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A contribution to identification of the port machinery maintenance importance

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Abstract

Overall importance of maintenance and, in that context, importance of port machinery maintenance, from different points of view, is analyzed in numerous references. In this paper are shown results of a research on port machinery maintenance system importance, based on the recognized importance level of port machinery for achieving required level of productivity in the cargo handling process. Research is conducted, using specific methodology, within the cargo handling and port machinery maintenance system in the Port of Bar (Montenegro).

Key words

port machinery;
maintenance;
importance;

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1. Introduction

The general purpose of maintenance is to maximize an asset's useful lifetime and minimize costs [1]. Like other industries with the need for consistent turnaround rates, the shipping industry depends on port machinery and trained operators to maximize uptime. Improper maintenance can significantly decrease the productivity rates projected during an operational assessment [2]. General inter-connections between cargo handling system and port machinery maintenance system in a seaport are very complex [3]. The most rational approach in defining port machinery maintenance system objectives is the one based on the key elements of the cargo handling process and the role which port machinery has in that process. Implementing mentioned approach, following principal objectives of the port machinery maintenance system can be recognized [4]:

- enabling maximal operative readiness of the port machinery;
- enabling maximal level of the port machinery reliability;
- minimizing duration of the port machinery downtime status; etc.

All of defined principal objectives have complex structure – have their own „sub-objectives". In a condensed manner, general objective of the port machinery maintenance can be defined as follows: "to improve the productivity and efficiency of the port by increasing equipment availability" [5].

The scale of port investment in equipment and the growing significance of equipment running and maintenance costs on revenue budgets and company profitability justify a considerable rise in the status of the maintenance function [6]. Overall importance of maintenance and, in that context, importance of port machinery maintenance, from different points of view, is analyzed in numerous references (published all over the world). Just as an example, and in order to illustrate very wide variety of years of publishing, countries of origin, attitudes, etc., here are just mentioned references [1], [2], [6], [7], [8], [9], [10].

In this paper are shown results of a research on port machinery maintenance system importance, based on the recognized importance level of port machinery for achieving required level of productivity in the cargo handling process. First phase of the research was identification of the decisive influence of port machinery on productivity level in the cargo handling process. Following research phase, using results of the previous phase as an input, as well as results of some author`s previous researches of negative impacts of cargo handling process interruptions caused by port machinery on the achieved level of productivity, is oriented to generating bases for confirming importance of the port machinery maintenance. Concrete results of research shown are related to the cargo handling and port machinery maintenance systems in the Port of Bar.

2. Identifying influence of port machinery on productivity level in the cargo handling process.

2.1. Initial theoretical bases of the research

Productivity is defined as the amount of output per unit of input [12, 14, 15] and is based on local circumstances of labor, equipment, land, capital, management, infrastructure and politics [11, 13]. It can be also defined as a summary measure of a quantity and quality work of performance with resource utilization considered [16].

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 [11, 12, 15, 17].

2.2. Object of the research

In the Table 1 are systematized elements which determine object of the research done.

2.3. Basic hypothesis of the research

Starting hypothesis of the research is: Productivity level in handling operation with bauxite on the relation from wagon to open storage area is directly depending on used types of port machinery as well as on used number of port machinery.

