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INFORMATION TECHNOLOGY APPLIED TO CONTAINER TERMINALS AUTOMATION

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This research is the final thesis of a Master of Science in Management Engineering at the Politecnico di Milano, Italy. Its main goal was to link different subjects studied over the years (Innovation Management, Finances, Human Resources Management, Economics, Operations Management, Information Technology, Logistics and others) with student's previous graduation experience in Naval Engineering (at Escola Politécnica da Universidade de São Paulo, Brazil).

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ABSTRACT

Due to an accelerated growth on containerized freight over the last two decades, terminals are challenged to overcome obstacles and constraints in order to enhance their own capacity and productivity.

The capacity of a container terminal is measured by the number of Twenty-Foot Equivalent Units (TEU) handled each year. Many factors can impact terminal performance: area, layout of ground slots, stacking density (yard utilization) and technology are some of them.

This thesis aims on deepening the knowledge on how to increase terminal productivity, focusing on the use of Information Technology (IT) possibilities (for both hardware and software).

Investments on terminal automation are substantially high and involve many risks. Important decisions have to be made and STAFF resistance to innovation has to be eliminated. If top management team, as well as all sectors of the terminal, gets engaged on the project with full commitment, I.T most likely will be seen as an asset, with costs and risks; but also returns and benefits.

After discussing basic aspects of terminal operations and its possibilities of improvement, a study case was done to the Port of Genoa, in Italy. A practical vision of a real scenario was really important for the student to understand how difficult changing present situation can be. Specific conditions, obstacles and constrains exist in every terminal, no matter their country, size or current state of automation.

Keywords: container terminal, productivity, information technology, asset, automation, investments.

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ABREVIATIONS LIST

ASC – Automated Stacking Crane

AGS – Automated Gate System

AGV – Automated Guide Vehicle

CAPEX – Capital Expenditure

EDI – Electronic Data Interchange

EDIFACT – Electronic Data Interchange for Administration Commerce

ETA – Estimated Time of Arrival

ETD – Estimated Time of Departure

HHT – Hand-Held Terminal

IRR – Internal Rate of Return

IT – Information Technology

LPR – License Plate Recognition

MHC – Mobile Harbor Crane

NPV – Net Present Value

OCR – Optical Character Recognition

OPEX – Operating Expenditure

RFID – Radio-Frequency Identification

RMG – Rail Mounted Gantry

ROI – Return on Investment

RTG – Rubber Tyred Gantry

STS – Shit-to-Shore

TEU – Twenty-Foot Equivalent Unit

TOS – Terminal Operating System

UN – United Nations

VMT – Vehicular Mounted Terminal

WAAC – Weighted Average Cost of Capital

WSC – Wide-Span Crane

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1. INTRODUCTION

1.1 THE IMPORTANCE OF INFORMATION TECHNOLOGY

Information Technology, IT, highly impacts any company's efficiency and quality of service. It also contributes to decreasing the percentage of errors and the total time used for companies' operations. Nowadays, IT became fundamental on differentiating one company from the others by increasing competitiveness. It's directly associated with companies' strategy: *strategy needs technology and technology can determine strategy*.

However, investments on IT involve risks and high costs. Therefore, when it comes to restructure and automate a container terminal, it's fundamental to understand WHEN, HOW and WHAT is applicable in each case. It's important to analyze and find out some basic considerations regarding the current and eventually the future situation at the port of interest, such as:

- Investments CAPEX required (funds that will be used to acquire or upgrade physical assets such as property or equipment);
- How much it is possible to reduce OPEX (operating expenditure);
- How much time it will take to implement all changes;
- Eventual high traffic of vessels due to access restrictions;
- Total area needed for new system;
- The current system for documentation check and how its processes can be converted into automatic and digital ones;
- Laws and restrictions regarding the country's customs;
- Social and employment context.

To meet growing demand, ports need to enhance capacity. The process of automation of container terminals around the world has been taking place more and more, especially in the last decade, as we see below:

- Hutchison, Rotterdam (since 1993);
- Hutchison, UK (since 1994);
- HHLA, Hamburg (since 2002);
- Patrick Autostrad Terminal, Brisbane (since 2004);
- TCB, Nagoya (since 2006);

- Wan Haiin, Tokyo (since 2006);
- APMT, Portsmouth (since 2007);
- DP World Antwerp Gateway, in Antwerp (since 2007);
- Evergreen, Kaoshiung (since 2007);
- Euromax Terminal of Maasvlakte, Rotterdam (since 2008);
- Hanjin, Algeciras (since 2010);
- BNCT [2,3], Korea (since 2012);
- Burchardkai, Hamburg (since 2012);
- Tercat, Barcelona (since 2012);
- And many other important expansion plans within 2014 (in Island, Rotterdam, New York)…

This thesis aims on deepening the knowledge of automation applied to container terminals of ports in order to use the acquired concepts to analyze the current situation of the Port of Genoa, Italy.

1.2 THE IMPORTANCE OF CONTAINERS

The idea of using some type of container-like box to transport and trade cargo is not new. Two centuries ago, in 1792, England started using boxes to combine rail and horse-drawn transport. During the Second World War, the U.S. government used standard-sized boxes to increase their speed and efficiency on unloading and distributing goods.

But only in 1955, the American trucking entrepreneur Malcom P. McLean had the idea of lifting an entire truck trailer on to a ship [1], without any need to previously open it and rearrange goods: the idea led to modern containers' official birth, in 1956. They could be moved seamlessly between trucks, trains and ships, with the minimum need of interruptions. In 1961, the International Organization for Standardization (ISO) set standard sizes for all containers. The 20-foot container, referred to as Twenty-foot Equivalent Unit (TEU), has become the industry standard reference.

Volume and vessel capacity are commonly measured in TEU.

By efficiently linking different modals (ways of transportation), the modern container led to a revolution in cargo transportation and international trade over the following six decades and it will surely continue transforming the world of freight.

According to the World Container Census 2010, global container fleet has grown over 400% in the last two decades and today it exceeds 30 million TEUs [2], as showed in Figure 1.

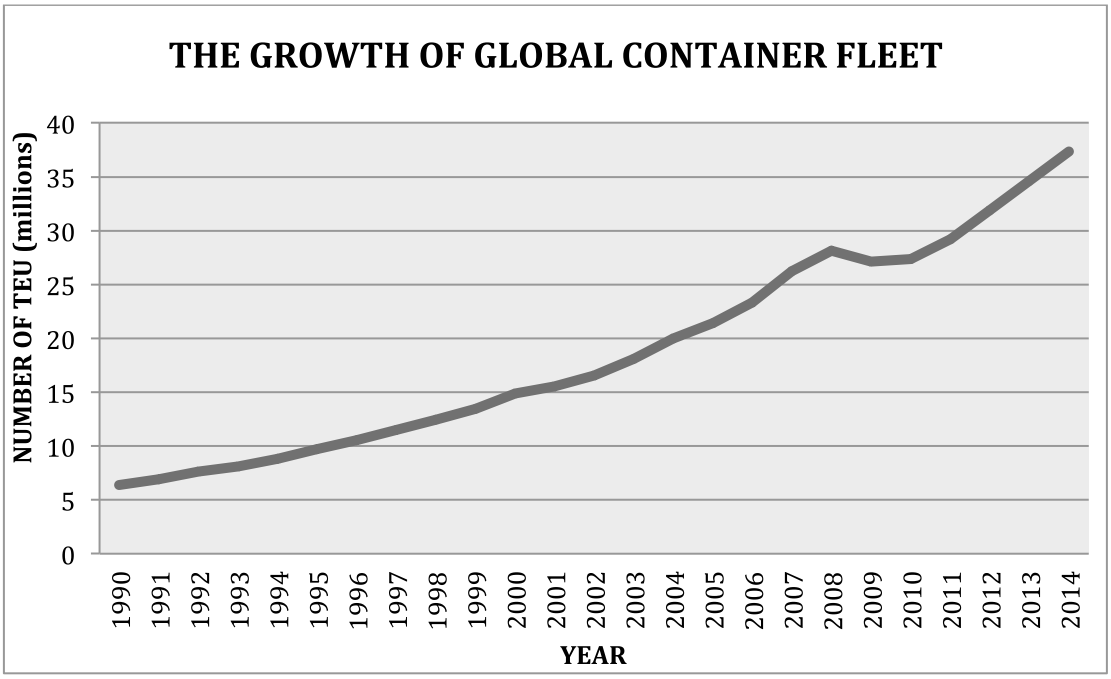

Figure 1 - The growth of global container fleet from 1990 to 2014

There are many reasons why the use of containers will keep on growing substantially during the next years. First of all, globalization became a concrete reality, which gives a considerable strength to international commerce. Besides that, the world's most modern ports have been more and more prepared to handle containers efficiently. Ports from undeveloped countries tend to follow the trend and get more "containerized" every year. Unit price of container handling tends to reduce and productivity increases vastly.

Not so long ago, important commodities such as sugar and coffee were carried in big tanks inside appropriate vessels. Nowadays, almost 100% of their transport is done in containers. Not only commodities, but also the international trade of industrialized goods is also growing and a big part of them is carried in containers.

Also, humans have never been so specialized in the construction of giant and efficient ships. For example, *Maersk Line* will deliver in 2013 the world's biggest and most efficient container vessel [3], Triple-E. Its capacity will be of 18,000 TEUs (if all of them were to be put on a train, it would have to be 110 km long).

Containers are definitely the key to the future of international trade. Ports that work on the capacity, agility and efficiency of their container terminal will certainly be highly benefited from this growth.

In 2010, the 50 largest container ports in the world handled together about 360 million TEU[4]. But, incredibly, just the 5 largest container ports by themselves (Shanghai, Singapore, Hong Kong, Shenzhen and Busan) handled together 118 million TEU.

In the same year, the three largest European container ports (Rotterdam, Antwerp and Hamburg) handled together 27.5 million TEU (after handling 24 million TEU in 2009).

The world's 20 largest container ports in 2010 [4] are listed on Table 1 as well as their total volume of handled TEU in 2009 and 2010.

RANK	PORT, COUNTRY	VOLUME 2009 (MILLION-TEUS)	VOLUME 2010 (MILLION-TEUS)
1	Shanghai, China	25.00	29.07
2	Singapore, Singapore	25.86	28.43
3	Hong Kong, China	21.04	23.70
4	Shenzhen, China	18.25	22.51
5	Busan, South Korea	11.98	14.19
6	Ningbo-Zhoushan, China	10.50	13.14
7	Guangzhou Harbor, China	11.20	12.55
8	Qingdao, China	10.26	12.01
9	Dubai, United Arab Emirates	11.10	11.60
10	Rotterdam, Netherlands	9.74	11.14
11	Tianjin, China	8.70	10.08
12	Kaohsiung, Taiwan, China	8.58	9.18
13	Port Kelang, Malaysia	7.31	8.87
14	Antwerp, Belgium	7.31	8.47
15	Hamburg, Germany	7.01	7.91
16	Tanjung Pelepas, Malaysia	6.00	6.54
17	Los Angeles, U.S.A	6.75	6.50
18	Long Beach, U.S.A.	5.07	6.26
19	Xiamen, China	4.68	5.82
20	New York and New Jersey,	4.56	5.29

Table 1 – Container handling of the 20 largest container ports (2009-2010)

1.3 THE USE OF CONTAINERS IN BRAZIL

Until 1995, all Brazilian ports were controlled by the government. They showed a low service level, long waiting time for berthing of vessels and considerably high operating costs (situation of monopoly). In 1995, the country issued the most important law in terms of modernization of its ports (law 8.630/1993), transferring their control to private sector. The very first terminal built under to the new law (terminal 37 at *Libra Terminais*) started operating in November of 1995 and since then the service level of Brazilian ports never stopped growing.

Due to this recent modernization, the number of containers handled in Brazilian ports showed a significant growth in the last years. In the year of 2000, the country's number of handled container was 1.9 million TEUs. In 2011, Brazil handled 5.2 million TEUs in one year (achieving a 180% growth over one decade). The volume in 2011 was 9% greater than the 4.6 million TEUs handled in 2010. So far, all specialized terminals have received US$ 2.8 billion [5] in investments on expansion, construction, acquisition of modern machinery and qualifying human labor.

Table 2 shows the evolution of container handling for the top 15 largest Brazilian ports, from 2007 to 2011, as well as the nation's overall volume each year. Figure 2 shows the geographical location of each port, according to the numbering in Table 2.

