Journal of Traffic and Transportation Engineering 14 (2020) 127-136
doi: 10.17265/2328-2142/2020.03.004

DAVID PUBLISHING

An Analysis of Net Berth Productivity in the Handling Operations with Dry Bulk Cargoes in a Seaport

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Abstract: Productivity at the berth is one from the group of port productivity measures which is closely tied to ship turnaround times. Net berth productivity is value of productivity related to the operational time at the berth. Based on the facts identified from available literature about minor share of researches related to the net berth productivity in the handling operations with dry bulk cargoes in a seaport, it was decided to take this port productivity metrics as an object of a research. After a detailed analysis of different categories of the net berth productivity in the handling operations with dry bulks, key groups of influential factors which determine values of the net berth productivity are identified and systematized. Some principal elements related to improving net berth productivity are taken into consideration, too. Concrete results shown in this paper are related to the Dry Bulk Cargo Terminal in the Port of Bar (Montenegro).

Key words: dry bulk cargoes, net berth productivity, improving.

1. Introduction

Ports form a vital link in the overall trading chain [1]. Productivity and efficiency are the two important concepts and are frequently utilized to measure port performance [2].

Port efficiency is an important factor to stimulate port competitiveness and boost regional development and is often associated with productivity [3]. Ports cannot meet carrier needs for productivity without technology, and they can't achieve the required financial results without improving efficiency [4].

Productivity is defined as the amount of output per unit of input [2, 5, 6] and is based on local circumstances of labor, equipment, land, capital, management, infrastructure and politics [1, 4]. It can be also defined as a summary measure of a quantity and quality work of performance with resource utilization considered [7].

In the available literature sources can be found numerous additional definitions of productivity. Very detailed literature reviews related to the productivity in ports are presented in references [1, 2, 6, 8].

Productivity at the berth is one from the group of port productivity measures which is closely tied to ship turnaround times. It shows which ports and terminals are the best at working ships and getting them back to sea quickly. Gross berth productivity between a ship's arrival and departure from berth, with no adjustments for labor or equipment down time regardless of the reason—is among the broadest definitions of productivity [9]. Net berth productivity is value of productivity related to the operational time at the berth (when non-operational time is deducted from total berthing time).

It is obvious that most of principal common objectives of both key parties (ship/carrier and terminal operator) in the port cargo handling process are related to productivity: ship/carrier - maximize productivity on the ship, ...; terminal operator – maximize berth productivity, ...; [8-10].

Increased berth productivity lead to reduction of the Terminal Operating Time (length of the ship`s time in a port – sum of operational and non-operational periods of time at berth). In general, it is vital to evaluate port performance in relation to how efficient

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are their services from the perspective of the port users: ship-owners, shippers (importers and exporters), land transport owners, etc. [6].

Based on the recognized facts, from the available literature, about minor share of researches related to the berth productivity in the handling operations with dry bulk cargoes in a seaport, it was decided to take this port productivity metrics as an object of a research in this paper. The key objectives of the research are to analyze values of the net berth productivity with different dry bulk cargoes, to identify and systematize key influential factors which determine values of the net berth productivity in a seaport and to recognize optimal directions of productivity improving. Starting hypothesis of the research is: *values of different categories of the net berth productivity in handling operations with dry bulk cargoes in a seaport are determined by numerous factors; there is a significant potential for improving net berth productivity.* Concrete results shown in this paper are related to the Dry Bulk Cargo Terminal in the Port of Bar (Montenegro).

2. An Analysis of Values of net Berth Productivity at the Dry Bulk Cargo Terminal in a Seaport

2.1 Description of the Port of Bar as a Multipurpose Seaport

Principle elements of the WORKPORT model structure [11], in Table 1, are systematized basic performances of the Port of Bar [12].

Some from the group of basic operational features of the Dry Bulk Cargo Terminal in Port of Bar, with special focus on the port machinery at operational quay (berths), are systematized in Table 2.