Table 1. Elements which determine object of the research

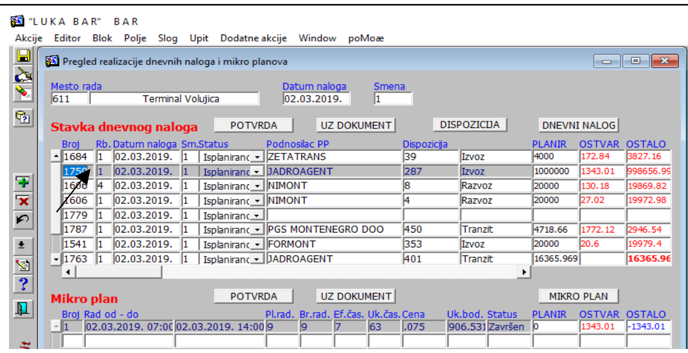
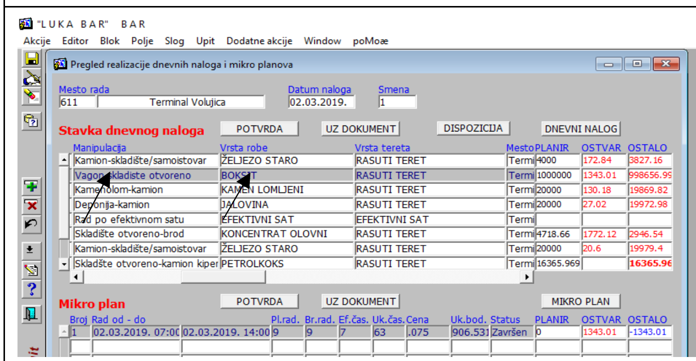
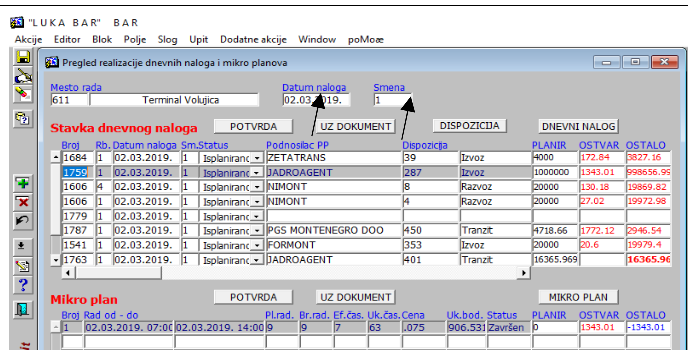
Cargo handled	Bauxite (specific density: 1,7 t/m3)	
Cargo handling operation	Wagon to open storage area	
Port machinery used – basic identification	Gantry cranes - Cerretti e Tanfani (ITA): SWL 12 t (with grab); Material handler 825 M - Sennebogen (GER); *port machinery which is the same for all analyzed variants is not considered	
Port machinery used – variants	Variant 1: Gantry crane (GC)	*Sub-variant 1-1: 3 workers* *Sub-variant 1-2: 4 workers* *Sub-variant 1-3: 5 workers* *Sub-variant 1-4: 6 workers* *Sub-variant 1-5: 7 workers*
	Variant 2: Two Gantry cranes (2 GCs)	*Sub-variant 2-1: 3 workers* *Sub-variant 2-2: 4 workers* *Sub-variant 2-3: 5 workers* *Sub-variant 2-4: 6 workers* *Sub-variant 2-5: 7 workers*
	Variant 3: Three Gantry cranes (3 GCs)	*Sub-variant 3-1: 3 workers* *Sub-variant 3-2: 4 workers* *Sub-variant 3-3: 5 workers* *Sub-variant 3-4: 6 workers* *Sub-variant 3-5: 7 workers*
	Variant 4: Gantry crane (GC) + Material handler (MH)	*Sub-variant 4-1: 3 workers* *Sub-variant 4-2: 4 workers* *Sub-variant 4-3: 5 workers* *Sub-variant 4-4: 6 workers* *Sub-variant 4-5: 7 workers*
	Variant 5: Two Gantry cranes (2 GCs) + Material handler (MH)	*Sub-variant 5-1: 3 workers* *Sub-variant 5-2: 4 workers* *Sub-variant 5-3: 5 workers* *Sub-variant 5-4: 6 workers* *Sub-variant 5-5: 7 workers*
	Variant 6: Three Gantry cranes (3 GCs) + Material handler (MH)	*Sub-variant 6-1: 3 workers* *Sub-variant 6-2: 4 workers* *Sub-variant 6-3: 5 workers* *Sub-variant 6-4: 6 workers* *Sub-variant 6-5: 7 workers*
	Variant 7: Material handler (MH)	*Sub-variant 7-1: 3 workers* *Sub-variant 7-2: 4 workers* *Sub-variant 7-3: 5 workers* *Sub-variant 7-4: 6 workers* *Sub-variant 7-5: 7 workers*