PORT	2007	2008	2009	2010	2011
1. Santos	1.654.713	1.743.412	1.469.151	1.762.205	1.915.292
2. Itajaí	390.394	396.287	346.479	565.017	594.486
3. Rio Grande	388.320	372.811	394.005	408.835	395.218
4. Paranaguá	348.000	356.577	367.798	399.590	413.245
5. Rio de Janeiro	290.575	289.059	244.536	299.623	321.160
6. Itaguaí	174.865	213.272	154.289	196.267	216.420
7. Vitória	207.234	197.773	156.420	184.737	204.393
8. São Francisco do Sul	201.500	175.288	152.478	118.802	177.112
9. Salvador	165.715	150.497	144.263	168.283	167.286
10. Manaus	174.570	189.330	190.000	238.646	293.065
11. Suape	163.500	201.562	167.870	226.538	284.124
12. Pecém	77.689	60.575	88.301	111.334	120.788
13. Fortaleza	80.689	41.201	33.000	46.855	46.514
14. Belém	43.465	27.479	18.363	22.377	17.787
15. Vila do Conde	17.690	14.498	17.605	21.527	20.756
Others	88.205	89.213	28.620	23.438	28.573
	4.467.124	**4.518.834**	**3.973.178**	**4.794.074**	**5.216.219**

Table 2 – Container handling in all Brazilian ports, from 2007 to 2011

Figure 2 – Geographical location of the 15 largest container ports of Brazil

In the last 11 years, even considering the economic crisis of 2008/2009, the average growth of Brazilian volume of containers was 10.63% per year. If these two years were to be ignored, the average growth would reach about 14.00% per year, in the same period.

As the volume of container handling grows, vessel dimensions also tend to increase. In Brazil, ships with a 7.100 TEU capacity are already in use by *Hamburg Sud* and 9.600 TEU vessels have already been ordered.

As the dimensions (length = LOA; width = beam) of container ships become greater, investments in ports infrastructure become crucial. Terminal containers have to increase their own dimensions in order to make the berthing of big ships possible and they must acquire larger portainer cranes in order to properly load and unload berthed vessels, reaching a higher number of “pilled up container” levels (also known as tiers).

Along with investments on new equipment, the use of information technology becomes very important for any container terminal to obtain efficiency, speed, functionality, high level of service and low operational costs. As it’s been said, strategy needs technology and technology can determine strategy. Information technology applied to ports will be detailed below.

2. CONTAINER TERMINAL PRODUCTIVITY

2.1 GOALS AND INFLUENCING FACTORS

The function of any container terminal is basically to transfer and to store containers. The goal of the operators is to constantly try to maximize operational productivity, using available ground space efficiently.

Container handling productivity is measured by transfer functions inside the container terminal, such as:

- The number of container cranes and their movement rate;
- The total use of yard equipment;
- The productivity of workers employed in waterside, landside, and gate operations.

The efficient use of available ground space relates to the number of containers stored in a given area of the terminal. There is a common trade-off between the number of containers stored and their accessibility. Stacking reduces land costs while it increases handling costs. Therefore, operators must define container accessibility in relation to ground space utilization based on the terminal’s operational targets and its unique physical characteristics.

Another challenge for the operators is to be able to deal with all the factors that can influence the productivity of a container terminal. Only some of them can actually be controlled and changed by the operators.

Factors internal to the terminal and under the control of the operator include:

- Terminal configuration and layout;
- Capital resources invested;

- IT system;
- Labor productivity (though not fully controllable).

External factors affect the productivity of terminal operations, but they are beyond the control of operators. Common examples are:

- Trade volumes;
- Shipping patterns;
- Ratio of 20 feet to 40 feet containers on vessel;
- Ratio of import to export containers (which influences the number of empty containers handled at a terminal and the availability of container chassis);
- The size and type of ships accommodated by a terminal;
- Landside capacities;
- Tariffs;
- Performance of intermodal rail and highway systems.

2.2 OPERATIONAL INDICATORS

Indicators of terminal productivity can be very useful for comparing and analyzing operational results. There are several ways to calculate them, even for rates regarding each element of the terminal. A few examples are detailed in Table 3.

ELEMENT	MEASURE OF PRODUCTIVITY	UNIT
Crane	Crane Utilization	TEUs/year per Crane
Crane	Crane Productivity	Moves per Crane-Hour
Berth	Berth Length Utilization	TEUs/meter of quay length
Berth	Berth Utilization	Vessels/year per Berth
Berth	Service Time	Vessel Service Time [hours]
Land	Land Utilization	TEUs/Gross Area
Land	Storage Productivity	TEUs/Storage Area
Gate	Gate Througput	Containers/hour/lane
Gate	Truck Turnaround Time	Truck Time in Terminal
Gang	Gang Labor Productivity	Number of Moves/man-hour

Table 3 – Indicators of productivity for different elements of the terminal

Some care should be taken when these aggregate statistics are used to quantitatively measure the performance of different terminals. While the numbers may indicate that a port is underperforming in a certain aspect relative to other ports, a hurried effort to improve the productivity measure of a specific operational element could ruin the overall economic efficiency of the entire container handling system. Another problem that may be caused by having such a wide range of aggregate indicators is the lack of uniformity between ports. Two ports may use a different set of indicators to measure their own results. Sometimes, they even have data about the same indicator, but measured in a slightly different way (for example, "average service time" can be the total time a vessel is berthed at the terminal or just the time a ship is actually worked, excluding waiting time and shift breaks).

So far, no public mechanism or set of regulations has been established for the monitoring of terminal performance, which makes the comparison between different major container ports hard and tricky. To avoid that, it is usually made at a high level of aggregation (such as TEUs per year, as used in item 1, or even TEUs per m^2 of terminal area).

Once terminal operators are aware of which indicators are important for the respective container terminal, they shall study and compare then, being careful for specific local factors that might influence one or other indicator such as labor cost, environmental or geographical restrictions, etc.

The most impacting ways to increase productivity are expanding physically or in terms of processes. The first one is not always possible, since many ports have their growth limited due to legislation. The second option is where Information Technology plays an important role.

3. TERMINAL AUTOMATION

3.1 THE TOS

As mentioned before, technology shouldn't be applied superficially at a container terminal (for example, exclusively for collecting data and calculating indicators). It can also be a used by terminals as a strategic tool to redefine their processes and obtain better costs and productivity.

I.T. can definitely be approached as an asset, once it involves a cost, risks, returns and benefits. But in order to obtain good economic returns, it's primordial to have full commitment of the terminal's top management team. Its returns are only limited by the ability on using the technology (and not by the capacity of I.T. itself). Benefits are not reached automatically; they depend on a complex equilibrium between:

- Strategy;
- Structure;
- Processes;
- Labor.

Thus it's fundamental to have the commitment of all sectors of the terminal as well. Technological innovation will most likely create some conflicts at its initial phases and managers might run into obstacles, such as resistance and slow apprenticeship by workers. Employees have to be stimulated, willing to change and aware that doing things just like they have always done before will not bring different results. These aspects are important for a successful implementation of I.T. at any terminal.

The choice of what software to use is also relevant. There are several options available around the world and when choosing the Terminal Operating System (TOS), it's important to consider:

- If the cost is compatible with terminal budget;
- If that software has already been used in the respective country (this way, terminal avoid being used as an "experience");
- If the package has reached international success and recognition;
- If the company offers support in that region and the eventual timing of reply;
- If the package is reliable;
- If the software is flexible and customizable for each terminal, without causing application to crash;
- If product's eventual limitations won't limit operations in that terminal;
- If both functional and integration aspects are ideal for the terminal.

These TOS have an amazing operational capacity and can even learn from users and critically think, which helps operators to reach accurate and reasonable conclusions. They can control gate activities, orders (in and out), single positions at the yard, container sequence during boarding and need of support. The systems also communicate with all agents involved in the operations (such as customs, banks, transport agencies, immigration department) through the use of Electronic Data Interchange technology, EDI (if the technology outside the terminal allows it).

EDI is globally the most popular way to allow automatic transactions and exchange of information between systems. EDI works through standardized electronic messages, regulated by international organizations among which the United Nations, UN, and the Electronic Data Interchange for Administration Commerce, EDIFACT. EDI directly connects computer systems, not people (it shouldn't be confused with e-mail and other ways of electronic communication that connect people to people and transfer unstructured data).

The acquisition of a package or software is closely followed by some changes in terminal hardware (acquisition of new equipment and automation of processes). The intensity of automation will depend on many factors, but regardless software and hardware must work well enough together in order to successfully:

- Attend all needs;
- Control and re-plan steps;
- Guarantee the correct operations;
- Gain velocity on replies;
- Generate information to support decision making;
- Originate efficacious and efficient operations;
- Reduce costs;
- Guarantee security;
- Guarantee quality;
- Build a strategy.

The asset restructuration can take place in several zones of the terminal. The item 3.2 explains in details how the work flows inside a container terminal.

3.2 THE OPERATIONAL CYCLE

In order to deepen the knowledge of how the TOS is related to each operation part, it's convenient to order the following topics in a specific sequence: the same one done by a singular container as it arrives to terminal to be exported, all the way until it completes the operational cycle.

First, it passes through documentation check, then through the gate. If both coincide, the container is allowed to enter the terminal and will be directed to a certain slot. It will, then, wait inside the export area until the ship of destination is berthed and ready to receive it. As the container is boarded among with other export units, the quay cranes will also withdraw containers to be imported by that terminal. These will be allocated at a chosen slot inside the import area and will wait to be picked and finally leave terminal.

3.2.1 ONE STOP OFFICE

The office collects and processes all import/export documentation.

The back office manages all booking operation. It receives EDI or paper orders for export (booking) and import (delivery) cycles and keys them into the system, just like the back office of an airport does when a ticket is booked.

The front office (a.k.a. trucker desk) collects and checks import/export documentation from inland container vehicle (for example truckers). If all is correct, the office grants their access to the terminal (just like the front office desk does to a passenger who checks in for flying) and the vehicle may proceed to gate control.

All information from the one stop office is automatically shared with the TOS through EDI messages, thus with no need of human work.

3.2.2 GATE

The gate office checks all IN/OUT traffic on terminal. As trucks arrive, basic information is checked (units ID, license plate and eventually reefer temperature and IMO stickers) and communicated directly to the TOS. Security seals can also be applied (if there are none) to guarantee that containers will not be opened during waiting time.

Some modern ports around the world have a completely automated gate operation. The reading of characters on both truck and container is done by an automated system using Optical Character Recognition (OCR). The systems can contain side and back container camera/illumination units, LPR (License Plate Recognition) camera/illumination units, chassis recognition camera/illumination units, sensors and loop detectors. After capturing pictures, they are analyzed by a software (such as Visual Gate System or SeeGate) capable of converting image into text. Information is then sent to TOS in a structured form.

Figure 3 [8] shows a possible configuration of OCR devices in order to have an automated container terminal gate.

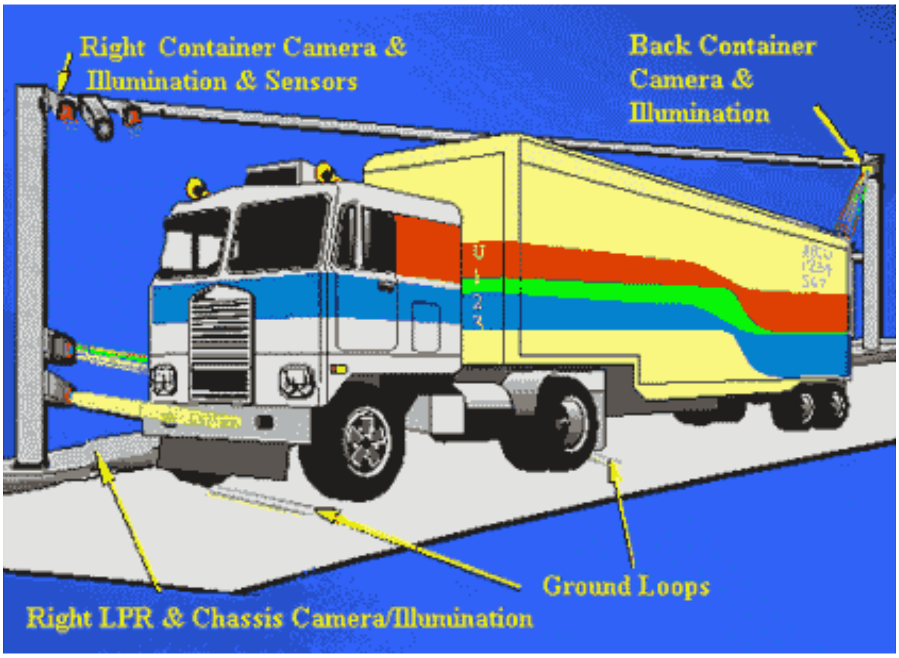

Figure 3 – Configuration of an OCR automated gate

Figure 4 shows an example display of SeeGate, a World's leading system for container ID reading [8]. The program transforms images of import/export trucks into text formatted data and send it to the used TOS.

