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Analysis of container handling processes on board a container ship and their transit through a conventional container terminal

George-Cosmin PARTENE[1*], Sorin IONESCU[2], Forin NICOLAE[3], Alexandru COTORCEA[4], Dragoș SIMION[1]

[1]Eng. PhD attendee, Politehnica University, Bucharest, Faculty of Entrepreneurship, Business Engineering and Management;
[2]Professor, PhD Eng., Politehnica University, Bucharest, Faculty of Entrepreneurship, Business Engineering and Management
[3]Professor, PhD Eng., "Mircea cel Bătrân" Naval Academy, Constanta, Department of Naval and Port Engineering and Management;
[4]Associate Professor, PhD Eng., "Mircea cel Bătrân" Naval Academy, Constanta, Department of Naval and Port Engineering and Management.
[*]corresponding autho: george.partene@stud.faima.upb.ro

Abstract. Containerized freight transport is on an upward slope worldwide, and specialist analyzes forecast an average growth of 3% annually until the year 2028. The pressure of rallying to the very emerging legislation in the shipping industry as well as the continuous increase in the level of operational efficiency of the container terminal requires a continuous analysis of the processes executed in the conventional container terminal and finding solutions to be sustainable and face the competition in the market.
Understanding in detail and finding solutions to improve the processes carried out in this type of terminal is necessary to have a continuous, harmonious and integrated flow between all the areas involved in the terminal, the importance of implementing and respecting a security climate within the terminal through risk awareness primarily by staff, but also ongoing research in this area.
This paper aims to highlight a detailed analysis of the processes carried out in the port operations area of a conventional container terminal in the port of Constanța, with a minimum level of technological development based on observations made in the field. Next, ways to improve these processes are proposed by improving some already existing procedures or by proposing the modification of some sub-processes by introducing some equipment to optimize the described process.
Keywords: container terminal, processes, maritime industry, yard management, optimization.

1. Introduction

Starting from the idea that the world population reached the threshold of 8 billion on November 15, 2022, estimating that in 2037 it will reach 9 billion, and in 2058 at 10 billion, society is forced to keep up with the changes to which it is subject and to continue to provide a decent living for the entire population [1]. This involves the movement of goods of all kinds, worldwide at the same time as technological development, which is experiencing an exponential momentum, and plays a role in solving society's problems and implicitly increasing the standard of living. In light of these things,

containerized cargo transport plays a particularly important role in carrying out cargo exchanges from one area to another and ensuring the minimum necessary in some areas of the globe.

Containerized freight, a relatively young means of transport, celebrated almost 70 years since it timidly took off, thanks to the rapid globalization of supply chains, the volume of containers is on an upward slope, ranking 3rd as tonnage of goods transported by the fleet of specialized ships worldwide, with a percentage of 14% of the total goods transported by sea in the year 2024 [2].

The maritime industry must keep up with the technological development of container ships, which implies continuous changes in port infrastructure and especially in specialized terminals for containers to meet ever-increasing requirements [3]. To be able to do this, it is necessary for each terminal to undergo its own analysis, because there are elements specific to each terminal related to location, limitations regarding storage area, berths, safe operating depths of ships, operating periods, handling equipment, occupational health and safety rules and others, and later to intervene with new proposals to improve the performance of the terminal, which will result in the ability to respond to market demands. For the implementation of some ideas to improve some sub-processes or processes within the terminal, specialized modeling and simulation software can be used to obtained results as quickly as possible and with minimum cost [4].

This paper aims to study what happens to a container that arrives by sea or land, with the help of trucks or trains, in a conventional container terminal and has to go further to reach its destination. It also aims to help define processes that play a role in creating a map of the processes carried out in the conventional container terminal, which plays a very important role in finding answers to streamline many problems in the field studied.

2. Research methodology

The research methodology of this paper is based on the authors' interpretation of official data obtained through the study of specialized literature and mainly through on-site research and discussions with specialists in the field within the largest container terminal in the port of Constanta, Romania.

The questions we propose to address in this paper are as follows:

1. What is a process in the container terminal?
2. How does the container terminal manage the huge information flow?
3. How can all areas of the container terminal be integrated to ensure a coherent and continuous flow of a container?
4. What processes are involved in the good transit of a container through the specialized container terminal?
5. How can processes in a conventional container terminal be optimized to achieve better and better performances and to be able to face the local and even international challenges of containerized transport?