Short description of the used port machinery and workers roles:	*Element of the variant/sub-variant*	*Description*
	Gantry crane(s)	Unloading cargo from the wagons
	Material handler	Unloading cargo from the wagons
	Workers	Collecting cargo residuals in the wagon at the outreach of gantry crane and/or material handler; repairing damaged wooden floors of the wagon - damaged during the unloading operations; assisting in the process of shifting wagons over the operational area;
Period	January 2017 – December 2019	
Number of working shifts analyzed	248	
Indicators of productivity analyzed	**Indicator 1: Number of wagons unloaded per working hour;** **Indicator 2: Cargo quantity unloaded per working hour;**	

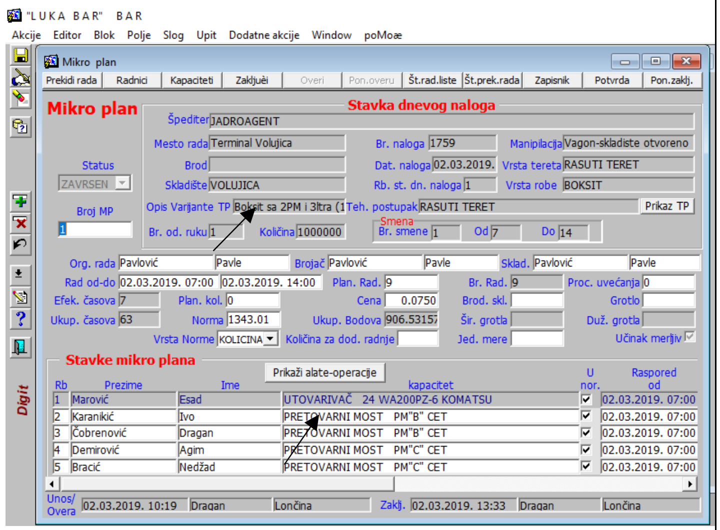
2.4. Research methodology

Elements of the used methodology for conducting this research are presented in the Table 2.

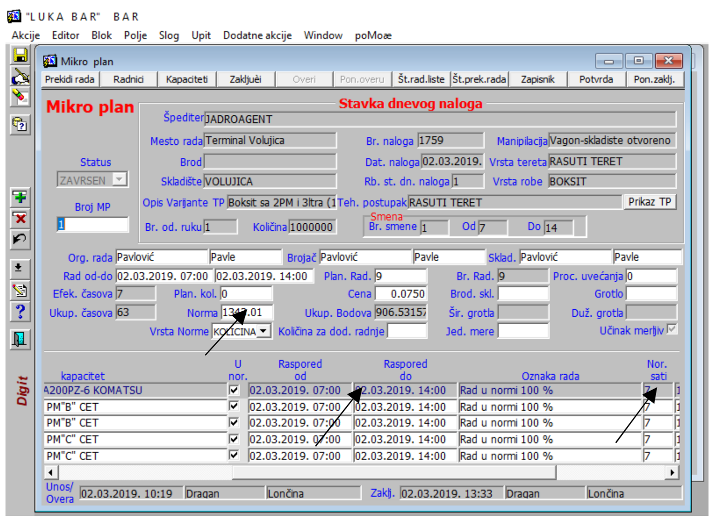
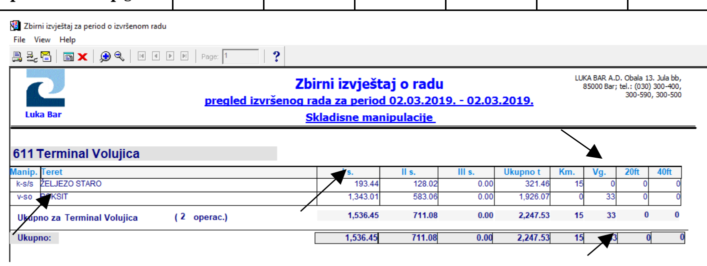
Table 2. Elements of the used research methodology