Table 1 Basic performances of The Port of Bar

Element \ Year	2014
OWNERSHIP/ MANAGEMENT MODEL	• The Port of Bar is a landlord port; it is functioning based on the Montenegrin Law on ports; at the port area are operating two main Port Terminal Operators: Port of Bar H. Co. (a share holding company, where majority of shares – 54% - are owned by the Government of Montengro) and the Port of Adria, where major part of shares – 62% - are owned by the Turkish Company Global Ports; • The first Port Terminal Operator, Port of Bar H. Co. is managing following specialized terminals: Terminal for dry bulk cargoes, Terminal for liquid cargoes, Terminal for grain, Ro-Ro and Passenger terminal; • The second Port Terminal Operator, Port of Adria is managing Terminal for general cargoes, Terminal for containers and Terminal for sawn timber;
THROUGHPUT STRUCTURE	Main cargo groups which are handled in The Port of Bar are: liquid bulk cargoes (LB); dry bulk cargoes (DB); general Lo-Lo cargoes (G-Lo-Lo); Containers Lo-Lo (C); General Ro-Ro cargoes (G-Ro-Ro); as well as passangers;
CARGO HANDLING TECHNOLOGIES	Handling operations with general cargoes are mechanized, as well as handling operations with dry bulk cargoes; Operations with liquid cargoes are highly mechanized and automatized;
INFORMATION SYSTEM	Automatized integral information system which covers all business activities takes place; EDI system is implemented in process of distribution of Quality system documentation;
WORK FORCE/WORK ORGANIZATION/ EMPLOYMENT RELATIONS/LABOUR RELATIONS	Hierarchical work organization; Degree of work force specialization is increased; Greater emphasis on qulity aspect of provided services; Internationally certified Quality Management System, modeled according to standard ISO 9001: 2008, exists.
PORT FUNCTION/ PORT DEVELOPMENT	Handling operations are in the focus; The Port of Bar, at complete territory (except a part of Ro-Ro and Passenger terminal), is a Free Zone; There is the Detail Urban Plan for the Port Zone.
HEALTH AND SAFETY ASPECT OF WORKING ENVIRONMENT	• Improved training in safety awareness; Decreasing accidents rate and physical health problems; Health and safety policy exists; • Complete port territory is under video surveillance; ISPS Code is fully implemented since July 1st, 2004;
ENVIRONMENTAL PROTECTION	Process of introducing certified Environmental Management System is taking place; Analyses of environmental aspects are obligatory part of all projects realized within the port area;

Table 2 Operational features of the Dry Bulk Cargo Terminal in the Port of Bar

Number of the berth	Water depth (m)	Availability of the shore port machinery		Type of the port machinery	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;					Cargo handling operations (number of possible operations)
		Yes	No		LB	DB	G Lo-Lo	C	G Ro-Ro	
(1)	(2)	(3)-1	(3)-2	(4)	(5)-1	(5)-2	(5)-3	(5)-4	(5)-5	(6)
SO1	6.5		*	-		*				Dry bulks: Ship – silo (1);
03	14.0	*		Ship to shore gantry cranes (3 pcs.), SWL 12 t, rail mounted, movable by all three berths;	*	*	*			Liquid bulks: Ship – reservoir (1); Dry bulks: Ship to shore/ truck/ wagon (and vice versa) (3); General Lo-Lo: ship to shore/truck/ wagon (and vice versa) (3);
02	14.0	*				*	*			Dry bulks: Ship to shore/truck/ wagon (and vice versa); ship to silo (and vice versa) (4);
01	14.0	*				*	*			General Lo-Lo: ship to shore/truck/ wagon (and vice versa) (3);

Table 3 Net berth productivity in the Port of Bar for the period from 2010 to 2014。