3. Research

3.1. Conventional container terminal – an overview

A specialized container terminal is a specially designed platform with the purpose of storing a maximum number of containers that operates 24/7, and depending on the information received from the downstream and upstream trades of the terminal, containers can be transhipped or received/sent from/to the hinterland area of the terminal. Such a terminal must be prepared to accommodate ships of different sizes and also to operate the loading and unloading of containers on board it. It also includes very well-defined areas for each type of operation and type of container, and all coordination is done from a single terminal command point in accordance with a previously established plan, with the help of specialized equipment. It is an area where vehicle and personnel access is very well regulated, with a set of internal rules and very well-established occupational health and safety, and most of the problems that arise are solved with internal means, so a comparison can be made with a small town that must be self-sustaining [5].

For a conventional container terminal, there are the following areas that must be interconnected with the help of a command center that has under control all the processes in the terminal and that transmits the necessary information in each sub-process for the overall smooth running of the terminal, and these areas are as follows: the berths, the apron, the container yards, the container freight station (CFS), the control tower, the gates, the maintenance workshop, administration offices, canteen, computer rooms, oil depots, but also other areas in order to create all the facilities for efficient operation 24 hours a day. With all these facilities at your disposal, next, the secret lies in the integration of the ships with the operations in the terminal to ensure an efficient operation of a production line with a very fine-tuned flow, quite well mechanized, which can be intervened in permanence with flow improvement operations having of course the ultimate goal of fulfilling the main functions of conventional container terminals [6].

Figure 1, illustrates a schematic representation of typical container terminal operations and equipment, including quay cranes for loading and unloading berthed ships, trucks, trailers for transporting containers in the terminal area, and RTG - rubber tyred gantry crane for handling full or empty containers in terminal yard stacks or RMG - rail mounted gantry crane for handling full or empty containers in the rail operations area. The main operating areas within a conventional container terminal are also represented.

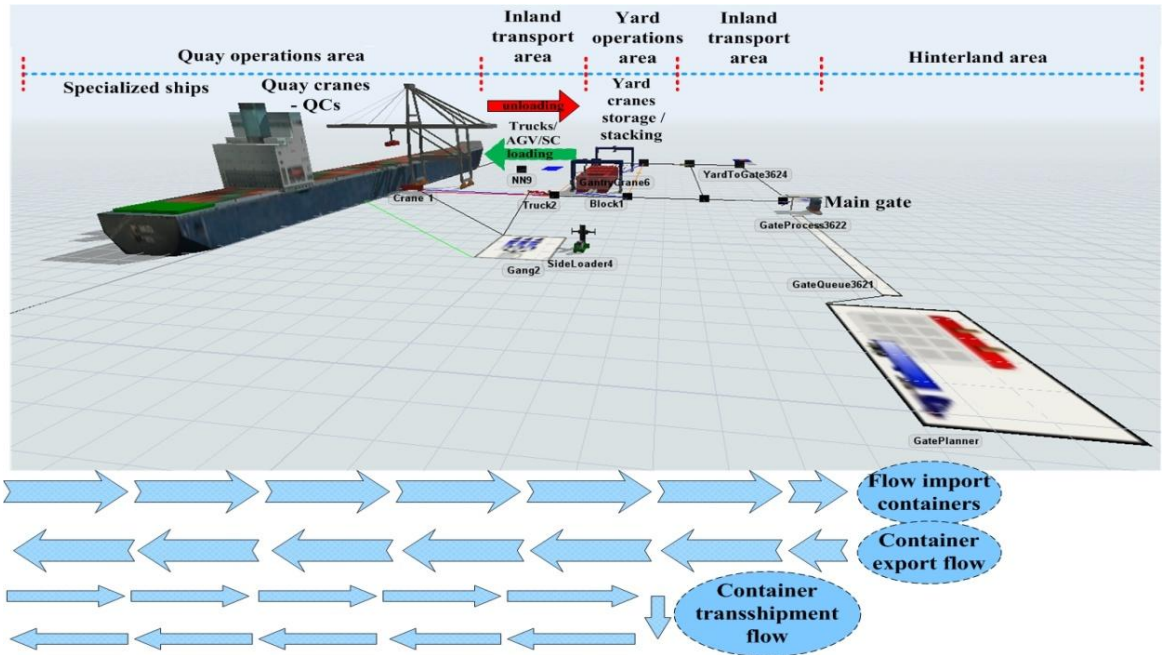

Figure 1. Overview of a conventional container terminal, modeling using FlexTerm software [7].