Parameter	**Source of values (applications within the Port of Bar information system – LUBARIS)**	**Method of callculation**
Type of the cargo, C		-C – bauxite;
Type of the cargo handling operation, O		-O – wagon to open storage area;
Number of working shifts analyzed, S		-creation a sample: random selection of working shifts from the period from January 2017 to December 2019; -number of analyzed shifts: 248 $S = \sum_{i=1}^{248} s_i$ where: i = 1, 2, ..., 248;

<table>
<tr><th>Parameter</th><th colspan="7">Source of values (applications within the Port of Bar information system – LUBARIS)</th><th>Method of callculation</th></tr>
<tr><td>Variant of the cargo handling operation, V_l

Used port machinery per variant of the cargo handling operation, P_f</td><td colspan="7"></td><td>-</td></tr>
<tr><td>Cargo quantity handled in a shift, q_h;

Effective working time per shift, T_e

Hourly productivity per cargo handling operation variant and per shift, p_g</td><td colspan="7"></td><td>$p_g = \frac{q_h}{T_e}$
where:
g = 1, 2, ..., 248;
h = 1, 2, ..., 248;
e = 1, 2, ..., 248;</td></tr>
<tr><td rowspan="2">Mean value of hourly productivity per all analyzed working shifts and per cargo handling operation variant, P_v</td><td>Number of shifts, s_i</td><td>1</td><td>2</td><td>3</td><td>...</td><td>247</td><td>248</td><td rowspan="2">$Pv = \frac{\sum_1^{248} p_g}{248}$</td></tr>
<tr><td>Hourly productivity per shift, p_g</td><td>p_1</td><td>p_2</td><td>p_3</td><td>...</td><td>p_{247}</td><td>p_{248}</td></tr>
<tr><td>Number of wagons unloaded per shifts and per cargo handling operation variant, w_g
Average number of wagons unloaded per all analzyed shifts per cargo handling operation variant, W_v</td><td colspan="7"></td><td>$W_v = \frac{\sum_1^{248} w_g}{248}$
where:
v = 1, 2, ..., 248;
g = 1, 2, ..., 248;</td></tr>
</table>

2.5. Research results

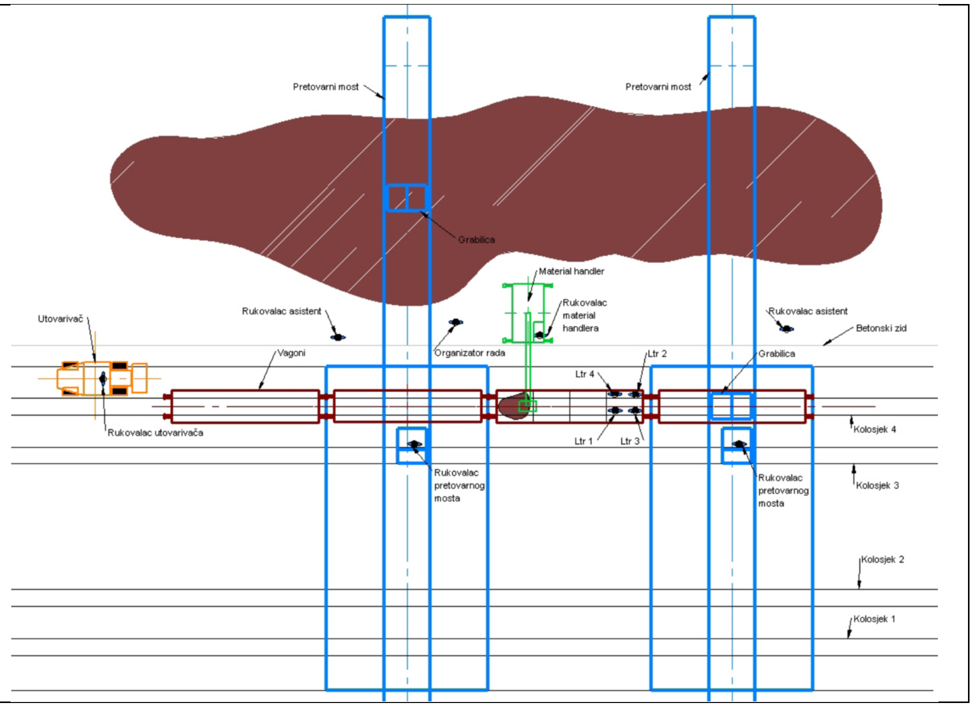
In this paper chapter are presented two groups of the research results: *Distribution of cargo handling operation variants per shifts* (describing what was the share of an operation variants implementation in the total number of analyzed shift) and *Influence of types and number of used port machinery on the productivity in the cargo handling process*.