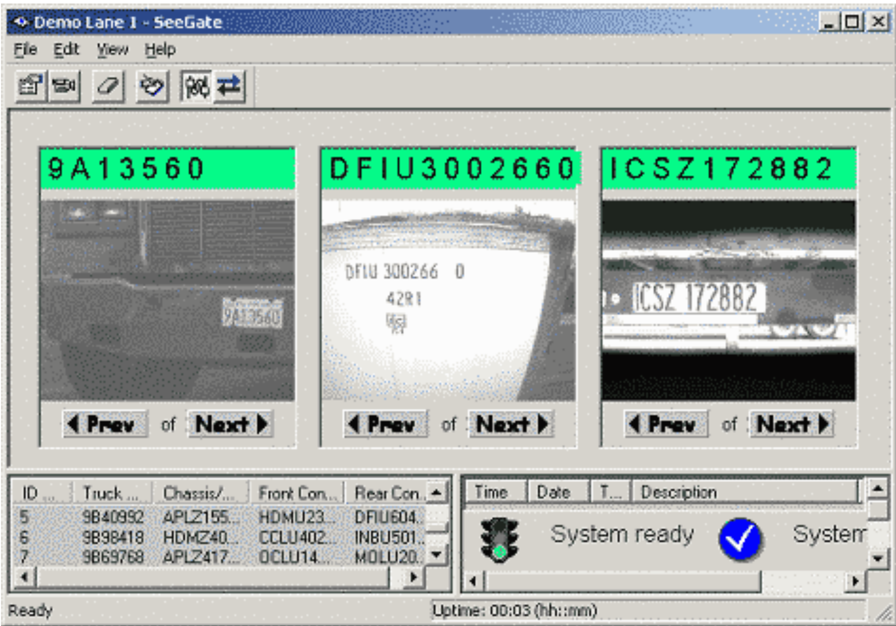

Figure 4 – Example of SeeGate system display

Electronic seals can send their code via RFID with no need of human resources to read them. However, E-seals might not be a reality in certain countries or regions and incoming trucks are not equipped with them. In this case, having a fully automated gate is not practicable, because an employee needs to manually read the seal (this number is too small to be captured by OCR cameras) and send data with the system. This operation can be easily done via radio by HHTs (Hand-Held Terminals), like NEO (from Psion Teklogix), in Figure 5 [9].

Figure 5 – A Hand-Held Terminal for gates

Once information was collected (automatically or semi-automatically), the TOS compares it to data received from the One Stop Office and if both coincide, the truck is free to pass the gate and deliver/pick up the container at/from a specific position provided by the TOS.

3.2.3 YARD PLANNING

When trucks are finally authorized to pass through gates to deliver or pick up a container, the driver is told exactly where to leave/find the cargo. The position is accurately defined by the TOS, guided by a strategy of land and resources optimization (for both equipment and human labor).

The layout of a yard is highly relevant on its performance. The land is divided into macro areas and each of those has a specific subdivision to be respected. The main areas are: quay wall, import/export stock, empty stock, sheds and landside traffic area (hinterland operations).

Figure 6 gives an example of a possible macro division of a yard.

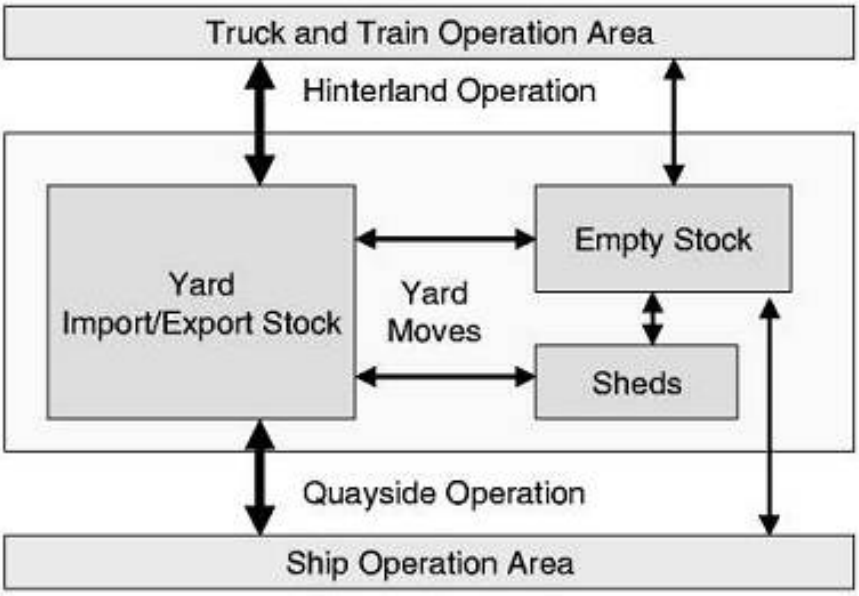

Figure 6 –An example of a yard layout

The main area to plan and control is "import/export". Containers to be loaded (export) and blocks assigned for discharge containers (import) should be as close as possible to the respective vessel.

The export division is definitely tricky and complex to plan. The TOS designates each stacking position based on relevant criteria for internal productivity and the embarkation of the respective vessel. The optimization is possible because planners know well enough vessels' Estimated Time of Arrival (ETA) and Estimated Time of Departure (ETD).

The main micro subdivisions are:

- Length of container (20'/40');
- Weight Class: heavy containers will be given lower positions inside the vessel;
- Maritime service (or ship line);
- Vessel of destination;
- Port of destination.

The situation might not be the same for import containers. If there's no truck preannouncement system implemented in the region, terminal planners don't know when each container will be required. In this case, the import division is separated only by length (20'/40') and by normal/special cargo (reefer, dangerous) and it should have machines that will do the smallest number of shifting moves possible, in an unpredictable scenario. Gantry cranes are highly flexible for this matter and recommended for this case. The three most used types are:

- Rubber Tyred Gantry Crane (RTG):

  RTG cranes work very well in a high stacking density scenario, like the ones found in very large container terminals (an example can be seen on Figure 7 [10]). They run over wheels, so they can move and serve different blocks of the yard. In this case, blocks are usually parallel to quayside.

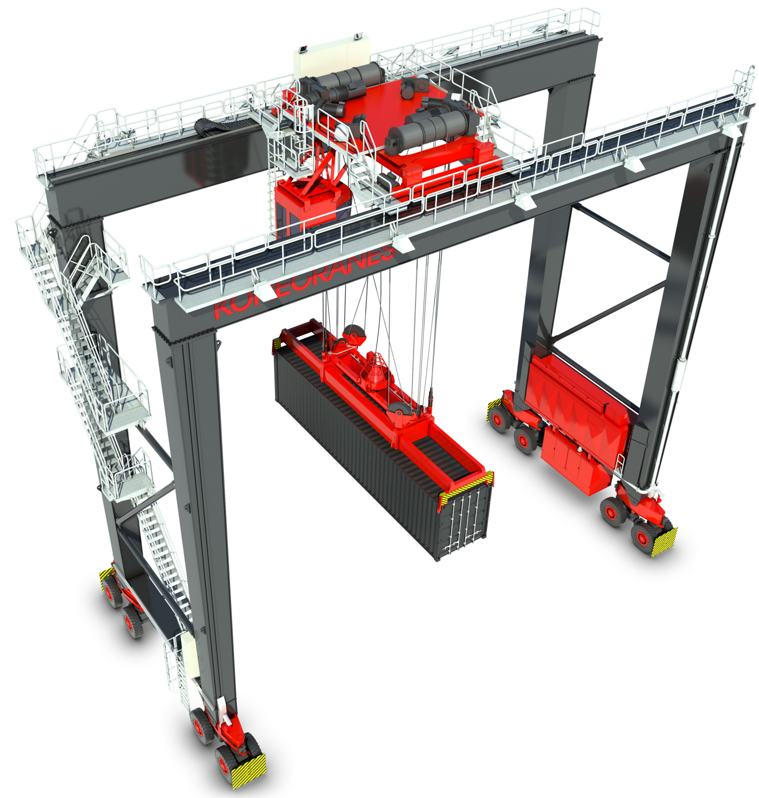

Figure 7 – An RTG (Rubber Tyred Gantry)

Table 4 shows the most relevant advantages and disadvantages of RTG cranes.

ADVANTAGES	DISADVANTAGES
Uses small operational space	Needs frequent maintenance
Highly flexible	Needs appropriate pavement
Enables a high productivity	Needs two handover procedure

Table 4 – Advantages and disadvantages of RTG cranes

Table 5 shows the technical details and capacities of a typical RTG crane (Kalmar RTG) [17].

PARAMETER	RTG PERFORMANCE
Capacity under spreader	40 ton
Lifting height	1-over-5 TEU
Stacking width	7 + vehicle lane
Hoisting speed empty	40 m/min
Hoisting speed full	20 m/min
Trolley speed	70 m/min
Gantry speed	135 m/min

Table 5 – Technical details of a typical RTG Crane

- Rail Mounted Gantry (RMG):

RMG cranes are also convenient for very large terminals. They move on rails, faster than RTGs. Also, because rails can spread the loads better than wheels, the pavement and soil constraints are not as relevant as they are for RTGs. RMGs are also wider, thus stacking blocks can be up to 12 lanes wide. RMG terminals usually have their stacking blocks perpendicular to the quay. Figure 8 [18] shows a model of a RMG crane.

Figure 8 – The 3D model of a Liebherr RMG crane

Table 6 shows the most relevant advantages and disadvantages of RMG cranes. Table 7 brings the technical details and capacities of a typical RMG crane (Liebherr RMG crane) [19].

ADVANTAGES	DISADVANTAGES
Adequate solution for automation	Needs frequent maintenance
Enables a high productivity	Needs rail construction
	Not movable outside rails

Table 6 – Advantages and disadvantages of RMG cranes

PARAMETER	RMG PERFORMANCE
Capacity under spreader	Up to 50 ton
Lifting height	1-over-5 TEU
Crane span	22 to 70 m
Hoisting speed empty	52 to 80 m/min
Hoisting speed full	23 to 40 m/min
Trolley speed	Up to 180 m/min
Gantry speed	Up to 240 m/min

Table 7 – Technical details of a typical RMG Crane

- Automated Stacking Crane (ASC):

ASCs are automated RMGs. They can reach a very high utilization rate and can certainly impact the operational cost. They are also wider than RTGs and allow block width of up to 10 lanes.

Table 8 brings the technical details and capacities of a typical ASC (Gottwald ASC) [17].

PARAMETER	ACS PERFORMANCE
Capacity under spreader	40 ton
Lifting height	1-over-5 TEU
Crane span	32.5 m
Hoisting speed empty	72 m/min
Hoisting speed full	39 m/min
Trolley speed	60 m/min
Gantry speed	240 m/min

Table 8 – Technical details of a typical ASC

Table 9 shows the most relevant advantages and disadvantages of ASC.

ADVANTAGES	DISADVANTAGES
A vary low labor cost	Expensive implementation
Enables a high productivity	Needs rail construction
Provides a great yard utilization	Not movable outside rails

Table 9 – Advantages and disadvantages of ACSs

Figure 9 [20] shows a functioning ACS in the Port of Antwerp, Belgium.

Figure 9 – A fully Automated Stacking Crane, operating in Belgium

All three types of cranes offer a considerably high productivity. But they also require a big investment. Another category of yard machines, the non-passive vehicles, cost much less and can also be convenient in situations of automation. Non-passive vehicle are equipment that are capable of lifting containers on their own. As these vehicles are smaller and simpler than cranes, they have a shorter (and independent) operational cycle at yard. Therefore, they can eliminate the waiting time during handovers between quay and storage equipment.

Three well-known different types of non-passive vehicles are forklifts, reach stackers and straddle carriers, as detailed below:

- Reach stacker:

  Reach stackers are highly flexible trucks that are equipped with spreaders that can lift containers from above. They represent an economical solution for container handling within the yard. The most modern reach stackers (like the Kalmar model DRF100-52S8) can operate up to 8 levels of containers. Their biggest disadvantage (in comparison to cranes) is that they can only handle three lanes of container depth. And containers from second and third lane might require a high number of shifting operations in order to be finally accessible. Figure 10 illustrates how a reach stacker functions.