3.2. Integration of processes in the conventional container terminal

For the maritime industry a process means an activity or group of related activities that combine to transform one or more types of inputs, add value to them and provide new outputs for beneficiaries within or outside the maritime industry.

Moreover, the maritime and port industry had to adapt to a continuous development and understood the fact that only through integration and development in accordance with industrial development can they meet the requirements at the world level, making this maritime industry occupy an indispensable place in the chain of global supply and at the same time towards the concept of smart ports [8], [9].

With technological development, the specific processes carried out in each terminal must change and rally to the new standards that the field demands, and it is true that this does not always happen as it should due to the fact that the necessary funds are missing or doing a market analysis, this is not feasible. However, in order to survive on the market in a very competitive environment, maritime

terminals must maintain a high standard in the implementation of digital innovations in the basic processes, respecting the requirements imposed by costs, efficiency, security and sustainability.

In addition to industrial development, for the processes carried out in the maritime industry, the human factor also play an important role, causing over 80% of accidents in the field. The introduction of systematic training programs adapted to the characteristics of the new requirements in the field and the requirements imposed on the human operator are vital [10].

To align with today's trends in the demand for sea freight, container terminals have increased their handling infrastructure capacity and have continuously focused on improving the productivity of operations, processes and decisions using digital, communication tools and informational [11].

Processes carried out in a conventional maritime container terminal, with an average level of technological development, depending on the operating areas of the terminal as presented, can be classified as follows: processes carried out in the port operations area of the container terminal; processes carried out in the land operations area of the container terminal; processes in the yard area, grouping/storage of the container terminal. The integration of all these processes will materialize in a process map that constitutes a starting framework for the optimization of many sub-processes that contribute to obtaining a global level of performance of the terminal.

The processes exemplified in this paper are valid for terminals that use an indirect container transfer system using Rubber tyred gantry crane (RTG) for storing containers in stacks. Figure 2 exemplifies the symbols used to build process diagrams in a conventional container terminal, terminals found a lot in Eastern Europe, and this aspect is also valid for the specialized container terminals in Constanța, Romania.

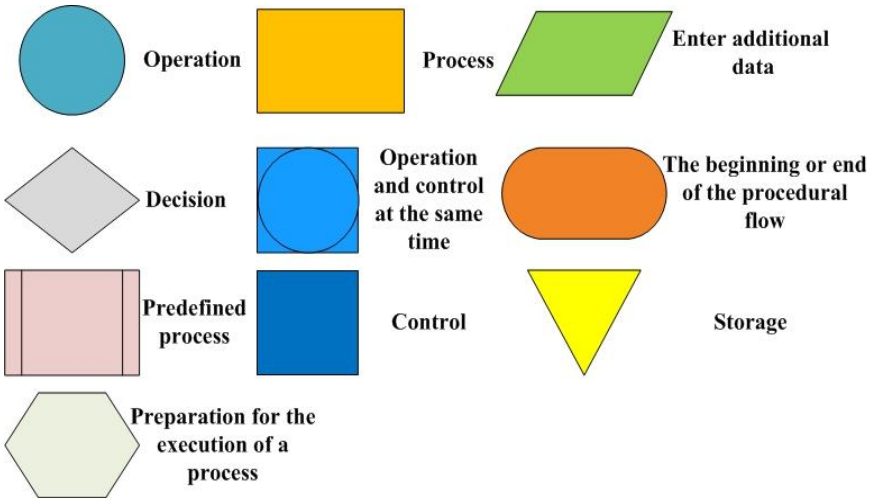

Figure 2. The meaning of the symbols used to create process diagrams with the help of MS Visio software.

3.3. *The importance of the container ship-terminal information flow and the development of container handling processes in the terminal*

The optimization of the container storage plan on board the specialized ships, but also within the terminals, represents the problem to which the staff involved seeks to have the best solution every time.

On board a specialized ship, there must always be a clear situation regarding the container storage plan according to the segregation criteria agreed by the transport company, and the information must be transmitted in time to the command center of a terminal where certain types of operations are to be executed.

