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TOOLS FOR ANALYSING OPERATIONAL OPTIMIZATION IN A CONTAINER SHIP TERMINAL

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Abstract: *Placing the work in context*: Containerization has made transportation cheaper, and this has changed the global economy and trade. The efficiency of a container terminal requires: a) high-performance equipment for high performance management; b) large area to facilitate the movement of handling equipment and placement of containers; c) good organization of its operation. *The purpose of the work*: The present paper aims to present operating tools in a container terminal, which will contribute to reducing operating times and possible human errors. *Research, methodology*: a) Analysis of container terminal design tool; b) Optimization, automation and integration of technological equipment in containerized shipping. Results: a) structure and calculus of the model of the container ship terminal-case study new terminal Port Agigea-Constanta; b) different scenarios of different parts of the terminal- handling operation, the characteristics of quay crane and the characteristics of different equipment types for transferring container between quay-yard and inside the yard; c) selecting the best scenario that would lead to short operating times and to the exclusion of human errors that can lead to accidents at work. Conclusions: The goal of the study is to find the tools for optimal design of the container ship terminal which includes more functionalities with reduced operational times and exclusions of human errors.

Key words: container terminal, scenario, operational indicator, optimization.

1. INTRODUCTION

The transhipment of goods is the main function of the modern seaport and involves a development of port infrastructure and superstructure. The process of transhipment of goods is carried out with various installations, equipment and port means of handling, which have been continuously improved over the years. "Container transport was initially promoted by shipping carriers as a solution to streamline the transportation of general cargo other than bulk. The solution is based on the introduction of standard loading units, easy to transport, handle and store, which allow the transport of a very diverse assortment of goods. The solution proved to be a success, as it allowed the optimization of the use of the transport capacity of seagoing ships and, at least as important, allowed the efficiency of the loading-unloading operations of ships in ports" (Figure 1, Figure 2) [1].

Fig. 1. Container ship, [1]

Fig. 2. Container loading-unloading terminal-container ship, [1]

The classic logistics chain of container shipping is shown in Figure 3 [1]:

Fig. 3. The classic logistics chain of container shipping, [1]

A port terminal consists of a quay or a group of quays intended for private traffic and supplemented by ground facilities required for such traffic. Container flows are undoubtedly the main traffic and require the use of a large number of cranes, large open spaces for storage of containers and air conditioning structures for the preservation of perishable goods. The effectiveness of a container terminal requires:

- high-performance equipment for performing administrations;
- large area to facilitate the movement of handling equipment and placement of containers;
- good organization of its operation.

An intermodal terminal for container and general cargo operations is located in Constanţa South Port Agigea (Figure 4) [2].

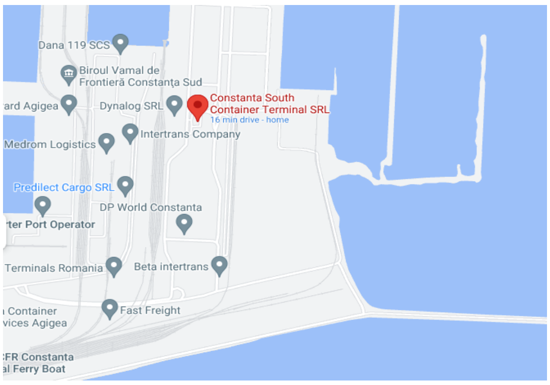

Fig. 4. The location of Constanţa South Port Agigea Container ship terminal, [2]

The terminal was opened in July 2018 and in the basic infrastructure, it has a container and cargo storage platform, with an area of 10,000 m^2, with the possibility of operating on the railway and a modern warehouse of 1,600 m^2 (Figure 5), [3].

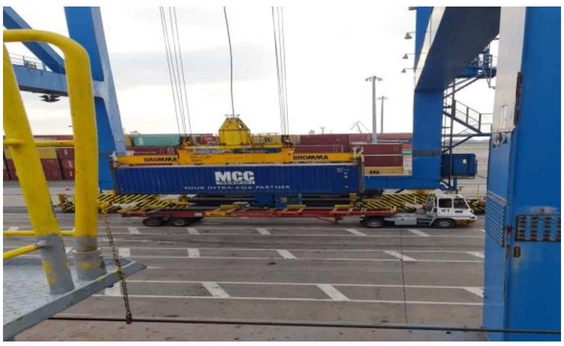

Fig. 5. Intermodal terminal in the Agigea Port of Constanta South, [3]

Development technology in the field of containerizations has grown. "The capacity of maritime terminals of containers remains limited, to which are added the traffic congestion generated by such an economy emissions and harmful emissions from the environment, as well as development delays regional inland where road transport has an extremely high share. That is why the Union European Union and other international fora, through studies, debates, laws, procedures and rules, seeks to reduce all these shortcomings by reducing their negative impact on economic life and development", [5].