Cargo	Handling operation	Parameter	Values of parameters per years				
			2010	2011	2012	2013	2014
C1: Zink ore	Open storage area - ship	Total cargo quantity loaded/unloaded in/from ships in a year (t)	105,650.4	149,944.4	83,664.5	-	32,566.5
		Operational time at berth (h)	204.1	329.4	179.7	-	76.9
		Net berth productivity (t/h)	517.6	455.2	465.6	-	423.5
C2: Alumina	Ship - truck	Total cargo quantity loaded/unloaded in/from ships in a year (t)	7,925.2	21,412.7	15,500	4,150.1	33,655.9
		Operational time at berth (h)	119.3	286.2	166.7	52.3	281.2
		Net berth productivity (t/h)	66.4	74.8	93	79.4	119.7
C3: Zinc concentrate	Open storage area – ship	Total cargo quantity loaded/unloaded in/from ships in a year (t)	2,792.9	3,564.7	2,875	9,503.9	-
		Operational time at berth (h)	25.7	22.8	23.5	82.3	-
		Net berth productivity (t/h)	108.7	156.3	122.3	115.5	-
C4: Iron scrap	Open storage area – ship	Total cargo quantity loaded/unloaded in/from ships in a year (t)	55,576.5	17,462.2	29,344.1	23,795.8	14,683.6
		Operational time at berth (h)	422.4	199.6	254.7	195.4	108.9
		Net berth productivity (t/h)	131.6	87.5	115.2	121.8	134.8
C5: Salt	Ship – truck	Total cargo quantity loaded/unloaded in/from ships in a year (t)	3,950	10,150	2,650	5,684.1	4,800
		Operational time at berth (h)	38.5	90.6	25.3	49.3	36.5
		Net berth productivity (t/h)	102.6	112	104.7	115.3	131.5

2.2 An analysis of net Berth Productivity

With Table 3 are presented results of analyses of the net berth productivity, P_{nb} (t/h), at the Dry Bulk Cargo Terminal in the Port of Bar for the period from 2010 to 2014 – total number of ship calls analyzed: 581; total number of cargo types analyzed: 5 (cargo types with the biggest share in the total throughput at the Dry Bulk Cargo Terminal) [12].

Net berth productivity, P_{nb} (t/h), is calculated using equation (1):

$$P_{nb} = \sum(\text{total cargo quantity loaded/unloaded in/from ships in a year})(t) / \sum(\text{total operational time of all ships in a year})\ (h) \quad (1)$$

Variations of net berth productivity achieved values are presented with Table 4.

In order to make bases for conclusions about the potential for improving net berth productivity (and to increase values of the existing capacities utilization rate), in the next phases of analysis are defined values of the theoretical net berth productivity (theoretical productivity per hour), P_{th} (t/h) (Table 5).

Table 4 Variation of net berth productivity.

Cargo	Handling operation	Variations of the net berth productivity		
		Minimal	Maximal	Maximal/minimal
C1: Zink ore	Open storage area - ship	423.5	517.6	1.22
C2: Alumina	Ship - truck	66.4	119.7	1.80
C3: Zinc concentrate	Open storage area – ship	108.7	156.3	1.44
C4: Iron scrap	Open storage area – ship	87.5	134.8	1.54
C5: Salt	Ship – truck	102.6	131.5	1.28

Table 5 Values of the Theoretical net berth productivity (theoretical productivity per hour), P_{th} (t/h).