The operations will be processed by both parties before the vessel enters the terminal, so that the terminal and vessel can allocate the necessary resources to fit into the proposed plan. In addition, if problems are identified, mutual information and solutions must be sought from both sides so that the operation is safe for the ship, terminal, cargo, personnel, operations are executed in the fastest time

and the space available on the ship to be exploited to the maximum. Thus, the staff must take into account the positioning of containers on board according to the port of destination, the type of container as well as the degree of dangerousness of the goods, respecting the requirements of the IMO (International Maritime Organization) and the IMDG code ((International Maritime Code for Dangerous Goods), as well as the requirements regarding the calculation of an appropriate stability factor to avoid exposure the ship as well as the container lashing system to dangerous oscillations.

Each process in the container terminal areas requires compliance with a process matrix of information flow, a matrix constructed by terminal managers and disseminated hierarchically for application down to the lowest level, so that each department must know when to use information and when to enter information into the system for further use. The problem is complicated when the terminal has to manage the upstream and downstream information flows, thus the terminal is a hub that must know how to analyze an enormous amount of data that it must later transform into information.

Adequate information quality is crucial to correctly manage the flow of a container as well as all related logistics processes, however, there is a lack of information quality due to erroneous, late or imprecise information that accumulates throughout the entire transport logistics chain of a container from sender to recipient [12]. A schematic representation is described by figure 2.

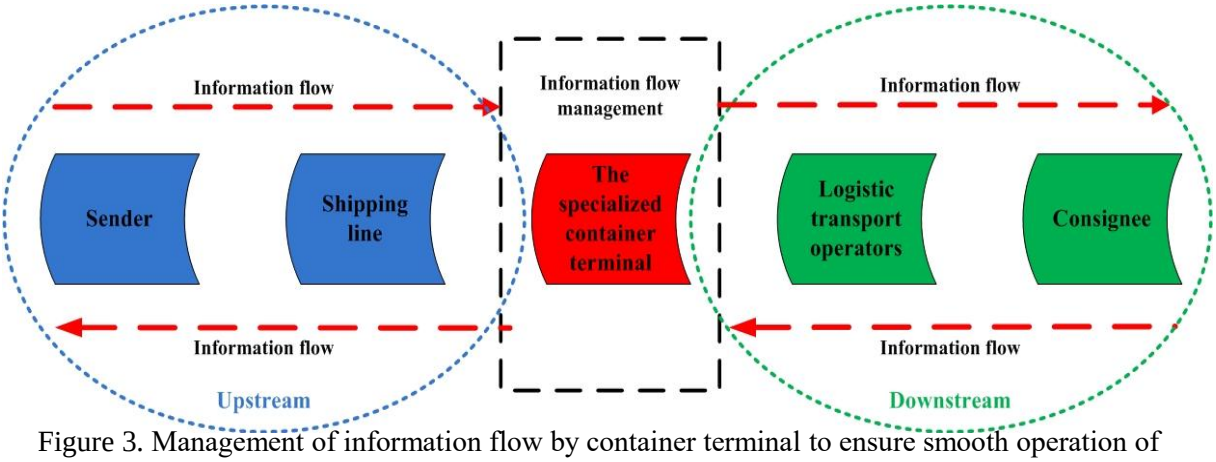

Figure 3. Management of information flow by container terminal to ensure smooth operation of logistics transport chain

As can be seen in Figure 3, at the center of the information flow diagram, the main role is played by the specialized container terminal, which has the role of applying the latest complex technological solutions, to maintain informational connections with upstream and downstream stakeholders whenever needed, which requires that all those involved provide the highest quality information that can be used when needed and on time, in order to prepare and optimize the flow of freight transport. In short, continuous research is required to find solutions to maintain the golden rule regarding the key to success, namely communication between stakeholders.

For this, the universal standard for EDIFACT messages (Electronic Data Interchange for Administration, Commerce and Transport) has been constantly improving for almost 50 years, being a global set of rules defined by the United Nations (UN) for the electronic exchange of data between companies through the electronic data interchange system, EDI (Electronic Data Interchange) [13]. Such a type of preformatted message can be of great help in the smooth running of processes in a container terminal and not only, thus eliminating many of the communication problems that may arise throughout the logistics transport chain. It is important that these messages can be integrated into the terminal operating system (TOS) to allow the information to be used in real time. Of the over 180 preformatted messages of this standard for the process of unloading a container in a specialized terminal, 6 messages would be the most relevant to have all the necessary information between the shipping line - the line agent - terminal and vice versa, this aspect being exemplified in figure 4.