2. RESEARCH AND METHODOLOGY

The present paper aims to present operating tools in a container terminal, which will contribute to reducing operating times and possible human errors." The efficiency of a container terminal requires: a) high-performance equipment for high management; b) large area to facilitate the movement of handling equipment and placement of containers; c) good organization of its operation", [4].

In the terminal is a special equipment for handling atypical containerized goods, which can meet any challenge. These include a machine with a capacity of up to 100,000 kg and which allows the containers to be tilted to 75°, but also equipment that considerably reduces the loading and unloading time of containers with a load of up to 35,000 kg, the operations taking place in only 20 minutes. The equipment also has a built-in weight measurement system and allows the containers to be weighted during loading. Thus, in the terminal in the Port Agigea of Constantza South it will be possible to handle different types of goods from palletized loads, to steel, aluminium pipes, profiles, marble blocks or bulk goods.

To analyse the operational optimization of container ship terminal in Constantza South Port must following next points:

- Analysis of container terminal design tool;
- Optimization, automation and integration of technological equipment in containerized shipping.

The rapid development of containerized transport is explained by their high economic efficiency. Into the maritime transport, for example, efficiency is manifested by: reducing transhipment operations and increasing work productivity in carrying out these operations 10 - 15 times, reducing accordingly the work force necessary; reducing the cost of stacking goods by about 10 times; 5 - 8 times reduction in time berthing of ships in ports; reducing the total costs of transport and transhipment of goods by about three or compared to classical methods of transport, [5].

2.1 The analysis of the container transfer

The containers are arranged on top of each other in cells to maximum six level high due to the value in weight that the bottom container can with-stand from those on top (Figure 6). The inside of a containership is built in different shape which depend de shape of compartments. The loading/unloading plans depend on the balance of the ship, the weight category of each container and the maximum allowable weight of each compartments of ship [7].

Fig. 6. The plan of the container's arrangements of ship, [6]

2.2 Crane working details

The load / unload of the container to / from a ship depends on the location where is stored on the ship and also depends on the time of quay crane (QC)' operation. Quay cranes load / unload containers to the marshalling areas (Figure 7) [7].

There are many studies about algorithms which investigate routing for load/unload in real time the containers from/to ship to minimize the travel distance [8, 9, 10].

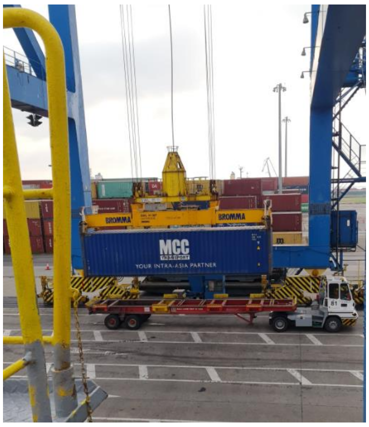

Fig. 7. The import/export process of containers, [7]

The discharge plan for this case study is presented in Figure 9:

2.3 Case study example

In this case study is presented an operational report for quay cranes (Table 1) and for vessel (Table 2). There are 10 bays worked, five quay cranes (QC_i, i=1, 2, 3, 4, 5) and three mobile harbor cranes (MHC_i, i=1,2,3) and first lift is at 2.00 o'clock, last lift is at 21.10 o'clock.

The load plan for this case study is (Figure 8), where load means number of moves due to loading of a vessel by Quay Crane (QC), Mobile Harbour Crane (MHC) or Ship Crane (SC) from horizontal transport or ground to vessel.

Discharge means number of moves due to the unloading of a vessel by Quay Crane (QC), Mobile Harbor Crane (MHC) or Ship Crane (SC) to horizontal transport or ground.