Figure 10 – A Reach Stacker grabing a single container

Table 10 shows advantages and disadvantages of a typical reach stacker.

ADVANTAGES	DISADVANTAGES
Highly flexible	Low capacity
Small investment needed	Big workspace

Table 10 – Advantages and disadvantages of reach stackers

- Forklift trucks:

Forklift trucks are similar to reach stackers, but they operate in a slightly different way. They grab containers from the side, with side-lift spreader, or from below, with forks (not from above). For this reason, they are not as stable and are usually used to handle empty containers. They are also flexible and not an expensive possibility. A functioning forklift truck with side-lift spreader, handling empty containers, is shown on Figure 11 [21] (the most modern ones can even handle two at a time, increasing productivity).

Figure 11 – A forklift truck handling with side-lift spreader

Table 11 shows advantages and disadvantages of a typical forklift truck.

ADVANTAGES	DISADVANTAGES
Highly flexible	Low capacity
Small investment needed	Big workspace
Ideal for empty containers	

Table 11 – Advantages and disadvantages of forklift trucks

- Straddle carriers:

Straddle carriers have been among the most popular types of equipment. Differing from reach stackers and forklift trucks, they can cover all kinds of horizontal movements inside the terminal (not only vertical). They manage to load, unload, stack and transport containers from stack to quay area (and vice-versa). Figure 12 [22] shows an example of a straddle carrier and Table 12 the specifications of a Kalmar CSC450 [17].

Figure 12 – A 3D model of a straddle carrier

PARAMETER	PERFORMANCE
Lifted load	50 ton
Width	4.9 m
Inside clear width	3.5 m
Overall length	5 m
Maximum travel speed	20 km/h
Lifting height	1-over-3 TEU

Table 12 – Technical details of a typical straddle carrier

A typical stocking layout made for straddle carriers has blocks up to twenty meters wide. Blocks can basically be as long as managers want, but if they are too short, yard utilization won't be maximized; if they are too long, straddle carriers might not be able to leave block at a convenient position and their driven distance will not be minimized. Usually, blocks tend to be 14 to 18 TEU long [17].

Table 13 shows the most relevant advantages and disadvantages of a typical straddle carrier.

ADVANTAGES	DISADVANTAGES
High throughput capacity	Needs high investments
It can be the only type of equipment used by the terminal	Not so simple and intuitive (it requires qualified labor)
Flexible	Require maintenance often
Very high productivity	

Table 13 – Advantages and disadvantages of straddle carriers

The APM Terminals Rotterdam, for example, uses 81 straddle carriers in their yard operations [23]. The terminal owns only three empty handlers and doesn't own any reach stacker. Their current annual capacity is of 2.7 million TEUs [23].

All these vehicles and machines can be used either for import and export. If a good preannouncement system is successfully implemented in the region (this doesn't involve exclusively the terminal), import division can be as planned and optimized as the export part.

In all cases, vehicles follow orders of the TOS and provide it a feedback after every move, informing if the move was performed as TOS said or if any eventual change happened. Common ways of communication with the central system are via Wi-Fi or narrow band radio frequency. Wi-Fi is not always ideal, because of the high number of physical obstacles among the terminal. A commonly used radio device is similar to the HHT, used at the gates, but it's built in vehicles: it's called VMT (Vehicle Mounted Terminal) and a product from Psion Teklogix is used as an example. Refer to Figure 13 [12].

Figure 13 – A Vehicle Mounted Terminal, for yard machines

3.2.4 SHIP PLANNING

Available berth space is used to accommodate ships, meeting all contractual commitments, working as efficiently and as cost effective as possible. If vessel's ETA was not respected, it's not the terminal's responsibility to end loading operations within ETD.

The vessels' berthing positions are determined by the TOS and it's as near as possible to the yard blocks having all containers to be loaded and to blocks that are reserved for discharge. If the distance is minimized, the terminal saves time, fuel, human resources and equipment.

Once all containers are positioned on their designated slots and the vessel is moored, loading operation is ready to take place. In the most modern container ports, a simulator interfaced with the TOS can automatically plan the entire operation with a single click of the operator. It creates discharge and loading sequences, maximizing crane utilization and workload in the shift, taking into consideration the following conditions:

- Container distribution by loading/discharge port;
- Container spreading over yard during the loading of vessel;
- Crane-split and workload (working the vessel with more than one crane);
- Vessel stability (weigh distribution), both transversal and longitudinal;
- Mandatory plan for special units (refrigerated and dangerous containers).

Horizontal transport vehicles receive their missions and follow the vessel's loading plan, bringing all containers near the base of the quay cranes, looking for the maximum crane utilization reachable. The horizontal transport can be done by specialized non-passive vehicles (like the modern straddle carriers, detailed on item 3.2.3) or by any type of passive vehicle, described below.

- Port tractor vehicles (prime movers):

These truck-like vehicles passively receive a container from a crane or a non-passive vehicle and transport it from stocking area to quay (or vice-versa). In certain cases, it's possible to have one tractor carrying more than one container. Table 14 shows advantages and disadvantages in the use of prime movers for yard horizontal transport.

ADVANTAGES	DISADVANTAGES
Small investment needed	Low capacity
Low labor cost	Low productivity
Low labor capacitation	

Table 14 – Advantages and disadvantages of port tractors (prime movers)

Figure 14 shows a container being loaded onto a prime mover at the Port Klang, in Malaysia [24].

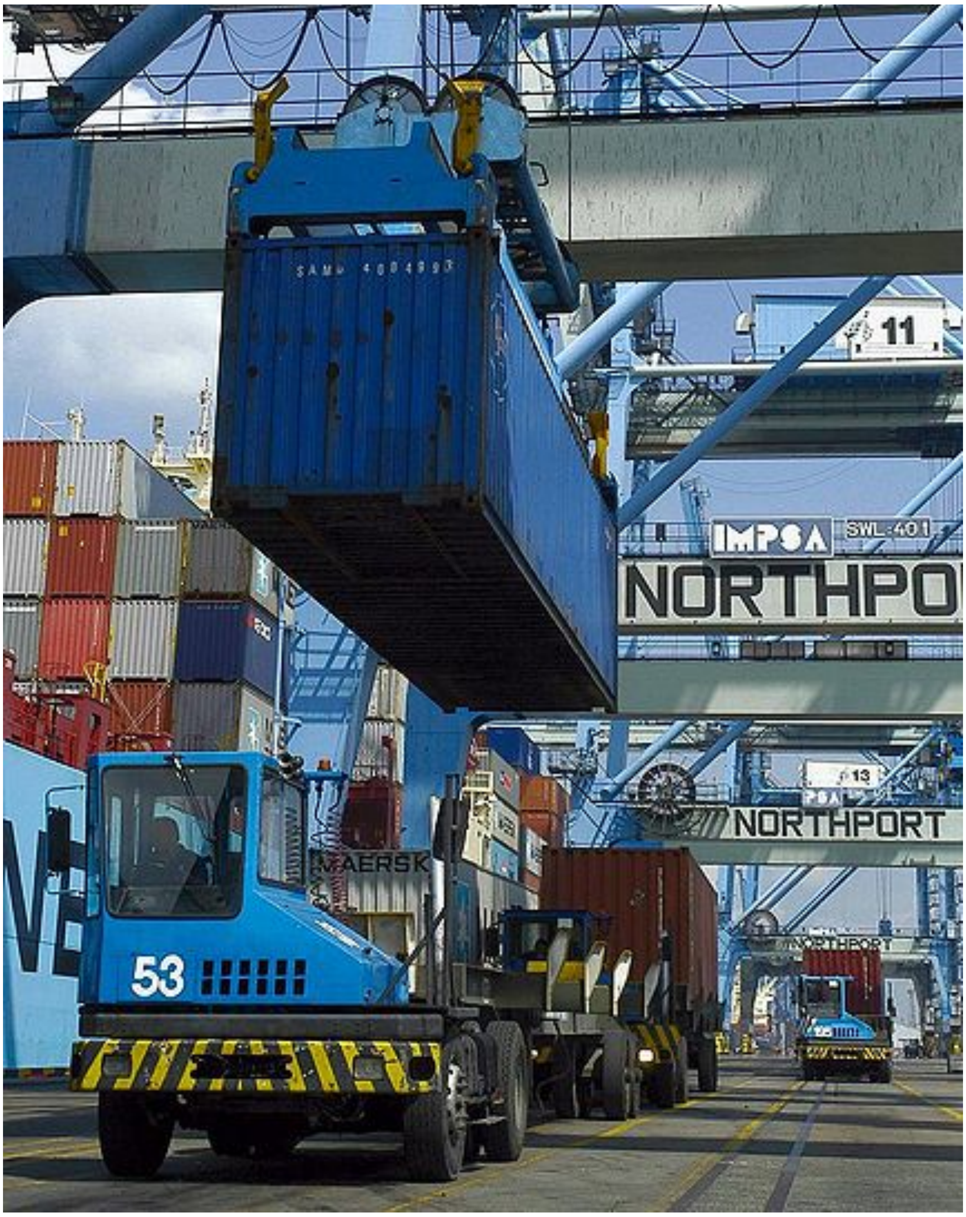

Figure 14 – A prime mover during yard operation

- Automated Guide Vehicles (AGV):

AGVs were developed used for the first time in Rotterdam, Netherlands (Maasvlakte II) [17]. These vehicles transport cargo from storage yard to quay (and vice-versa) in a fully automated way: no drivers are needed. A system of markers under the pavement (electric wires or transponders) guides them through the yard. Although they can be faster than port tractors, they usually go slow for security matters. The most modern types (called Lift AGVs) are even able to raise containers from a rack (beside the stacking cranes), transport them to waterside.

AGVs have come to great results, but they require a considerably high investment and maintenance effort. Table 15 sums up the main advantages and disadvantages of Automated Guide Vehicles applied to container terminals.

ADVANTAGES	DISADVANTAGES
Almost no labor cost	Requires large investment
High productivity	Needs often maintenance
	Complicated equipment

Table 15 – Advantages and disadvantages of AGVs

Figure 15 shows AGVs receiving and transporting containers at the terminal of Altenwerder, Hamburg, Germany [25].

Figure 15 – AGVs in operation in Hamburg, Germany

No matter how horizontal transport is done at a terminal, the main goal is always the same: to provide and to take away containers to/from the one or more quay cranes.

The number of quay cranes is balanced with the number of horizontal transport vehicles. A preset number of them serve each quay crane in an organized way; so available containers for loading are not too few or too many. The number of vehicles can be big or small, depending on terminal dimension, stacking layout and horizontal transport planning.

The number of available quay cranes can influence load/unload operation speed. Cranes are assigned to individual vessels according to their capacity, availability in each time slot and contractual agreements with the lines. Proper planning of loading/unloading operations are fundamental for achieving a great impact on OPEX. All types of cranes require a very high CAPEX investment, which has to be balanced by OPEX reduction.

The main types of quay cranes are:

- Ship-to-shore (STS) gantry crane:

  Ship-to-shore gantry cranes are designed with a rigid structure and move containers from ship to quay (and vice-versa) on a straight line. Cargo travels along the arm of the crane and operator commands operation from the same height. Cranes move sideways on a rail, serving vessels at a chosen position. Figure 16 [17] shows the details of a typical single trolley quay crane and Figure 17 [17] shows the functioning of three different types of STS gantry cranes (single trolley, twin trolley and dual trolley).