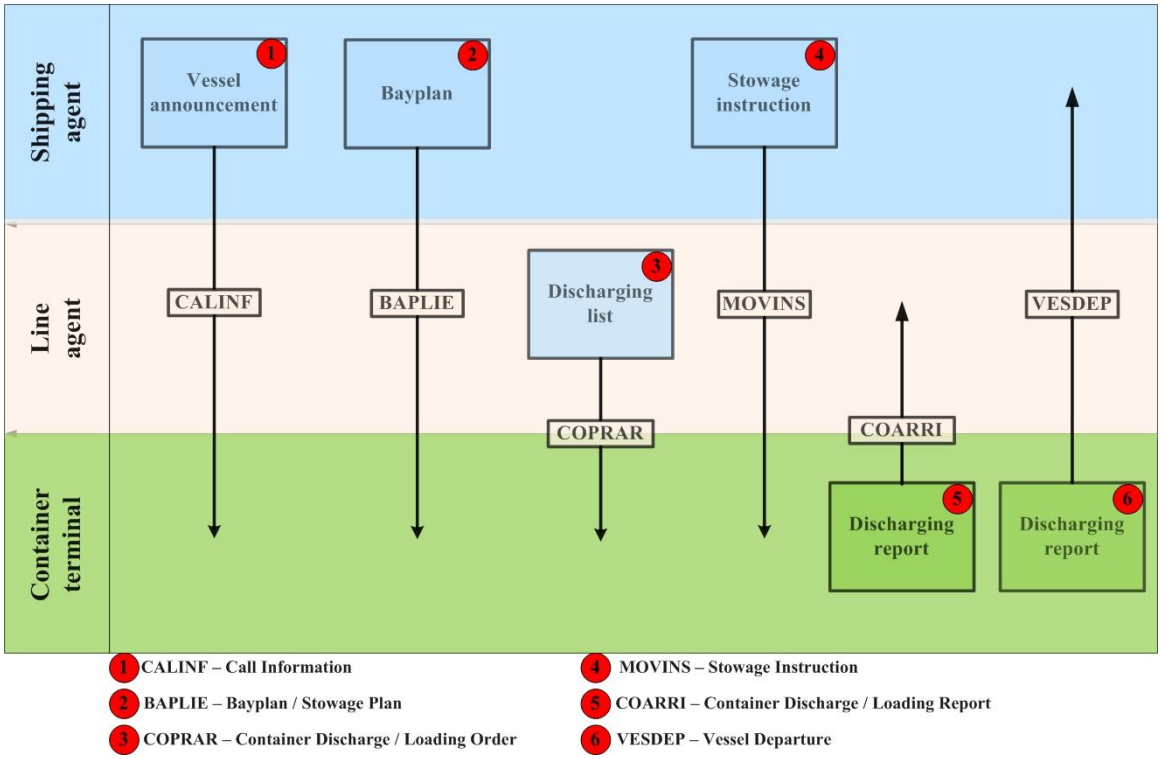

Figure 4. The most relevant and meaningful UN/EDIFACT messages for the container unloading process

3.3.1. Carrying out the process of unloading containers from a specialized container ship

In the specialized container terminal, the operations performed are divided into three categories: in the port area (loading and unloading of containers from specialized ships/barges), in the land area (receiving and delivering containers using specialized modes of transport), as well as operations in the terminal's storage stacks.

The first operation in this process of unloading a container from a specialized container ship is its handling by the quay crane with which the terminal is equipped (portainer). Once the container has been caught using the spreader and locked, the crane transports it from the hold or from the ship's deck to the quay where it is placed on an internal transport vehicle. There is an operator on the ship who supervises the unloading and compliance with the unloading plan, and he ensures that the container handling is carried out correctly, entering the container number into a data transmitter, and in the event that a container leaves for unloading without being planned, he signals this to the dispatcher to remedy the problem. In the unloading area on the ship at the berth there is an operator/verifier, who inspects the container, enters the container number and the internal vehicle number into a data transmitter. Thus, the container number is correlated with the internal vehicle number and transmitted to the terminal operating system which associates the container number with the information concerning it. During this operation, the removal of the container locking devices (twist-lock) is simultaneously performed by the dockers, this only applies if containers are unloaded from the deck, and these devices are returned to the ship. Then, after the verifier on the berth has finished, the position that has been assigned to the container appears on the data transmitter display in the cabin of the internal vehicle operator and, where appropriate, of the RTG crane operator or empty container equipment operator. In some cases, at the request of the line operators/container lessees, maintenance work may be performed for empty containers to comply with the international standards and conventions in force (Convention adopted on 2 December 1972 on the safety of full containers – CSC 1972 - Convention for Safe Containers, but which had legal effects starting from 7 September 1977). After the work is performed, the internal vehicle takes over the empty container and transports it to the empty container area of the