Cargo	Handling operation	Parameter	Values of parameters per years				
			2010	2011	2012	2013	2014
C1: Zink ore	Open storage area - ship	Net berth productivity (achieved values), P_{nb} (t/h)	517.6	455.2	465.6	-	423.5
		SWL of shore gantry crane, Q_c (t/crane)	12	12	12	-	12
		Number of used cranes per ship, N_{cs}	3	3	3	-	3
		Total SWL of used cranes, $\sum Q_c = Q_c \times N_{cs}$ (t/cranes)	36	36	36	-	36
		Volume of available grab, V_{g1} (m^3/grab/crane)	2.9	2.9	2.9	-	2.9
		Number of used grabs, N_g	3	3	3	-	3
		Total volume of used grabs, $\sum V_{g1} = V_{g1} \times N_g$ (m^3)	8.7	8.7	8.7	-	8.7
		Specific density of cargo, γ (t/m^3)	2.04	2.04	2.04	-	2.04
		Awerage number of working cycles per hour, N_c	26	26	26	-	26
		Weight of a grab, G_w (t)	4.9	4.9	4.9	-	4.9
		Useful part of the crane SWL, Q_{uf} (t) = SWL - G_w	7.1	7.1	7.1	-	7.1
		Theoretical cargo quantity per cycle, Q_t (t) = $Q_{uf} \times N_{cs}$	21.3	21.3	21.3	-	21.3
		Theoretical productivity per hour, $P_{th} = Q_t \times N_c$	553.8	553.8	553.8	-	553.8
		P_{nb} (t/h)/P_{th} (t/h)	0.93	0.82	0.84	-	0.76
C2: Alumina	Ship - truck	Net berth productivity, P_{nb} (t/h)	66.4	74.8	93	79.4	119.7
		SWL of shore gantry crane, Q_c (t/crane)	12	12	12	12	12
		Number of used cranes per ship, N_{cs}	1	1	1	1	1
		Total SWL of used cranes, $\sum Q_c = Q_c \times N_{cs}$ (t/cranes)	12	12	12	12	12
		Volume of available grab, V_{g1} (m^3/grab/crane)	7.6	7.6	7.6	7.6	7.6
		Number of used grabs, N_g	1	1	1	1	1
		Total volume of used grabs, $\sum V_{g1} = V_{g1} \times N_g$ (m^3)	7.6	7.6	7.6	7.6	7.6
		Specific density of cargo, γ (t/m^3)	1.05	1.05	1.05	1.05	1.05
		Awerage number of working cycles per hour, N_c	20	20	20	20	20
		Weight of a grab, G_w (t)	4	4	4	4	4
		Useful part of the crane SWL, Q_{uf} (t) = SWL - G_w	8	8	8	8	8
		Theoretical cargo quantity per cycle, $Q_t = Q_{uf} \times N_{cs}$ (t)	8	8	8	8	8
		Theoretical productivity per hour, $P_{th} = Q_t \times N_c$	160	160	160	160	160
		P_{nb} (t/h)/P_{th} (t/h)	0.42	0.47	0.58	0.50	0.75
C3: Zinc concentrate	Open storage area – ship	Net berth productivity, P_{nb} (t/h)	108.7	156.3	122.3	115.5	-
		SWL of shore gantry crane, Q_c (t/crane)	12	12	12	12	-
		Number of used cranes per ship, N_{cs}	1	1	1	1	-
		Total SWL of used cranes, $\sum Q_c = Q_c \times N_{cs}$ (t/cranes)	12	12	12	12	-
		Volume of available grab, V_{g1} (m^3/grab/crane)	2.4	2.4	2.4	2.4	-

Table 5 to be continued

C3: Zinc concentrate	Open storage area – ship	Number of used grabs, N_g	1	1	1	1	-
		Total volume of used grabs, $\sum V_{g1} = V_{g1} \times N_g$ (m^3)	2.4	2.4	2.4	2.4	-
		Specific density of cargo, γ (t/m^3)	2.75	2.75	2.75	2.75	-
		Awerage number of working cycles per hour, N_c	26	26	26	26	-
		Weight of a grab, G_w (t)	5.3	5.3	5.3	5.3	-
		Useful part of the crane SWL, Q_{uf}(t) = SWL - G_w	6.7	6.7	6.7	6.7	-
		Theoretical cargo quantity per cycle, $Q_t = Q_{uf} \times N_{cs}$ (t)	6.7	6.7	6.7	6.7	-
		Theoretical productivity per hour, $P_{th} = Q_t \times N_c$	174.2	174.2	174.2	174.2	-
		P_{nb} (t/h)/P_{th} (t/h)	0.62	0.90	0.70	0.66	-
C4: Iron scrap	Open storage area – ship	Net berth productivity, P_{nb} (t/h)	131.6	87.5	115.2	121.8	134.8
		SWL of shore gantry crane, Q_c (t/crane)	12	12	12	12	12
		Number of used cranes per ship, N_{cs}	2	2	2	2	2
		Total SWL of used cranes, $\sum Q_c = Q_c \times N_{cs}$ (t/cranes)	24	24	24	24	24
		Volume of available grab, V_{g1} (m^3/grab/crane)	2	2	2	2	2
		Number of used grabs, N_g	2	2	2	2	2
		Total volume of used grabs, $\sum V_{g1} = V_{g1} \times N_g$ (m^3)	4	4	4	4	4
		Specific density of cargo, γ (t/m^3)	1.48	1.48	1.48	1.48	1.48
		Awerage number of working cycles per hour, N_c	26	26	26	26	26
		Weight of a grab, G_w (t)	7	7	7	7	7
		Useful part of the crane SWL, Q_{uf}(t) = SWL - G_w	5	5	5	5	5
		Theoretical cargo quantity per cycle, $Q_t = Q_{uf} \times N_{cs}$ (t)	10	10	10	10	10
		Theoretical productivity per hour, $P_{th} = Q_t \times N_c$	260	260	260	260	260
		P_{nb} (t/h)/P_{th} (t/h)	0.51	0.34	0.44	0.47	0.52
C5: Salt	Ship – truck	Net berth productivity, P_{nb} (t/h)	102.6	112	104.7	115.3	131.5
		SWL of shore gantry crane, Q_c (t/crane)	12	12	12	12	12
		Number of used cranes per ship, N_{cs}	1	1	1	1	1
		Total SWL of used cranes, $\sum Q_c = Q_c \times N_{cs}$ (t/cranes)	12	12	12	12	12
		Volume of available grab, V_{g1} (m^3/grab/crane)	5.8	5.8	5.8	5.8	5.8
		Number of used grabs, N_g	1	1	1	1	1
		Total volume of used grabs, $\sum V_{g1} = V_{g1} \times N_g$ (m^3)	5.8	5.8	5.8	5.8	5.8
		Specific density of cargo, γ (t/m^3)	1.1	1.1	1.1	1.1	1.1
		Awerage number of working cycles per hour, N_c	20	20	20	20	20
		Weight of a grab, G_w (t)	4.96	4.96	4.96	4.96	4.96
		Useful part of the crane SWL, Q_{uf}(t) = SWL - G_w	7.04	7.04	7.04	7.04	7.04
		Theoretical cargo quantity per cycle, $Q_t = Q_{uf} \times N_{cs}$ (t)	7.04	7.04	7.04	7.04	7.04
		Theoretical productivity per hour, $P_{th} = Q_t \times N_c$	140.8	140.8	140.8	140.8	140.8
		P_{nb} (t/h)/P_{th} (t/h)	0.73	0.80	0.74	0.82	0.93