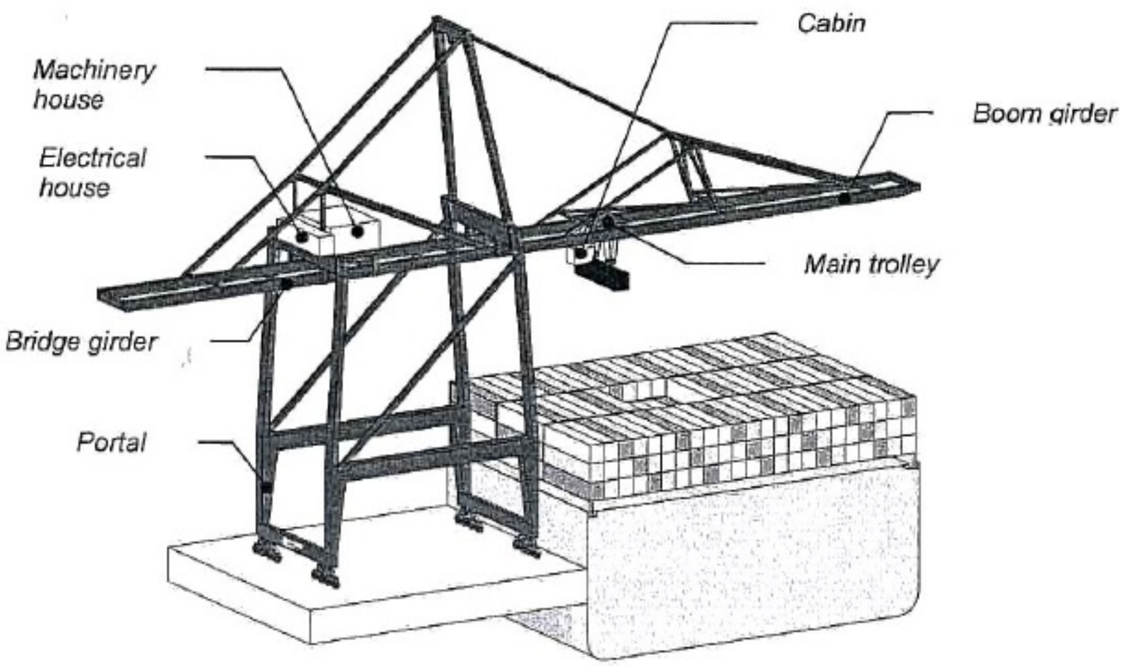

Figure 16 – A model of a single trolley STS crane

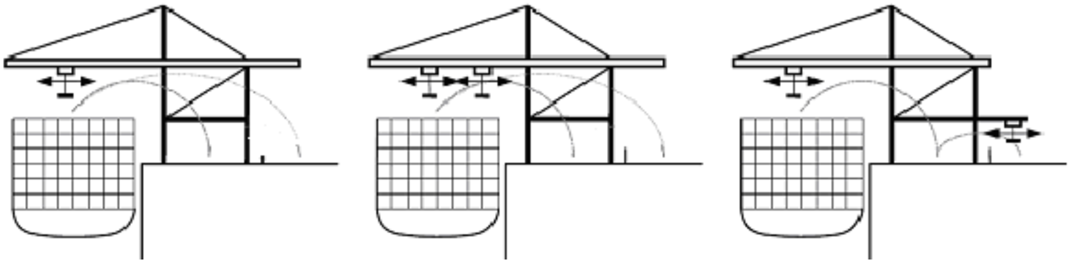

Figure 17 – Single trolley, twin trolley and dual trolley STS cranes

Dual trolley cranes allows a higher productivity in comparison with the standard single trolley cranes. Equipped with two trolleys, the crane can move a container out of the ship while loading or unloading horizontal transport equipment. A similar performance can be achieved with a twin trolley STS crane. These high productivity quay cranes are suitable to modern container terminals that are able to constantly feed the machines and maximize their utilization.

Table 16 lists the main advantages and disadvantages of quay cranes, while Table 17 [17] indicates technical details of a Kalmar STS crane (Nelcon) model.

ADVANTAGES	DISADVANTAGES
Limited space between cranes	Requires skilled operators
High productivity	Needs maintenance often
High capacity	Needs high investments

Table 16 – Advantages and disadvantages of STS cranes

PARAMETER	PERFORMANCE
Outreach	47 m
Rail span	30.5 m
Back reach	15 m
Hoisting height of spreader above top rail	32.3 m
Hoisting height of spreader beneath top of rail	32.3 m
Max. hoisting/lowering speed with 50 tons on ropes	60 m/min
Max. hoisting/lowering speed with 15 tons on ropes	120 m/min
Max. trolley travelling speed	60 m/min
Max. gantry travelling speed	5 m/min

Table 17 – Technical details of a typical STS quay crane

- Mobile harbor crane (MHC):

MHCs move on wheels and don't have horizontal and fixed arms. They offer a lower productivity in comparison to STS cranes (around 15 containers per hour against 30 to 40 on STSs [17]). But they are also simpler and definitely cheaper. MHCs' highlight is their large back reach. Because of this characteristic, they are capable of carrying each container directly to a transfer point on the yard, decreasing the need of horizontal transport vehicles.

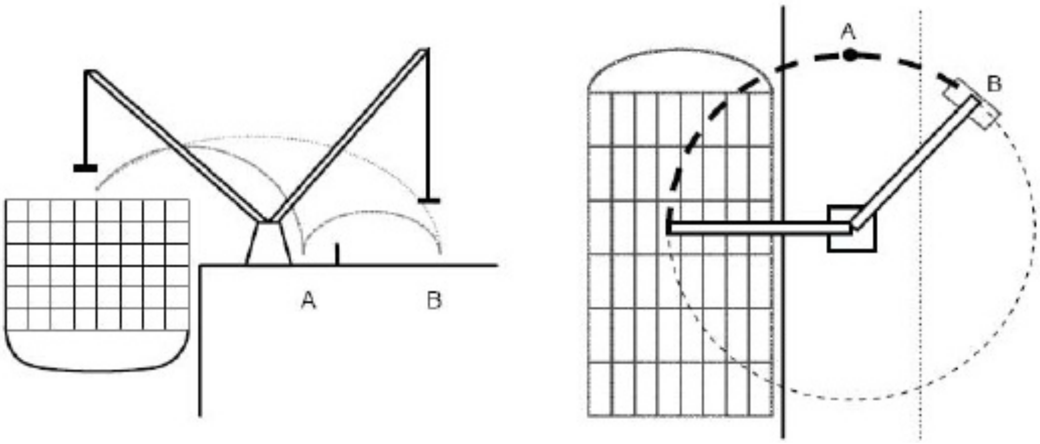

Figure 18 – The back reach of a typical MHC

Figure 19 – The model of a Mobile Harbor Crane

Figure 18 [17] illustrates the flexibility and the range of a MHC's back reach and Figure 19 [26] shows the model of a modern Liebherr MHC, designed for the Port of Antwerp in 2011. Table 18 relates the main advantages and disadvantages of MHCs. Table 19 lists technical details of a typical MHC, based on the model HMK 260 (Gottwald) [17].

ADVANTAGES	DISADVANTAGES
Limited space between cranes	Requires skilled operators
High productivity	Needs maintenance often
High capacity	Needs high investments

Table 18 – Advantages and disadvantages of MHCs

PARAMETER	PERFORMANCE
Capacity heavy lift	100 ton
Standard lift	45 ton
Hoisting/lowering	85 m/min
Travelling speed	80 m/min
Above ground level	36 m
Crane productivity	15 moves/h

Table 19 – Technical details of a typical MHC

- <u>Wide span crane (WSC)</u>:

WSCs are suitable for small terminals, where yard area is scarce. These cranes are substantially wider than other types of cranes and they allow container stacking underneath one crane span. Avoiding an intense need of horizontal transport vehicles. See Figure 20 [17].

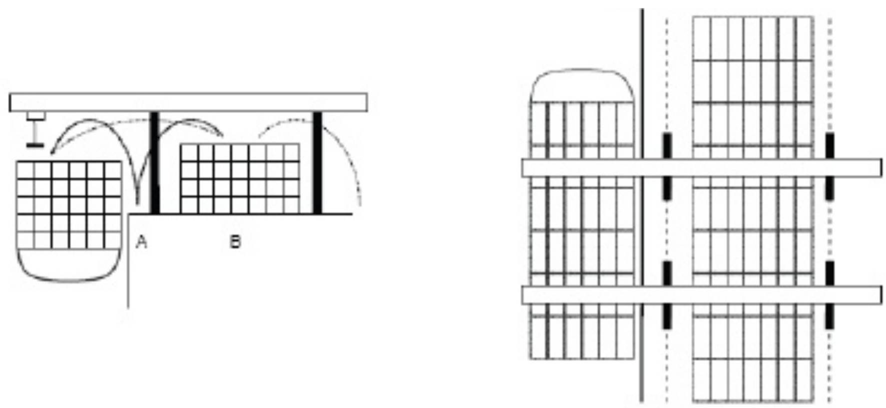

Figure 20 – WSCs allow stacking under the crane itself

Due to this feature, WSCs have a much shorter cycle during loading and unloading operations. Therefore, there's an increase on productivity. Table 20 summarizes technical information of a typical model of WSC (by Liebherr).

PARAMETER	PERFORMANCE
Lifted load	40 ton
Outreach	30 m
Rail span	48 m
Back reach	16 m
Hoisting speed	40-100 m/min
Trolley speed	180 m/min
Gantry speed	120 m/min
Handling capacity per crane	100,000 TEU/year

Table 20 – Technical details of a typical WSC

Table 21 advantages/disadvantages of WSCs.

ADVANTAGES	DISADVANTAGES
Compact	Not so flexible
Skips horizontal transport	Not suited for big terminals

Table 21 – Advantages and disadvantages of WSCs

As explained, ship planning is a very complex task to plan, full of variables (type and number of horizontal transport vehicles, stacking layout, type and number of quay cranes, infrastructure to host quay and yard machines, sequence of loading/unloading containers, communication between TOS and vehicles/cranes and many more). Is has to be planned by an expert in order to avoid wrong investments, waste of resources and a low reduction of OPEX.

3.2.5 SCANNERS

Some containers must be scanned before they are loaded into a vessel. For example, from July 1st, 2012, one hundred percent of units heading to the United States of America must be scanned for security reasons [13].

Scanning may also be applied for other reasons, such as manifest verification and the identification of contraband. In these cases, terminals must be equipped with a radiography system and a radiation detector.

Figure 21 – An example of an x-ray terminal station

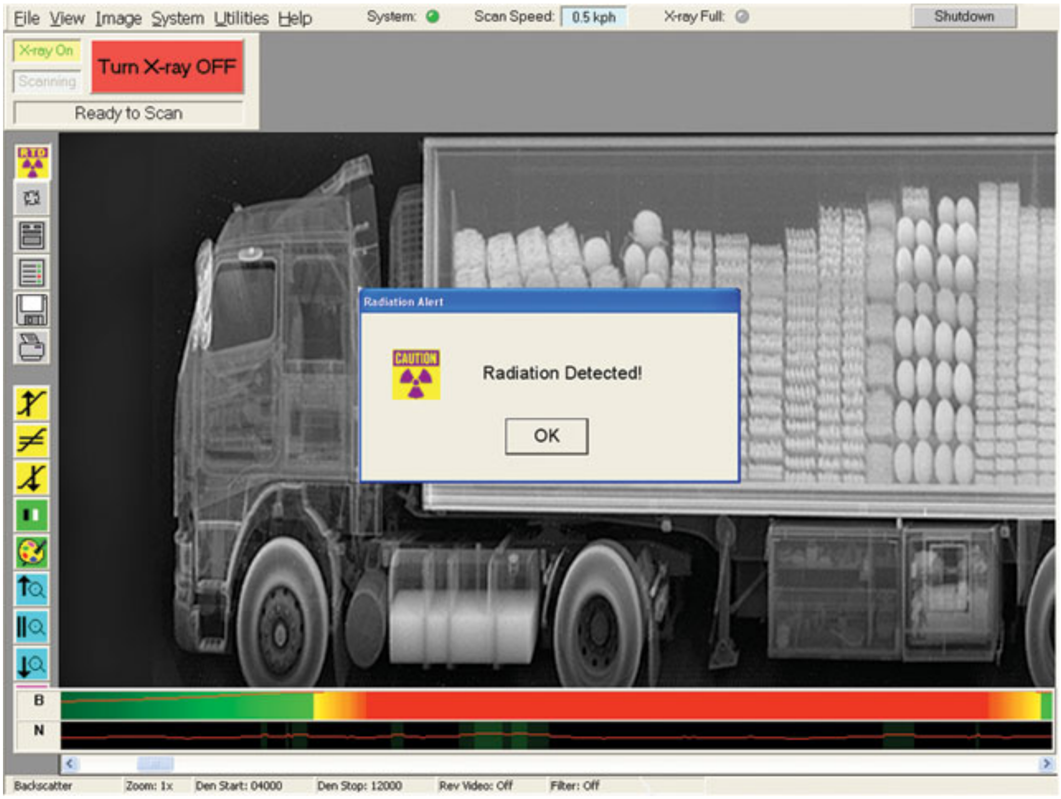

Figure 22 – Radiation detection inside a shipping container

Figure 21 shows a truck going through a Container/Vehicle x-ray inspection system and Figure 22 [14] shows a positive result obtained at an anti-radiation container inspection.

Before entering the gate, the TOS identifies the need of cargo scanning and send truck to X-ray/radiation portal before the freight is left at the designated position.