2.5.1. Distribution of cargo handling operation variants per shifts (% share)

Results on distribution of cargo handling operation variants per shifts are given in the Table 3.

Table 3. Results on distribution of cargo handling operation variants per shifts

Distribution of variants implemented per shifts (% share)	Variant/Sub-variant	% share of implementation (in total number of analyzed shifts)
	Variant 1: GC	2,7
	Sub-variant 1-1: 3 workers	*0*
	Sub-variant 1-2: 4 workers	*0,7*
	Sub-variant 1-3: 5 workers	*0,7*
	Sub-variant 1-4: 6 workers	*0*
	Sub-variant 1-5: 7 workers	*1,3*
	Variant 2: 2 GCs	14,9
	Sub-variant 2-1: 3 workers	*0*
	Sub-variant 2-2: 4 workers	*0*
	Sub-variant 2-3: 5 workers	*1,3*
	Sub-variant 2-4: 6 workers	*4,8*
	Sub-variant 2-5: 7 workers	*8,8*
	Variant 3: 3 GCs	13,5
	Sub-variant 3-1: 3 workers	*0*
	Sub-variant 3-2: 4 workers	*0*
	Sub-variant 3-3: 5 workers	*1,3*
	Sub-variant 3-4: 6 workers	*12,2*
	Sub-variant 3-5: 7 workers	*0*
	Variant 4: GC + MH	16,9
	Sub-variant 4-1: 3 workers	*10,1*
	Sub-variant 4-2: 4 workers	*0*
	Sub-variant 4-3: 5 workers	*6,8*
	Sub-variant 4-4: 6 workers	*0*
	Sub-variant 4-5: 7 workers	*0*
	Variant 5: 2 GCs + MH	**47,3**
	Sub-variant 5-1: 3 workers	*0*
	Sub-variant 5-2: 4 workers	*0,7*
	Sub-variant 5-3: 5 workers	*45,2*
	Sub-variant 5-4: 6 workers	*0,7*
	Sub-variant 5-5: 7 workers	*0,7*
	Variant 6: 3 GCs + MH	0
	Sub-variant 6-1: 3 workers	*0*
	Sub-variant 6-2: 4 workers	*0*
	Sub-variant 6-3: 5 workers	*0*
	Sub-variant 6-4: 6 workers	*0*
	Sub-variant 6-5: 7 workers	*0*
	Variant 7: MH	4,7
	Sub-variant 7-1: 3 workers	*4,7*
	Sub-variant 7-2: 4 workers	*0*
	Sub-variant 7-3: 5 workers	*0*
	Sub-variant 7-4: 6 workers	*0*
	Sub-variant 7-5: 7 workers	*0*

General layout of the cargo handling process – variant/sub-variant with the biggest share of implementation - Variant 5: 2 GCs + MH, 5 workers (Remark 1: the 5th worker is not shown – it is engaged in repairing eventually damaged wooden floors during the unloading operation and in assisting during the wagons shifting; Remark 2: as mentioned before, wheel loader is common for all analyzed variants and cannot be taken as a variable;	

2.5.2. Influence of types and number of used port machinery on the productivity in the cargo handling process

Average values of productivity (per both analyzed indicators) for all cargo handling operation variants are presented with the Table 4. Results of research show influence of types and number of used port machinery on the productivity in the cargo handling process.