Remarks: SWL – safe working load; average number of working cycle per hour is mean value of working cycles per hour over the analyzed period [13];

2.3 Discussion of Results

Relations between the achieved values of net berth productivity and theoretical net berth productivity (theoretical productivity per hour) are bases for identification of potential for improving berth productivity. From the results given in Table 5, following conclusions can be made:

- achieved values of net berth productivity, P_{nb} (t/h), in analyzed handling operation with zinc ore, over the considered period, varied from 423.5 t/h (in the year 2014) to 517.6 t/h (in the year 2010);
- ratio between values of net berth productivity and theoretical net berth productivity (theoretical productivity per hour), P_{nb} (t/h)/P_{th} (t/h), related to analyzed handling operation with zinc ore, over the

considered period, varies from 0.76 (in the year 2014) to 0.93 (in the year 2010);

- achieved values of net berth productivity, P_{nb} (t/h), in analyzed handling operation with alumina, over the considered period, varied from 66.4 t/h (in the year 2010) to 119.7 t/h (in the year 2014);
- ratio between values of net berth productivity and theoretical net berth productivity (theoretical productivity per hour), P_{nb} (t/h)/P_{th} (t/h), related to analyzed handling operation with alumina, over the considered period, varies from 0.42 (in the year 2010) to 0.75 (in the year 2014);
- achieved values of net berth productivity, P_{nb} (t/h), in analyzed handling operation with zinc concentrate, over the considered period, varied from 108.7 t/h (in the year 2010) to 156.3 t/h (in the year 2011);
- ratio between values of net berth productivity and theoretical net berth productivity (theoretical productivity per hour), P_{nb} (t/h)/P_{th} (t/h), related to analyzed handling operation with zinc concentrate, over the considered period, varies from 0.62 (in the year 2010) to 0.90 (in the year 2011);
- achieved values of net berth productivity, P_{nb} (t/h), in analyzed handling operation with iron scrap, over the considered period, varied from 87.5 t/h (in the year 2011) to 134.8 t/h (in the year 2014);
- ratio between values of net berth productivity and theoretical net berth productivity (theoretical productivity per hour), P_{nb} (t/h)/P_{th} (t/h), related to analyzed handling operation with iron scrap, over the considered period, varies from 0.34 (in the year 2011) to 0.52 (in the year 2014);
- achieved values of net berth productivity, P_{nb} (t/h), in analyzed handling operation with salt, over the considered period, varied from 102.6 t/h (in the year 2010) to 131.5 t/h (in the year 2014);
- ratio between values of net berth productivity and theoretical net berth productivity (theoretical productivity per hour), P_{nb} (t/h)/P_{th} (t/h), related to analyzed handling operation with salt, over the considered period, varies from 0.73 (in the year 2010) to 0.93 (in the year 2014);