3.2.6 OTHER ASSETS

So far, topic 3 has covered the acquisition of TOS, cranes, non-passive vehicles, horizontal transport vehicles, communication terminals, softwares interfaced with TOS, OCR and scanning system.

These acquisitions must be followed by other small purchases and restructuration: computers, other container-handling vehicles and infrastructure of control rooms, offices, gate, berthing canals and access to terminal.

If the terminal decides to operate on FULL-RTG (meaning, working exclusively with RTG cranes), the ground has to be prepared for that. RTG cranes are amazingly heavy and their weight is concentrated on the rubber tires. Grounds made from materials like asphalt may not support the pressure and may require frequent maintenance interventions. For that, the yard has to be fully covered by cement and it must be as flat as possible.

Another purchase to be considered is land. Adding more yard space to terminal may be convenient to face growing demand. However, for many ports this is not possible due to their geographic location or local legislation.

3.3 COMMUNICATION BEYOND TERMINAL

The TOS should be able to communicate in an automatic mode (like EDI) with all agents involved in the contained handling process. This doesn't depend only on the top management team of the terminal. It also depends on investments of:

- Customs;
- Port authority;
- Government systems (such as immigration, legislation and security department);
- Ship-owners;

- Agencies;
- Importers;
- Exporters;
- Banks and others.

Having an efficient communication with the outside of terminal is highly beneficial. The Port of Singapore (a govern-owned port) invested over U$50 million to interconnect all entities related to their operations and the average waiting time to release goods from bureaucracy dropped from 3 days to less than one hour [6].

4. AUTOMATION COSTS

Automation of terminals involves high cost of investment (CAPEX), but is compensated by the decrease in operational costs (OPEX). By developing its infrastructure, terminal capacity is increased and OPEX decreases due to the rise in offer.

For example, in 1993, the average cost of moving one container at the Port of Santos, Brazil, was around US$500 [15]. According to ANTAQ (Brazilian National Agency of Water Transport), in 2009 the same cost had dropped to about US$170 [16], on average, after improvements in infrastructure (detailed cost for each terminal is consultable on Attachment A).

Usually, ports that contain more than one terminal operate on more competitive prices and therefore benefit the ship service lines and users in general.

Before understanding how much the OPEX of a container terminal can be reduced with investments on automation, it’s important to point out what constitutes the Operating Expenditure.

First of all, OPEX can be divided in fixed and variable costs.

The first ones don’t depend on the level of service produced by the terminal. No matter how many ships berth each month or how many shifting moves were required at the yard, the fixed costs remain the same. Nevertheless, fixed costs are not permanently fixed; they could change in the long term. They are fixed in relation with the quantity of service during a determined period of time. Examples of fixed costs at a terminal are listed below.

- Port tariffs (due to dock dredging, signalizing and other maintenance services);
- Government taxes (those not related with service level);
- Salaries (except operators that are directly proportional to service need).

The second category, variable costs, refers to all expenses that are related to the service level of the terminal. They are flexible and easily vary in order to provide different levels of service. Variable costs can also change in the short term and thus constitute a wide acting scenario for automation to optimize.

Variable costs of a container terminal can be divided into two groups:

- Entry and exit of vessels;
- Container handling;

The first group covers all operations related to maneuverability, mooring, undocking and security of vessels. The total arrival cost of a vessel can reach up to U$14.000 [15], partially explained by the high risks involved in the mooring operation. Improvements on quayside, berth and access canals can reduce risks and costs of this task. The service of maneuvering vessel can represent 50% of the total cost of vessel arrival [15]. The terminal, depending on the country, might not be responsible for all operations related to entry/exit of vessels.

The second group is undoubtedly the most important one in terms of automation possibilities and OPEX reduction. It includes the number, the fuel used by machines, electricity, all material on operations, human resources (these may represent up to 60% [15] of total cost for container handling) and other related costs.

Automation can reduce the total number of yard operators and the total driven distance on yard, minimizing the cost of container handling. One possible obstacle can be unemployment legislation, due to the fact that part of the less specialized jobs is cut down.

The big dilemma for the automation manager is: “by how much OPEX should be reduced, in order to balance CAPEX investments on automation”.

In other words: “will the terminal obtain a positive Net Present Value (NPV), if discounting the generated free cash flows with the cost of capital, taking in consideration the initial investment”?

The equation showed on Figure 23 has to be true in order to have investments on automation worth and approved [27].

$$NPV = \left[\sum_{t=1}^{T} \frac{X_t}{(1 + WACC)^t}\right] - INVESTMENT$$

Figure 23 – Formula for the Net Present Value

Where:

- T = time horizon (in years);
- X_t = Operating cash flow at year t;
- WACC = Weighted Average Cost of Capital (it's an appropriate discount rate for the cash flows an it is the requires return of the terminal as a whole).

Another criterion that might be interesting to apply is the concept of Return on Investment (ROI). A high ROI means high returns that investors will get by financing a project. Figure 24 shows the formula for the ROI estimation.

$$ROI_t = \frac{NI_t}{Inv_t}$$

Figure 24 – Formula for the Return on Investment

Where:

- ROI_t = Return on Investment on year t;
- NI_t = Net income after tax on year t;
- Inv_t = Investment on year t.

If both methods bring to different results, it's usually the NPV the safest one.

The break-even point, or payback time, is the instant of time where 100% of investments were finally paid back by the accumulated cash inflows of the terminal. From break-even point on, cash inflows are profits that shall even be reinvested.

The investment needed to implement an automation project in a terminal varies according to some major factors:

- The choice of TOS:

There is a wide range of prices when it comes to TOS. A software like Jade™, which is not expensive (despite being a well known program), costs hundreds of thousand U.S. dollars (around US$500,000). They are not ideal, though, for terminals of huge dimensions. Probably the most expensive and powerful software, Navis™, can cost up to several million U.S. dollars (from US$1,000,000 to US$13,000,000, according to interview staff of the port of Genoa).

The prices are not fixed. The implementer sets the price according to terminal's dimension and situation. The price of a TOS includes an internal consultancy done by the implementer and all implementation processes, in every level.

- The need of new machines:

Container handling machines are not cheap. The type and number of vehicles needed determines how much more implementation can cost. Based on numbers provided by Erasmus University Rotterdam [27] and other reliable sources [28] [29] [30], it's possible to build Table 22, listing the estimated average equipment cost for the terminal (considering that €1.00 is worth US$1.26).

EQUIPMENT	COST PER UNIT (US$)
Rubber Tyred Gantry Crane (RTG)	1,500,000
Rail Mounted Gantry Crane (RMG)	3,000,000 + 12,000/m (rail work)
Automatic Stacking Crane (ASC)	2,500,000
Reach Stacker	400,000
Forklift Truck	300,000
Straddle Carrier	250,000
Port Tractor Vehicle	40,000
Automated Guided Vehicle (AGV)	500,000
Ship-to-Shore Gantry Crane (STS)	8,000,000
Mobile Harbor Crane (MHC)	5,000,000
Wide Span Crane (WSC)	8,500,000

Table 22 – Average cost of terminal equipment

- Changes on terminal infrastructure:

If there's a need to change current structure, cost of implementation will be even higher. For example, if terminal has chosen to became Full-RTG (using

RTG cranes to handle 100% of their container moves on the yard), it's convenient to have the yard ground made of cement. Other types of pavement, like asphalt, may not support the highly concentrated pressure under the cranes and might require frequent maintenance interventions (of yard flattening). Preparing for Full-RTG a yard area may cost up to US$80 per square meter, according to an interviewed operation manager of the Port of Genoa, Italy.

Another expensive infrastructure is the quay wall. It's built in enormous dimensions and the cost can reach up to US$82,000 per meter [17] (HPA, 2008). The cost of an eventual land extension depends on the country and on the port's surrounding area.

Even though estimations of cost can be made, each single cost may vary significantly from one port to another, depending on some factors like:

- Labor cost;
- Type of soil;
- Development of the country;
- Size of terminal;
- Technical specification of the crane/vehicle;
- Manufacturer/quality;
- Manufacturing costs (variation between countries);
- The size of an order (economies of scale).

Therefore, a deep consultancy has to be made prior to any decision. Every relevant detail of the port has to be taken into consideration in order for terminal managers to be able to answer the big dilemma.

5. A CASE STUDY: GENOA, ITALY

5.1 PORT OF GENOA

Among the largest ports in Italy, the Port of Genoa is the gateway to Central and Southern Europe. Favored by its strategic geographic position (Figure 25), it's placed at the heart of an important industrial and commercial area. The port hosts vessel service lines coming from all over the world: South and North America, Middle East, other locations within the Mediterranean Sea and the Far East. Genoa is the first Italian port in terms of overall handling [35] and it's among the first Mediterranean ports of final destination of containerized transport.

Figure 25 – Geographic position of Genoa and other main European ports

According to American Association of Port Authorities [32], Genoa is the second largest port in Italy in terms of volume containers handled (see Table 23). The only Italian port that is capable to handle more TEUs per year is Gioia Tauro, at the south of the country. The third largest port, La Spezia, is located in the same geographical location as Genoa (just 100 km away) and form the same access way to Central and Southern Europe. The three of them are among the world's 100 largest container ports (ranked 39, 68 and 85, respectively), according to 2010 data [32].

RANK	ITALIAN PORT	VOLUME 2010 (MILLION-TEUS)
1	Gioia Tauro (Calabria)	2.85
2	Genoa (Liguria)	1.76
3	La Spezia (Liguria)	1.29
4	Leghorn (Tuscany)	0.63
5	Taranto (Puglia)	0.58

Table 23 – The five largest container ports in Italy

The position if Genoa allows service lines to reach Central European land in a much shorter travel time. A vessel coming from the Far East takes on average four days less to reach Genoa than going all the way around until Rotterdam, as summarized on Table 24 [31].

ROUTE	AVERAGE DURATION
Far East → Rotterdam	17 days
Far East → Genoa	**13 days**
India → Rotterdam	13 days
India → Genoa	**9 days**
Mid East → Rotterdam	12 days
Mid East → Genoa	**8 days**

Table 24 – Routes' duration to Ports of Genoa and Rotterdam

Automation has been taking place in the last years, in different terminals. Port's performance has gone from 1.5 million TEUs, in 2001, to 1.8 million TEUs, in 2011, obtaining a 20% growth on operations even going through the years of 2008 and 2009, the worst period of the current financial crisis. Figure 26 [33] shows the evolution of the port over the last decade.

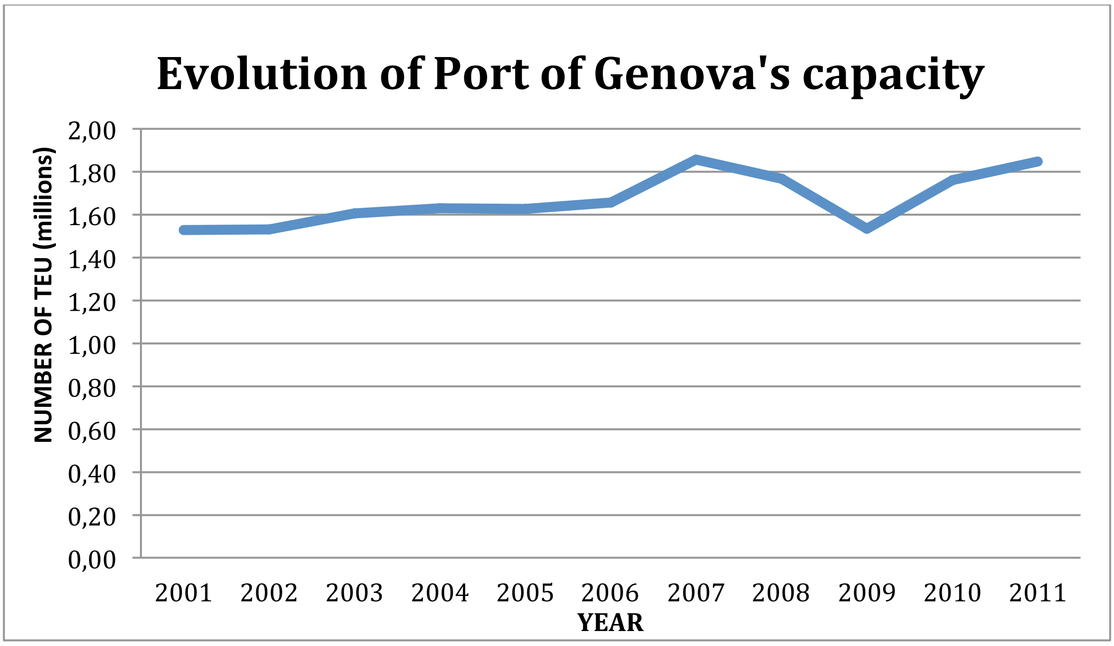

Figure 26 – The evolution of Genoa's capacity over a decade

Several different terminals, run by different companies, form the Port of Genoa. It is adequate to receive passenger cruises or any kind of cargo carrier (including container ships and solid/liquid bulk carrier).