Table 1. Quay Cranes operation report

Date	Crane QC_1 hours	Crane QC_2 hours	Crane QC_3 hours	Crane QC_4 hours	Crane QC_5 hours	Crane MHC_3 hours	Total hours	Gross gang hours, GGH	Total lost time TLT	Non terminal accountable delays, NTAD
8/5/2021	2.00-10.00 8.08hours GGH-18.33; TLT-6.61; NTAD-3.34	2.00-21.00; 19.27 hours GGH-19.27; TLT-5.64; NTAD-3.17	7.00-10.00; 3 hours; GGH-3.67; TLT-0.84; NTAD-0.17	-	-	-	30.25	41.17	13.09	6.68
8/5/2021	10.00-21.00; 10.25hours		10.05-10.40; 0.67 hours	-	-	-	10.92	41.17	13.09	6.68

Table 2. Vessel operations report

VESSEL MOVES	40'	20'
Full loadings		295
Empties loadings	7	183
Full discharge		286
Empty discharge		
Sub-total		588
Total Containers Load/Discharge	938	
TOTAL Containers moves	**938**	
Hatch lids (x2)	34	
Twist lock box moves	6	
Sub-total	40	
TOTAL VESSEL BILLABLE MOVES		
	978	
Break Bulk Moves		
Restores Port Convenience		
MAN CAGE MOVES		
SUB-TOTAL		
TOTAL MOVES	**978**	

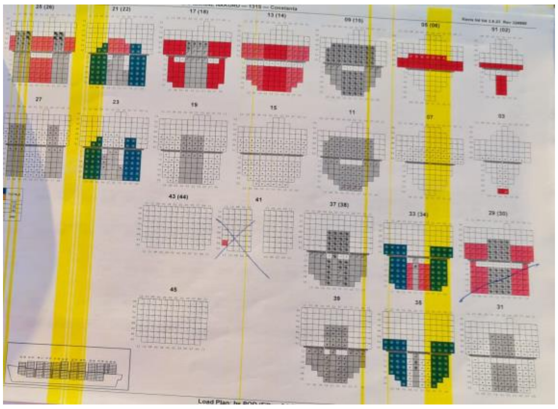

Fig. 8. The load plan

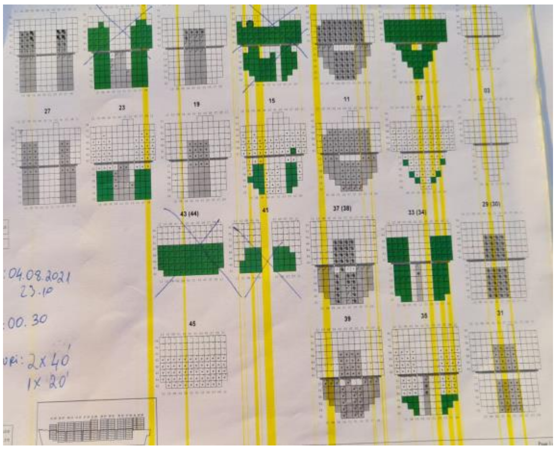

Fig. 9. The discharge plan

3. RESULTS AND INTERPRETATIONS

3.1 Operational results

In this period operated five type of vessel: main, feeder and common; there were 4625 lifts (7925.5 TEU) (Table 3):

Table 3. Analyse of total lifts

Total Main	1805	3201
Total Feeder	2820	4725
Total Common	0	0
TOTAL	**4625**	**7925.75**

So, there were 2820 containers' lifts by QC, that mean 4725 TEU (Total Operational throughput). Therefore, QC utilization will be (Table 4):

Table 4. Quay crane utilization

401.29	Main	10.79%
665.04	Feed	17.88%
0.00	Com	0.00%
1066.33	**Total**	**28.66%**

In the end it can be seen that operational flux in Constanta South Port Agigea is more efficient now, when operate with new performed equipments (Table 5):

Table 5. Comparative analysis of terminal's efficiency on Constantza South Port Agigea

ABMH	758880	m*hours
BMH	1397444	m*hours
QP	48.17107843	TEU / meter
BU	184.15%	-
QCU	-	-

where: ABMH-available berth meter hours, the available berth for container vessel;

BMH-actual berth meter hours, berth occupied in meter hours including mooring lines and maneuvering time;
QP-Quay performance, amount of TEU's handled per meter of quay;
BU-berth capacity utilization;
QCU-ratio of crane operational time to working hours within same period.