terminal, where it is handled and stacked using an empty container handling machine, and the stacking is formed in special blocks according to the criteria of the operating shipping lines, the condition of the container, dimensions, etc. After unloading into the stack, the operator of the empty container handling machine will confirm or enter into the system the position assigned to the empty container.

In most cases, full containers are not subject to customs control and are transported directly to the groupage area, where a wheeled port crane unloads the vehicle and places the container in the stack. Once it is placed in the stack, the RTG crane operator confirms the operation on the system in his cabin, moving on to the next command. The container will remain in the stack until another process starts and the container needs to be handled.

However, in some cases when the full container requires customs inspection at the request of customs officers or at the request of the beneficiary, in this case the process will be different. After unloading the container from the ship, the internal vehicle transports it directly to the customs inspection area, a special place designated within the terminal for ground inspection or within the CFS, where the container remains on the trailer at the ramp and the operations required by customs are performed. Then, two types of inspection can be performed: by unsealing the container and physically inspecting the cargo in the container (intrusive verification) or verification without unsealing the container using modern scanning means using X-rays or gamma rays, this procedure is performed if the terminal is equipped with such a scanner in compliance with the conditions imposed to avoid radiation, if there is no scanner in the terminal, it can be transported outside the terminal for scanning, after which the container can return to the intended groupage area [14].

Figure 5 illustrates the process of unloading a container from a container ship.