The terminal of interest for this case study is one of them: *Voltri Terminal Europa* (VTE). It is run by the PSA group (Port Authority of Singapore) and it's the largest container terminal in Genoa [34]. A deep study of the terminal's current scenario will be shown on item 5.2 ahead.

5.2 VTE: CURRENT SCENARIO AND CHALLENGES

Voltri Terminal Europa is the biggest container terminal within the port of Genoa and one of the most efficient of the Mediterranean Sea [34]. It's run by the acknowledged and specialized PSA group, in charge of 29 terminals in 17 different countries all around the globe. Together, these terminals employ around 26.000 STAFF and they handled 57.1 million TEU in 2011, 65.1 million TEU in 2010 and 56.9 TEU in 2009 [31].

VTE is well connected to hinterland both by rail and road. The seaside has a 700-meter wide turning basin and a depth of 15 meters, large enough to receive the mooring of very large containerships. Figure 27 shows the terminal connection facilities from above.

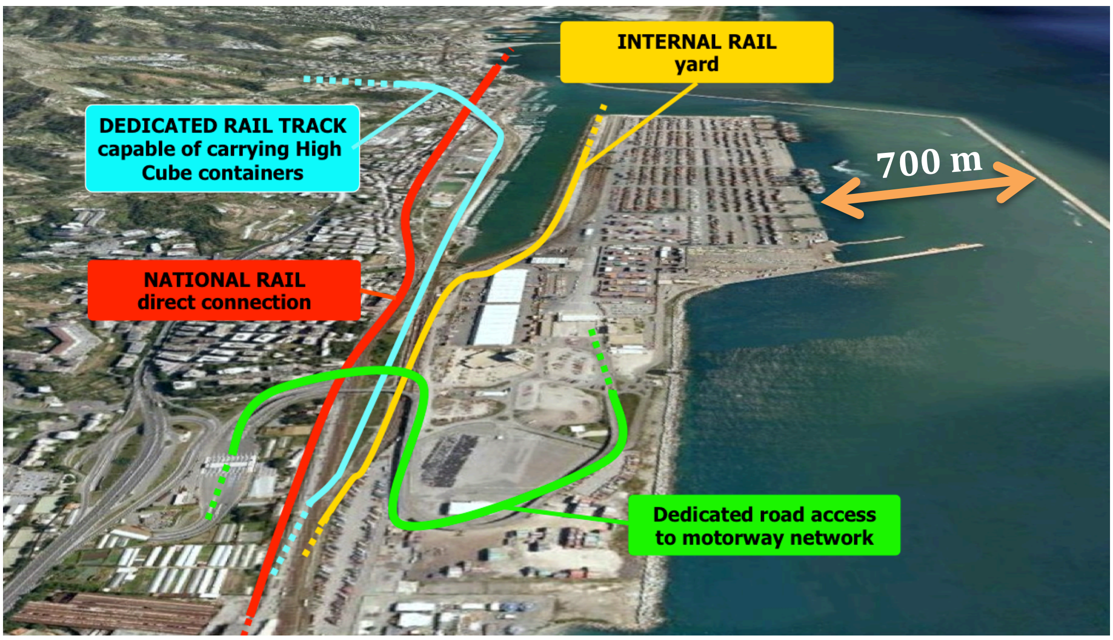

Figure 27 – Hinterland connection facilities of VTE

The biggest vessel ever moored at the Port of Genoa arrived at VTE on the 2nd of May 2012. It's the gigantic CMA CGM Titan (capacity of 11.000 TEU) that operates for the service Mediterranean Club Express (CMA CGM and Maersk Line).

VTE operates around the clock: 24 hours a day, 7 days a week, 363 days a year. 350 multi-skilled yard employees work alternately in four 6-hour shifts. The terminal has 680 direct employees, including an experienced management and operational team. External manpower is hired to cover demand on peak periods.

The level of container handling is currently around 1.3 million TEU, according to interviewed internal personnel.

To attend world's growing demand, the terminal must invest continuously in equipment and technology. The need to improve infrastructure and productivity is real. However, some obstacles might hamper the terminal development and these must be, somehow, overcome.

Below, different factors of VTE's current situation are explained and obstacles are discussed in order to point out why the terminal is specially challenged to maximize its capacity.

5.2.1 AREA AND LAYOUT

VTE has a terminal area of 110 hectares (1,100,000 m^2), equipped with 15,000 ground slots, 800 reefer slots and 1000 dangerous slots (DG) [31].

The yard is divided in 6 modules, as shown in Figure 28.

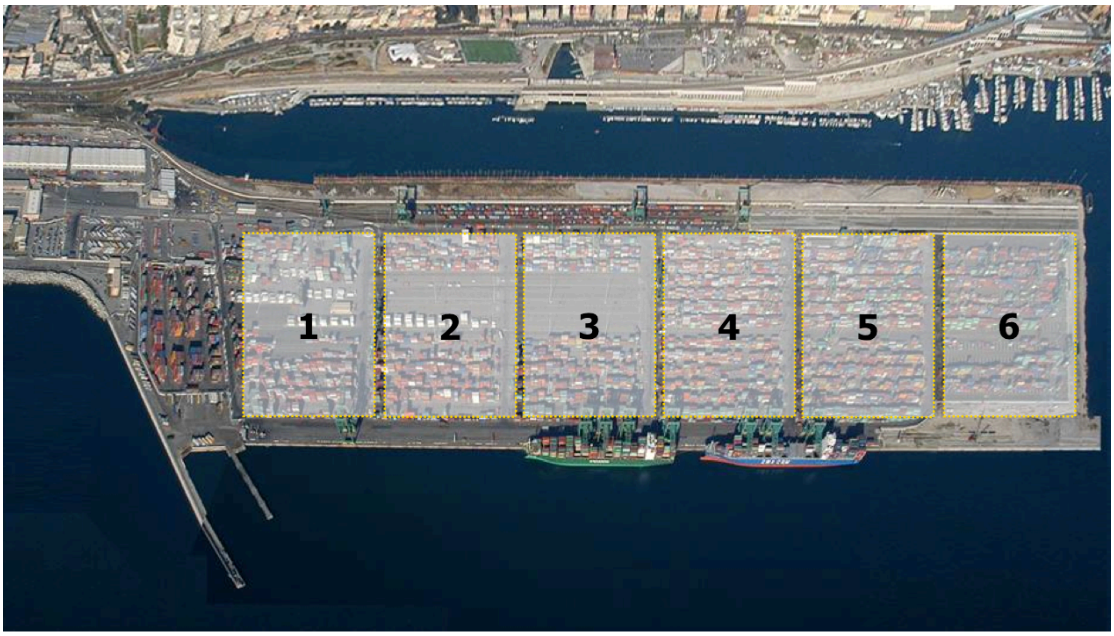

Figure 28 – Macro division of VTE terminal area

An area of 40,000 m^2 is designated for empty container stacking, providing about 5,000 slots. The same are also hosts various maintenance and repair services. Office space utilizes 7,000 m^2 of area. 2,500 m^2 are reserved kept for truck services. The distribution of the designated areas is indicated in Figure 29, as well as how each of the six modules is subdivided into import and export stacking area.

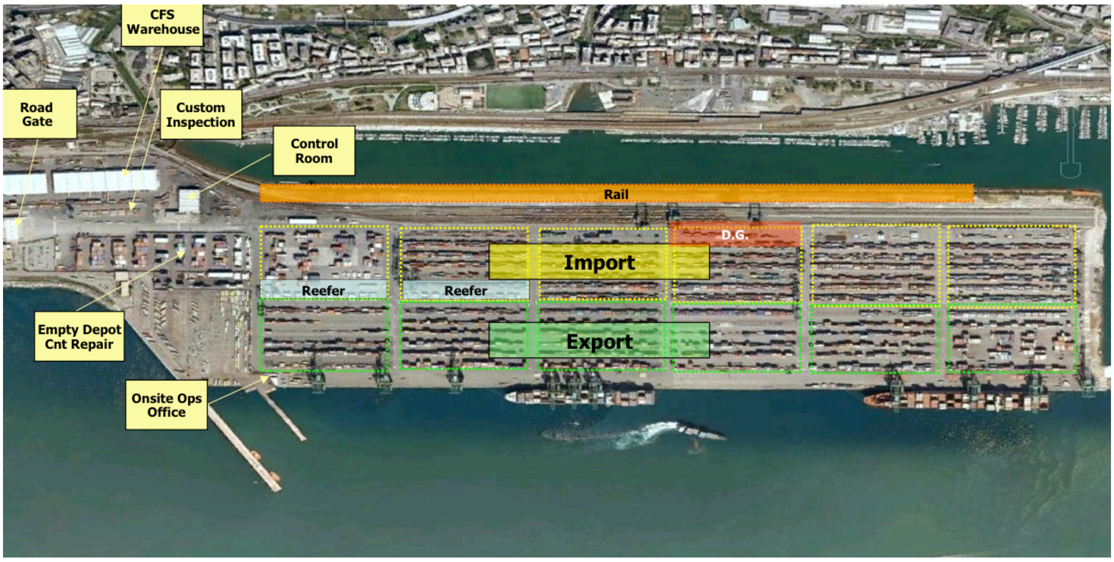

Figure 29 – Macro division of VTE terminal area

In order to increase capacity, expanding current area would normally be a possible solution. However, gaining more are seems physically impossible for VTE, due to the following local obstacles:

- The land behind the terminal is not flat. It's actually the first formations of the Alps, one of the great mountain range systems in Europe. Therefore, it's impracticable to grow backwards.
- Growing sideways is also impossible, due to security legislation of Genoa's airport (Cristoforo Colombo), which is located less than 2 km from the yard. The airport has set an inverted-conic-shape aerial space around itself, below which it's strictly forbidden to build anything. Actually, by being so close to the airport, the terminal is already under some height restrictions (of quay cranes, for example that may invade the security limits if the are too high).

- Having an inland separated stocking area connected to the port is also quite a difficult solution for VTE, once there is no available near-by area with flat connection to the terminal. Port of La Spezia, for example, is under similar restrictions on land expansion, but it can manage to store containers in a large area less then 10 km from the port, with flat convenient connection.

For these reasons, VTE is not able to horizontally expand its terminal area and is specially challenged to optimize the usage of current area through operation plan and control, stacking density and technology.

5.2.2 EQUIPMENT

TVE's quayside is well equipped with 10 STS quay cranes (8 Post-Panamax of 16 rows each and 2 Super Post-Panamax of 18 rows each). Two more Super Post-Panamax cranes were already ordered and should start operating within the next three months [31].

20 RTG cranes (16 RTGs of 6 rows each, 1-over-4 containers; 4 RTGs of 6 rows each, 1-over-5 containers), 24 reach stackers, 4 front loaders for empties and 63 prime movers are constantly available for yard operations. Besides that, 3 RMG cranes are dedicated to handle rail operations (8 rail tracks, each one 950 m long) [31]. All vehicles communicate with TOS via radio (built-in VMT).

The total investment on equipment, over the years, is estimated by Table 25.

EQUIPMENT	PRICE* PER UNIT (US$)	UNITS ACQUIRED	INVESTMENT ON EQUIPMENT (US$)
Quay crane	7,619,000	10	76,190,000
RTG crane	1,520,000	20	30,400,000
RMG crane (+ rail)	6,000,000	3	18,000,000
Reach stacker	550,000	24	13,200,000
Front loader	300,000	4	1,200,000
Prime mover	40,000	63	2,520,000
IT	1,000,000	---	1,000,000
---------------- TOTAL INVESTMENT ----------------			**142,510,000**

Table 25 – VTE investment on port equipment over the last years

* Average price paid per unit by the terminal (according to interviewed operation manager of VTE).

The access gate offers 12 different computer-assisted lanes. It's capable of handling over 2,000 trucks a day. In 2010, more than 50% of trucks spent less than 30 minutes from gate in to gate out [31]. Gate workers quickly check containers' and trucks' identifications and share with the TOS via radio (through a HHT). The TOS tells assigns a slot of destination for the truck.