3.2 Indicators of efficiency

The efficiency of operation in a container ship terminal are:

• *intensity of port concessions uses* which "determine the efficiency of the volume moved, based on the concession area licensed to each terminal, in order to evaluate the degree to which infrastructure is leveraged" [11]. With this indicator can establish the units' movements per terminal (Ul_T in tons or U_{cT} in TEUs)/ area (10 000m^2) subject to concessions in each terminal;

• *availability of specialized terminals* which "is measured by identifying the number of specialized terminals (Te_P) and non-specialized terminals at each port (Tn_P)" [11];

• *intensity of terminal and port occupancy rate* which "is measured by dividing the units moved per terminal (U_T in TEUs) each year by the dynamic capacity (Sa_T). Dynamic capacity is obtained from the product of dividing the static capacity of each terminal (Ce_T, in TEUs) and the stay time of the goods (Te_P in days) by the number of days in a year (365) and multiplying this by 100%, such that the indicator is expressed as a percentage" [11];

• *stay time of goods at port* which "is measured by adding the stay times for containers (T_c in hours) divided on total containers moved per terminal [Ct] or per port (C_P);

• *inspections prior to customs* which "is measured by dividing the total number of annual containers inspected at port terminals [N_{pt}, N_{aT} in TEUs] by the number of total containers moved in port every year (C_p, in TEUs), then multiplying by 100%, such that the indicator is expressed as a percentage"[11, 12];

• *empty container movements and the full/empty ratio* which "is measured by dividing the total number of empty containers moved per year (V_p, in TEUs) by the total number of containers moved per port per year (C_p, in TEUs), excluding petroleum and its derivative products." [11, 12].

In the Agigea terminal, scanning systems are proposed for implementation:

- A dual energy portal (bi-directional portal on the container side - 100% automatic container scanning for import and export on a 24/7 database);
- A 100% dual-energy rail scanner with automatic wagon scanning for import on a 24/7 database only.

This system is ready to provide two specialized military containerized modules, one for the data center and one for the remote analysis centre, or to deploy and deploy all hardware and software components within certain office areas.

3.3 High power load inspection system

The inspection system is a cargo inspection system with high penetration capacity and high speed. Capable of detecting threats and smuggling hidden in densely packed trucks, cargo containers and tanks, the portal is ideal for scanning operations at major seaports, border crossings and security points. With a compact footprint that allows installation in confined spaces, the system can scan up to 200 trucks per hour when driving at a rated speed of 12 km/h.