It is clear from the results shown in Table 5 that theoretical net berth productivity (theoretical productivity per hour) is calculated based on changed values of one parameter: handled cargo quantity per working cycle (that cargo quantity was taken as equal with the difference between Safe Working Load of the used crane and weight of the grab) – all other parameters (variables) for calculating net berth productivity were kept unchanges (number of working cycles per hour, number of gangs per ship, etc.). In addition, for the purpose of calculating theoretical net berth productivity is assumed that coefficient of the used grab capacity utilization is 100% (in practice, values of that coefficient are below assumed level).

Cases when achieved values of net berth productivity, P_{nb} (t/h), are very close to the values of theoretical net berth productivity, P_{th} (t/h) – cases when values of ratio P_{nb} (t/h)/P_{th} (t/h) are around 0.90 - are determined by optimaly dimensioned grabs used in the handling operations, high utilization of their capacities and bigger number of working cycles per hour comparing with average values for whole analyzed period.

When results of analyses are taken into consideration it is necessary to have in mind that the fact that an indicator does not vary intensively over time does not mean that the performance measured by that indicator is necessarily good. It may be consistently bad [13].

3. Influential Factors on Berth Productivity

In the references [4, 9, 13, 14] are found results of done considerations related to the influential factors on port productivity. It can be concluded that numerous influential factors on port productivity (berth productivity) are identified in mentioned references, but absence of their systematization (classification) is evident, as well, some of the important influential factors are not directly recognized.

In the further text are presented main groups of influential factors on net berth productivity (which can be considered as common and when in focus is berth productivity in general), based on results of already mentioned analyses found in the available literature and additional researches done by the author.

Group of factors which have decisive influence on net berth productivity (as one of the port productivity metrics) are:

F_1 – factors related to port infrastructure;

F_2 – factors related to port superstructure;

F_3 – factors related to port machinery;

F_4 – factors related to the port organization;

F_5 – characteristics of transport means for transporting cargo to/from the port;

F_6 – characteristics of cargo handled;

F_7 – characteristics of the lifting accessories;

F_8 – type of the cargo handling operation;

F_9 – factors related to the contract with the customer;

F_{10} – factors related to the port information system;

F_{11} – factors related to necessary administrative procedures;

F_{12} – factors related to the climate in the port zone;

F_{13} – factors related to the position of the port in the supply chain;

F_{14} – factors related to the adequacy level of the port (terminal) composition;

3.1 Influential Factors on Net Berth Productivity Related to Port Machinery

Port machinery has one of the crucially important role in achieving required values of productivity (all of its categories) in the cargo handling process.

As it was said, group F_3 - influential factors on net berth productivity related to the port machinery has several elements, where the most important are:

- factor f_{31} – port machinery exploitation characteristics;
- factor f_{32} – port machinery technological adequacy (level of coordination between port machinery exploitation characteristics and technological requirements which appear in the cargo handling process);
- factor f_{33} – port machinery operative readiness (level of readiness to be involved on demand in the cargo handling process);
- factor f_{34} – port machinery reliability (level of probability that port machinery will work without failure);
- factor f_{35} – port machinery importance rank, respecting current and expecting throughput structure (the highest importance rank is equal to the biggest share of the handling operations in overall number of operations for certain period where the concrete class of the port machinery is used as an element of the working technology);
- factor f_{36} – port machinery flexibility (capability of the port machinery to respond on changing requirements, positional and technological);
- factor f_{37} – port machinery coefficient of effective utilization (measure of usage of the available working time for a period);
- factor f_{38} - share of cargo handling process interruptions, caused by the port machinery, in overall number and duration of the cargo handling process interruptions for the certain period;
- factor f_{39} – expected length of the response time of the maintenance service after the port machinery failure;
- factor f_{310} – subgroup of factors related to the port machinery maintenance – model of organization, available staff, etc.;

In order to point out importance of establishing adequate correlations between values of the net berth productivity and parameters related to the port machinery, here are just outlined basic details referred on port machinery technological adequacy (factor f_{32}) and port machinery flexibility (factor f_{36}) and their interconnections with productivity.