Table 4. Influence of types and number of used port machinery on the productivity in the cargo handling process

Variant	Indicator 1: Number of wagons unloaded per working hour	**Increasing – number of wagons**	Indicator 2: Cargo quantity unloaded per working hour (t/h)	**Increasing – cargo quantity (t) unloaded per working hour**
Variant 1: GC	1,77	**0**	103,59	**0**
Variant 2: 2 GCs	2,08	**+0,31**	120,23	**+16,64**
Variant 3: 3 GCs	2,41	**+0,64**	140,50	**+36,91**
Variant 4: GC + MH	2,10	**0**	120,12	**0**
Variant 5: 2 GCs+MH	2,58	**+0,48**	149,41	**+29,29**

2.6. Key conclusions based on the results of the research

Based on results of the research shown with the Table 4., following key conclusions can be made:

- Productivity level in the cargo handling process is directly depending on used port machinery – its types and numbers;
- With increasing number of the used port machinery, average productivity (its both analyzed indicators) per analyzed variants of the cargo handling operation wagon to open storage area with bauxite is increasing;

Results of the research confirm starting research hypothesis: Productivity level in handling operation with bauxite on the relation from wagon to open storage area is directly depending on used types of port machinery as well as on used number of port machinery.

3. Recognition of the port machinery maintenance system importance

Key precondition for achieving optimal level of productivity in the cargo handling process and to confirm identified importance level of the port machinery is its reliable work through the whole process. When downtime of the port machine, S, occurs during the cargo handling process, then three possible actions are possible:

- replacing port machine S with technologically adequate port machine S1;

- replacing port machine S with technologically inadequate alternative port machine S2, enabling continuation of the cargo handling process but with lower values of characteristic parameters;
- cargo handling process interruptions lasts up to repairment of the port machine S;

From the managerial point of view, variant when the cargo handling process interruption lasts up to the port machinery repairment is the least favorable, as all negative impacts on the characteristic parameters are more intensive than in other two variants identified. A detailed analysis of negative impacts of the cargo handling process interruptions caused by port machinery is done in the reference [18], and here is only pointed out that reduction of productivity in the cargo handling process is one of the negative impacts which has to be focused in a specific way.

Key role in eliminating or minimizing (up to the absolute level) reduction of productivity belongs to the port machinery maintenance system. In that context, following priority managerial activities could be recognized: selection and full implementation of the optimal port machinery maintenance model; selection and full implementation of the optimal port machinery spare parts stock control; etc. At the more specific level, the especially important managerial task is minimization of the port machinery downtime duration, by eliminating or reducing to minimum components of the port machinery downtime period, as elaborated in the reference [19].

So, with presented two step approach – first step: identification of decisive role of the port machinery in achieving optimal level of productivity in the cargo handling process; and second step: recognition of decisive role of the port machinery maintenance in minimizing reduction of productivity, especially in variant when cargo handling process interruption caused by the used port machinery downtime lasts up to the repairment of that machinery – is fully confirmed importance of the port machinery maintenance system.

4. Conclusion

By the results of research shown in this paper is confirmed that productivity level in the cargo handling process is directly depending on used port machinery (its types and numbers) and that with increasing number of the used port machinery average productivity per analyzed variants of the cargo handling operation wagon to open storage area with bauxite is increasing. Based on these research results, by done considerations is recognized decisive role of the port machinery maintenance in minimizing reduction of productivity, especially in variant when cargo handling process interruption caused by the used port machinery downtime lasts up to the repairment of that machinery and thus fully confirmed importance of the port machinery maintenance system.

Some of the shown research results indicate necessity to take into consideration all other influential factors on the productivity in the cago handling process, too, what will be done in further engagement of author in this domain.

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