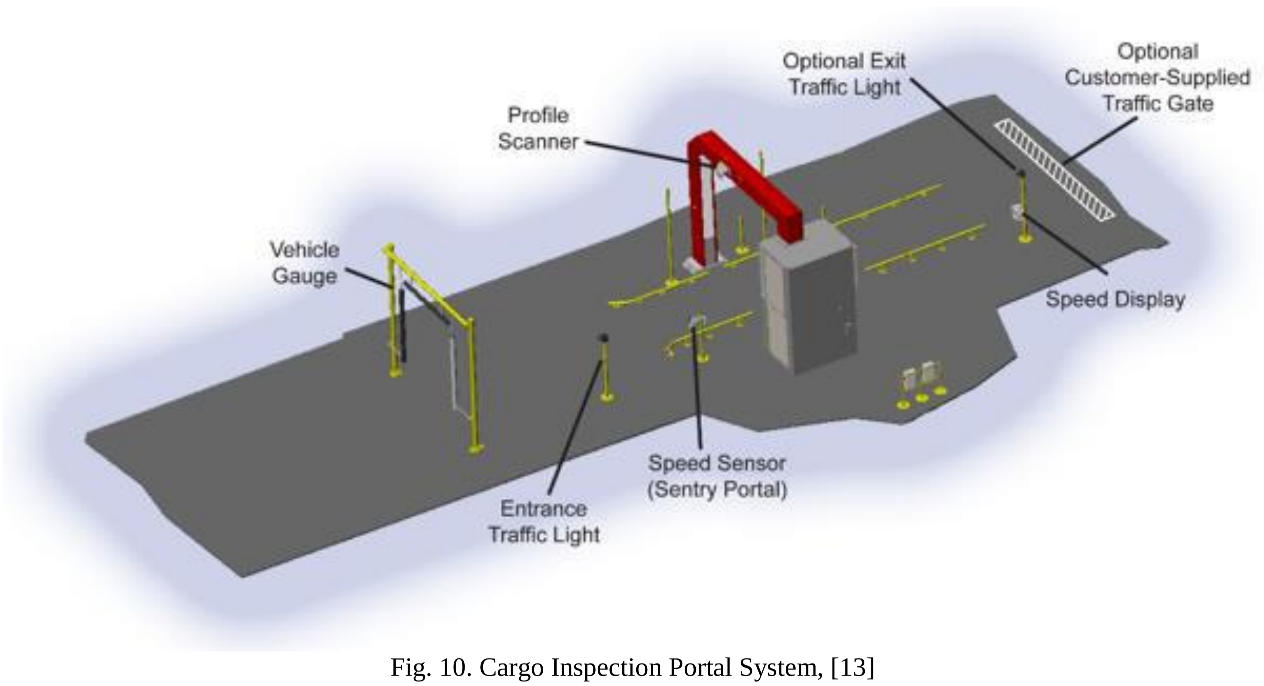

Fig. 10. Cargo Inspection Portal System, [13]

Using a high-power transmission X-ray source, the portal penetrates up to 300 mm of steel, while reducing the amount of radiation scattered in the cabin - the lowest in the industry. When operating, the system provides material discrimination, colouring of organic objects and blue metallic objects.

The configuration of the basic portal system is shown Figure 10[13]:The technology behind the Portal allows the beam from the high-energy (HE) X-ray source to penetrate the dense charge, while reducing the amount of scattered radiation.

3.4 Final daily operational indicators

Analyzing these indicators for the ship container terminal in Constantza South Port Agigea, the following results are obtained:

-berth time-112.1%;
- work time-89.2%;
- terminal delays-15.6%;
- non-terminal delays- 16.2%;
- total delays-31.8%;
- cranes working-68.2%;
- crane intensity-2.5%;
- crane density-3.72%.

The portal offers customers:

3.5 Superior detection capability

• up to 300 mm steel equivalent penetrates densely loaded containers generates a colourful image, which allows analysts to visually differentiate the classes of materials within the load.

3.6 High quality image

• 3 mm cable resolution.

3.7 High capacity

• Capacity of up to 200 trucks per hour with a speed of 12 km / h.

• Allows drivers to stay in their vehicles, increasing overall performance and minimizing the impact on traffic flow.

3.8 Safe radiation

• Cabs are not scanned, so drivers are not directly exposed to radiation;

• Extremely low radiation dose to drivers and operators;

•Low radiation dose at load.

3.9 Compact footprint

• Compact structure and small controlled area allow the system to easily integrate into any environment.

Automated gate systems have received wide diffusion because of the substantial benefits they provide for terminal access. They need to have documentation electronically provided before picking up or dropping at the terminal, which improves processing time and reduces the risk of errors with their associated delays.

4. CONCLUSIONS

The efficiency of a container terminal leads from an economic point of view to optimization and efficiency containerized freight traffic, reducing traffic costs of containers, creating business models, increasing the level of satisfaction of customers, reducing downtime operation / handling a container in the system transportation, new business opportunities for SMEs, regional. From a social point of view, traffic optimization in a container terminal leads to: reduction of road accidents; raising the safety level and container security arrived at the destination and are in transit; improving control containers from the point of view authority; improving control containers for beneficiaries by tracking / tracing.

The system is equipped with a linear particle accelerator, being assigned to provide a high-resolution radiographic image and to allow discrimination of materials by the use of high-energy photons. The system is based on a dedicated multispectral radiation generator, combined with an original approach to the use of attenuation coefficients for the effects of photon absorption - photoelectric generation and pairs (electron - positron).

The proposed solution is a combination of: high-energy X-ray pulse scanning with maximum energy values at a distance, special filtering and collimation, detection in several energy bands and dedicated processing algorithms.

The scanner provides a radiographic image analyzed by a trained operator. The operator uses specific integrated software both for system control and the scanning process and for image analysis.

With regard to the remote operation of the fixed portal X-ray inspection system, it should be emphasized that the portal will be designed in accordance with the principle applied as a fundamental requirement in radiological protection, the main purpose being to reduce radiation exposure of operators and the public. In this system, it is designed and built to be permanently operated remotely by an operator located outside the exclusion zone where the scanning process is performed, thus providing the maximum possible physical protection.

Use of this system is really a performance in operational terminal because offer: a superior detection capability, high quality image, high capacity per hour for trucks, safe radiation and compact footprint.

From an environmental point of view, this means: reduction of CO_2 emissions; noise reduction on road arteries; decongestion of car routes at seaport gate; "green freight corridors"; electrified railway; reducing the consumption of combustible; choosing locations for container ship terminal implementation without decisions related to relief.

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