzing investments justification, fully respecting, among other, port investment capability); **improving performances of the open storage area** – building elements which contribute to increased utilization of the available storing volume; **improving the level of coordination between subjects participating in the supply chain realization**;

4. DISCUSSION OF RESULTS

Only two cargo types – bauxite and scrap metal - were registered on all dates analyzed through the period from January 2014 to July 2021.

Utilization rate of the storage volume, k_1, ranges from 0.03 (October/2014 and October/2015) to 0.76 (January/2020).

Utilization rate k_2 is within the range of 0.02 (October/2014 and October/2015) to 0.57 (January/2020).

Utilization rate k_3 has values from 0.02 (October/2014 and October/2015) to 0,46 (January/2020).

The biggest stored cargo quantity (April/2021): 177,796.36 t does not correlate with the biggest utilization rate of the available storing volume (January/2020) which directly suggests that throughput structure (types of cargo handled and stored and their characteristics) of the port (terminal) has a significant influence on the space productivity – quantity passed through the certain area in the concrete period.

5. CONCLUSION

Optimization of space productivity in a seaport has to be one of the priority business objectives. It is determined by the general efforts to maximize available resources and potential utilization and to allow the biggest cargo quantities to pass through the concrete peace of space in a certain period.

In this paper were taken into consideration some elements on which space productivity is depending on (cargo characteristics, parameters that characterize implemented cargo handling and storing technology, parameters that characterize open storage area, and level of coordination between subjects participating in the supply chain realization). Demands related to space productivity are very relevant for the ports with limited available open storage areas and a lack of potential to expand it up to the necessary level. Among others, it is important to recognize the existence of a correlation between space productivity and overall throughput in a seaport.

The author plans to continue engagement in this field, being focused in the next phase on the research of mentioned correlation between space productivity in a seaport and the structure of its annual throughput.

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