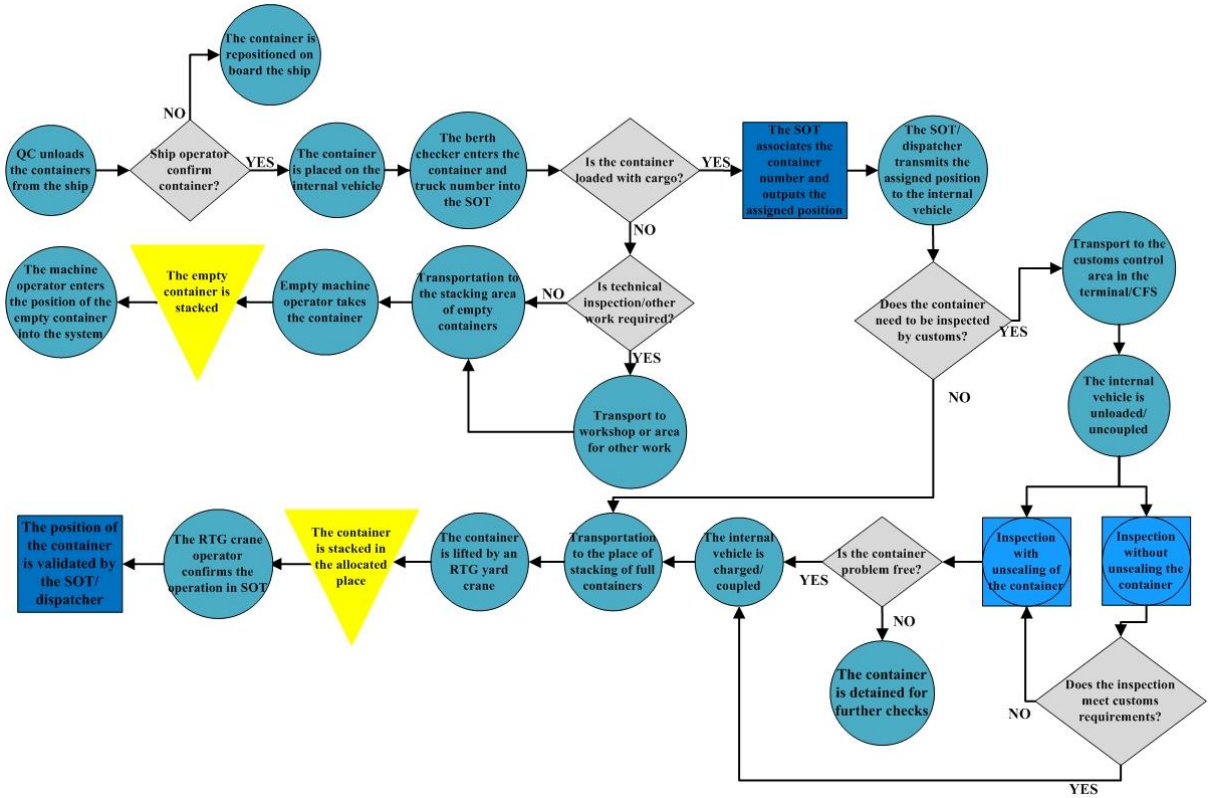

Figure 5. The process of unloading containers from a specialized container ship and stacking in the container terminal

Once the inspection using modern X-ray or gamma ray imaging or other technologies has been completed, there are two routes for the container to follow. If no further inspection is required, it is loaded/coupled onto an inland transport vehicle and the transport process continues to the groupage and stacking area. If further inspection is required, authorized persons will unseal the container and

conduct a thorough physical inspection of the cargo. This inspection process can take up to 1-2 days, and if the cargo is without problems, the container is returned to its original form, sealed, re-documented with new seals and endorsements, loaded onto an inland transport vehicle and the unloading process is resumed [15]. As can be seen, a container is inspected in most cases by the competent customs authorities by unsealing and physically checking the contents without prior inspection using imaging, as these means are in full development or implementation within many terminals.

3.3.2. Carrying out the delivery process of containers from the terminal using external trucks

To understand the entire transit of a container through the terminal as proposed in the thesis of this paper, we study the aspect of what happens to a container from the time it arrives in the storage stack until it leaves the terminal gate with the help of external trucks.

The process of delivering a container from the terminal by truck is preceded by the container reception process or the truck driver identification process, but in most cases the reception process takes the lead, because it is always desired to optimize the available resources.

When the truck arrives empty or loaded at the container terminal gate, the necessary checks are carried out for the existence and correctness of the documentation, the driver identification and granting the truck access or not, at the main gate of the terminal. When the truck has passed the main gate, it heads to the place specified on the ticket to pick up the container. As specified in the previous process, it is very important that the driver prepares his trailer for the size of the container to be delivered, and this can only be done in the inspection area / pin-unpin entries. Once the specified location is reached, the container is loaded onto the truck using an RTG crane, and if the container is not directly accessible, the crane performs additional manipulations to release the container and maintain the stacking arrangement. In Figure 6, the process of delivering containers using an external truck is graphically illustrated.