Port machinery technological adequacy degree – as it was previously said, it can be defined as a degree of

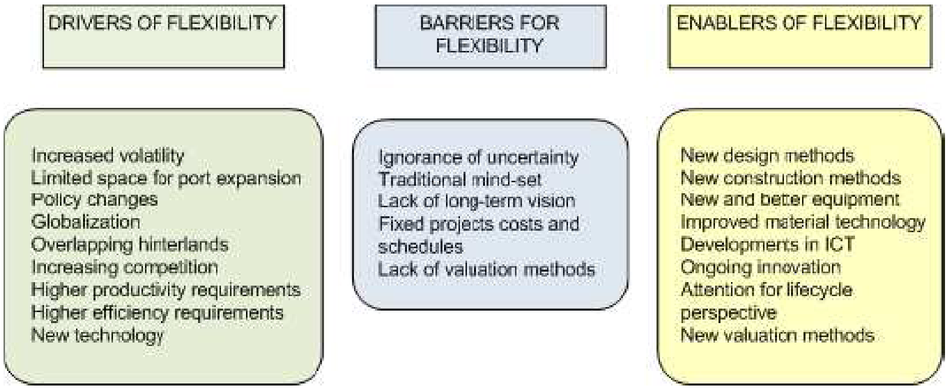

Fig. 1 Drivers, barriers and enablers of flexibility

coordination between port machinery exploitation performances and technological requirements generated in the process of cargo handling [15].

Research results presented in reference [15] clearly confirmed that only when technologically adequate port machinery is used optimal values of productivity in the cargo handling process can be expected. Reduction of the port machinery technological adequacy degree is followed by the significant reduction of the productivity – for example, in analyzed handling operations with aluminum ingots, productivity was reduced up to 50% with the reduction of the used port machinery technological adequacy degree.

Port machinery flexibility - In general, it is possible to identify two main “components” of port machinery flexibility: “positional” flexibility and “technological” flexibility [16]. “Positional” flexibility considers that port machinery performances make possible its usage on different positions within port (terminal) area and the “technological” flexibility means that exploitation characteristics of the machinery can match very wide range of technological requirements generated during the cargo handling process. Both flexibility components are determined by values of numerous factors, which are identified and analyzed in the reference [16].

In the relevant literature, requirements for higher productivity were recognized as an important driver of flexibility (general port flexibility and port machinery flexibility), as shown with the Fig. 1 [17].

4. Improving Net berth Productivity

It is important to point out that requires for improving port productivity was one of the key reasons for initiation of port reform processes worldwide [18].

Following previous fact, it can be said that improving net berth productivity (and other categories of productivity) in a seaport is one of the business objectives (managerial tasks) with the highest priority. It can be achieved if all groups (and their elements) of identified influential factors on net berth productivity are taken into consideration in a systematic (modelled) manner aiming to recognize correlations between productivity values and each of the factor. After that, it is necessary to weight influence of factors, to define possible variants of productivity improving, to choose optimal variant of improving and to concretize it. Of crucial importance is to understand that efforts directed to improve net berth productivity in a seaport have to be continuous.

In Ref. [19] is proposed a model of productivity improving, structured based on the elements of the process management model defined in [20], which has in focus role of the port machinery in the cargo handling process and enables recognition of following principal directions for productivity improving:

improving effective utilization of port machinery, improving number of working cycles in the time of effective utilization and improving characteristics (weight) of cargo manipulation unit

5. Conclusion

By the consideration done in this paper is clearly confirmed starting hypothesis of the research that values of different categories of the net berth productivity in handling operations with dry bulk cargoes in a seaport are determined by numerous factors of very different nature and intensity of influence and about existence of a significant potential for improving net berth productivity.

Respecting the variety of identified influential factors on net berth productivity, approach to its improvement has to be optimaly modelled and has to take into account complex correlations between a seaport and other numerous subjects of the logistic chain.

In order to create a model for optimizing berth productivity (to contribute to the maximal reduction of the ship turnaround time), intention of the author is to continue with researches of correlations between the net berth productivity values and identified factors of influence, especially those related to port machinery, and to develop a model of improving berth productivity in a seaport.

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