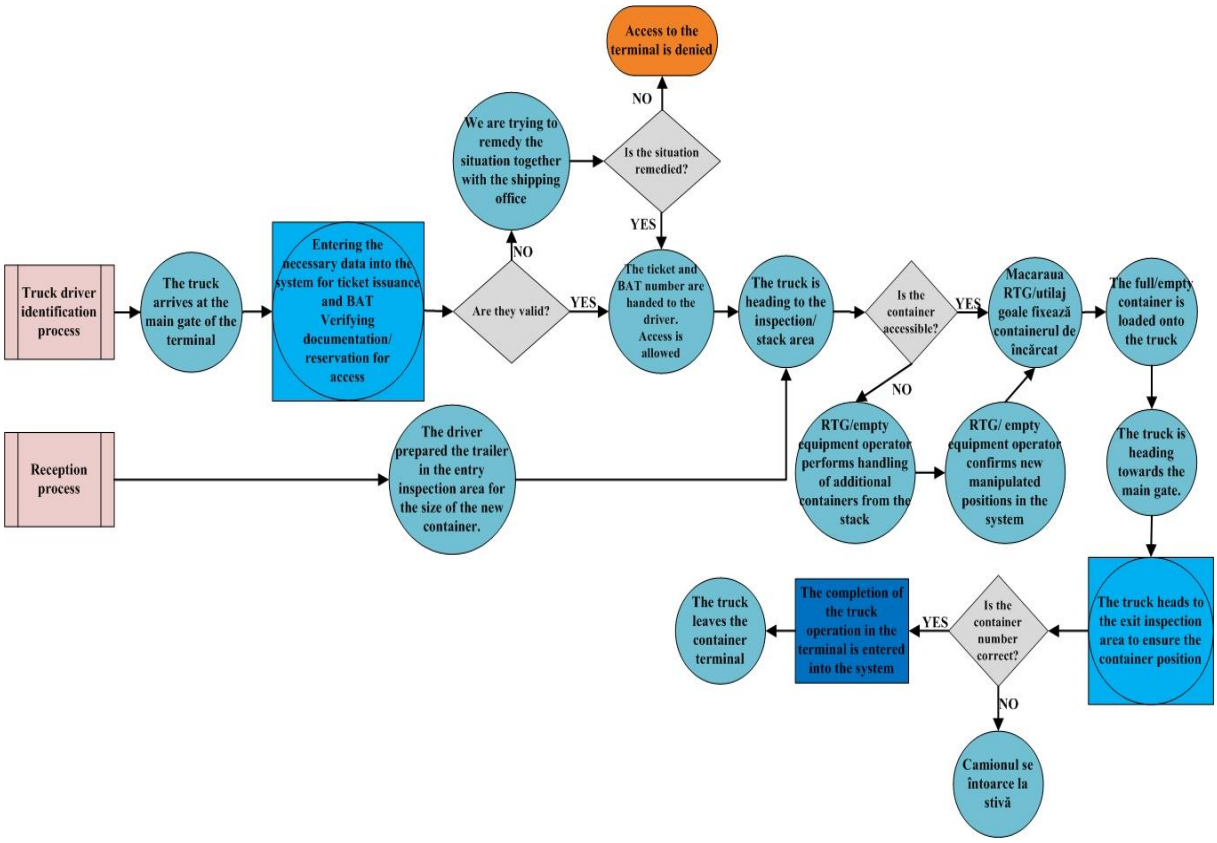

Figure 6. Exemplifying the process of delivering containers from the terminal using external trucks

Once the container is loaded onto the truck, it can begin moving towards the terminal exit gate. Before leaving the terminal, the driver must stop at an inspection area/pin-unpin exits, where the driver is allowed to get out of the truck to check the seals and exterior appearance of the container as well as the locking of the platform/trailer. If a problem cannot be fixed by one's own means, one can usually call on terminal staff located at the terminal's main gate.

Once the loaded truck arrives at the main gate, the container number is checked to match the one on the ticket, and if everything is in order, the truck leaves the terminal. Otherwise, the truck is redirected back to the loading stack to fix the situation.

4. Results

Considering what was studied in this paper, the following results can be highlighted as the most important:

- considering the documented statistical data on population growth at a rate of 0.8% per year, and 57% of the world's population living in urban areas, it is clear that commercial needs will increase, and global freight transport must develop and keep up with future requirements;
- in 2023, the maritime industry managed to reach the milestone of 12 billion tons of cargo transported worldwide using all types of ships, and the forecast for the period 2025-2029 is an average annual growth of 2.4% and for maritime container transport an average growth for the same period of 2.7% annually, in 2024 container ships representing 14% of the total capacity of the world's shipping fleet;
- understanding the needs and elements necessary for the proper functioning of a conventional container terminal represents the cornerstone for continuing studies regarding the development of such a terminal and its growth toward a semi-automated or even automated terminal;
- building process diagrams for each process and sub-process executed in the container terminal represents a huge help for the terminal management team in making strategic decisions regarding the development of future projects, solving existing problems, finding localized optimization solutions to make the terminal more efficient and to face external competition, etc;
- realizing the importance of information flow where the container terminal plays a leading role in the relationship with the other entities involved, and it must be prepared to deal with a very high information flow and be willing to find modern solutions permanently.

5. Conclusions

This paper present a study on the awareness of the need to develop maritime transport with a special emphasis on containerized cargo transport.

Some of the processes carried out in a conventional container terminal were highlighted following the study of the specialized literature, based on the observation of the processes on site and discussions with department managers in a specialized terminal in the port of Constanta, in order to understand the transit of a container from the time it arrives at the terminal on board a ship until it leaves the terminal by road. Of course, the processes and sub-processes carried out daily in the terminal are much more numerous, and their study will be materialized in future studies.

Another very important aspect that was studied is the capacity that a specialized container terminal must have in information management both internally and with downstream and upstream partners so that there are no syncopes in the transport of containerized goods from the sender to the recipient and especially that unnecessary and unplanned additional costs are not generated.

As future research directions starting from this work, one can continue with the study of all processes in a conventional container terminal and the creation of a process map that is so necessary for managers in the top management of a company. In addition, one can continue to study how to improve a process through modeling and simulation techniques using specialized software, as well as proposing models for its improvement.

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