A detailed list of VTE equipment is provided in Attachment B.

New investments on equipment may be done to improve productivity even more, respecting existing constraints from choices already made in the past (such as macro-type of cranes) and from the physical space (such as airport height restriction and fixed yard area).

5.2.3 TOS

The Terminal Operating System used by VTE is called COSMOS. All internal departments communicate efficient between them and with the TOS.

The One Stop Office uses CTCS application (see Figure 30 for screen shot) for both booking and for trucker desk [36]. It sends and receives internal and external information using mainly EDI.

Gates also use CTCS application and Hand-Held Terminals, both systems in direct contact with the TOS.

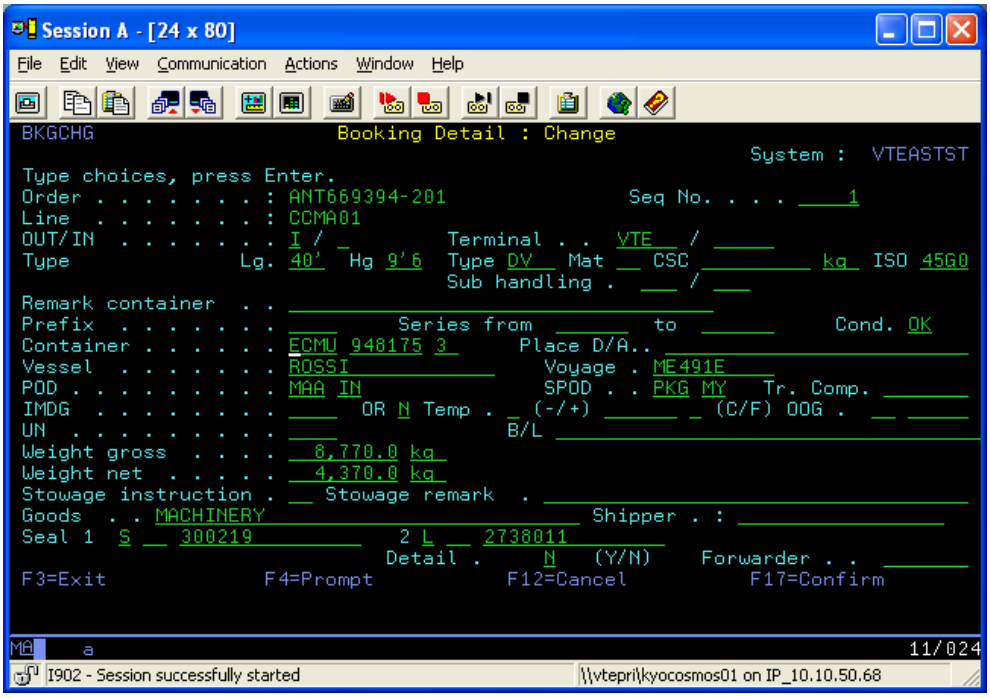

Figure 30 – Screen shot of the application CTCS

Yard Planning Office manages all stacking strategies using the application SPACE (see Figure 31 and Figure 32 for screen shots). The program splits containers (by import/export, size (20’/40’), service, vessel, port and weight class) in a way that it minimizes the number of shifts during yard operations.

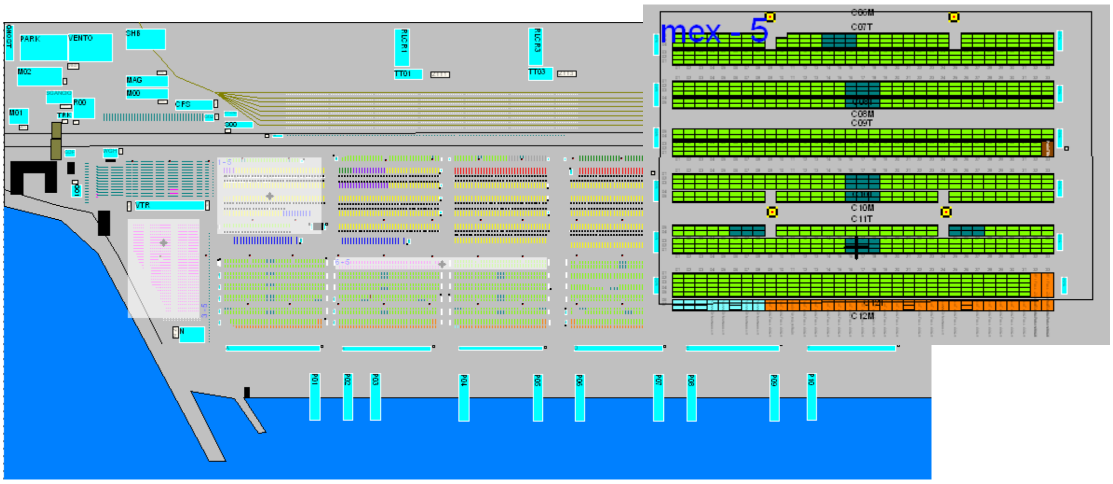

Figure 31 – Screen shot #1 of the application SPACE

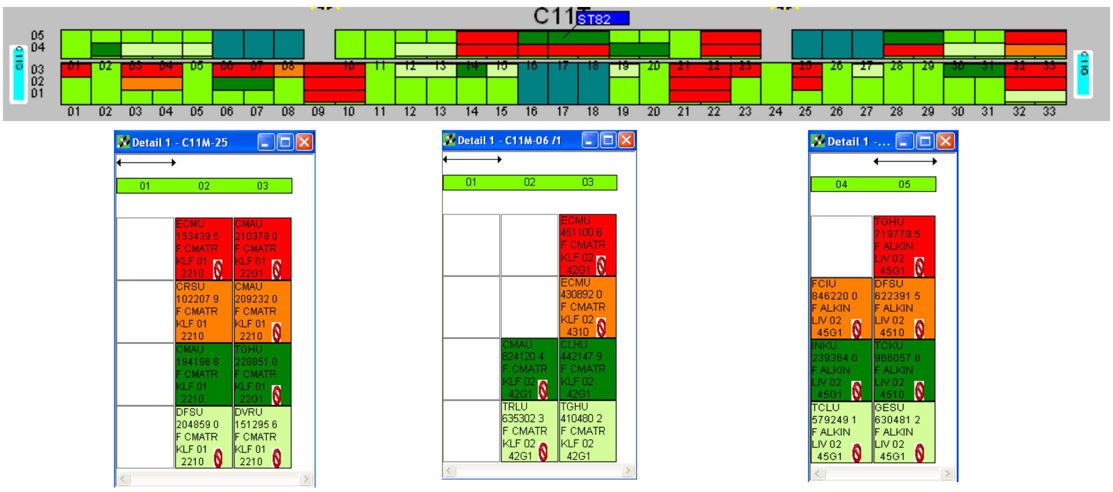

Figure 32 – Screen shot #2 of the application SPACE

SPACE is also in constant and direct contact with COSMOS.

Ship Planning Office uses the application SHIPS (see Figure 33 and Figure 34 for screen shots) to create the best discharge and loading sequences, maximizing crane utilization and productivity. Sequences then migrate to TOS, which distributes single mission to workers using narrow-band radio technology.

The TOS is also in contact with external agents like the port authority and customs through the system E-port [37].

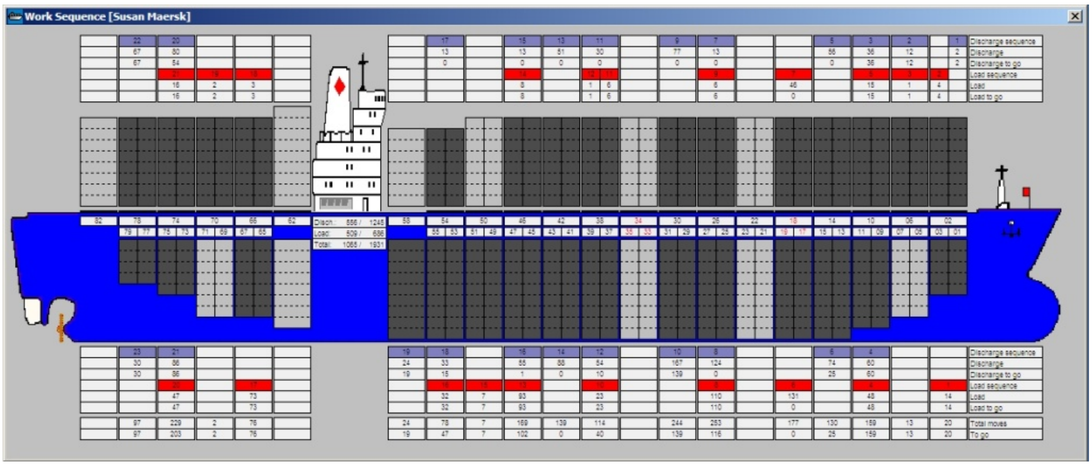

Figure 33 – Screen shot #1 of the application SHIPS

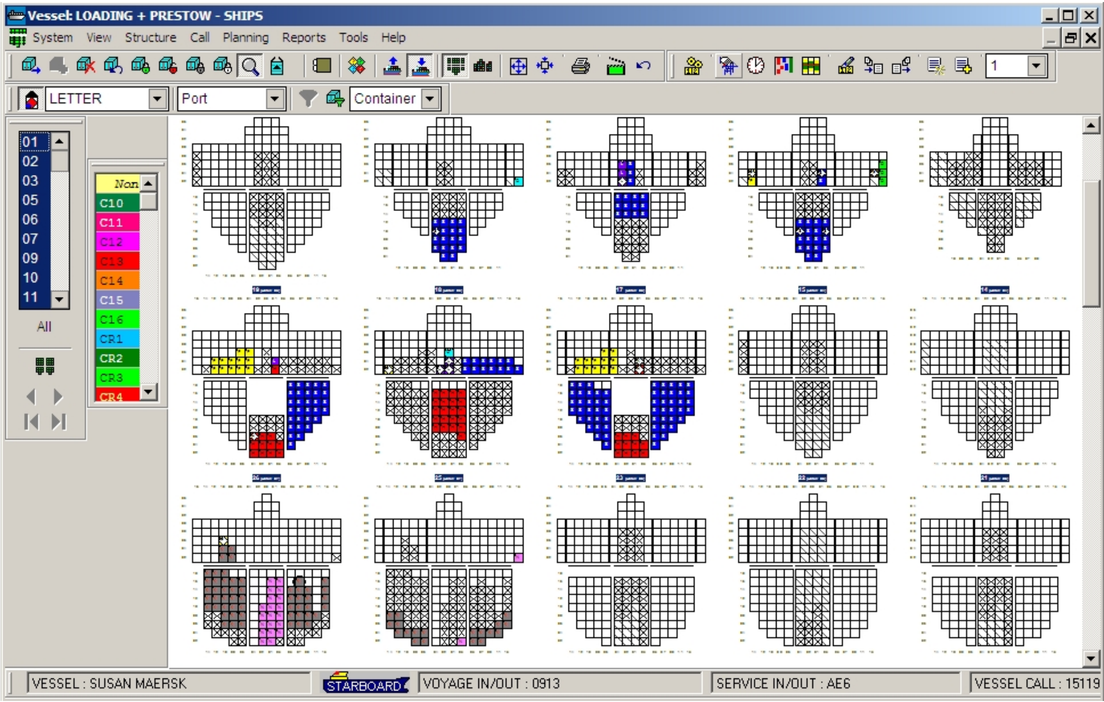

Figure 34 – Screen shot #2 of the application SHIPS

6. POSSIBLE INVESTMEN PLAN FOR VTE

Substantial investments and improvements have to be made in order to enhance VTE's capacity of handled volume of containerized cargo. However, physical land expansion is constrained by ports' vicinity. This leaves VTE with the challenge of increasing terminal capacity by improving internal processes and by acquiring better equipment.

Land expansion is not the only excluded solution for the terminal. Others follow:

- Separated stocking area in Hinterland;
- Change of software (unless absolutely needed);
- Complete change yard machines.

Most of containers handled by VTE are imports. For this type of market operation, the efficiency of marshaling yards and the transfer to landside transportation modals are particularly important. Thus, it's also convenient to develop a pre-announcement system for arriving trucks. This is being studied by VTE in partnership with the Port Authority and will soon become a reality.

A complete switch of technology (starting all over) might sound like a "dream solution", but that's not viable. Besides the tremendously high costs, is current trend of technology is completely ignored by managers, people may not be able to (or be willing to) work differently in order to break personal resistance towards innovation.

An suitable investment plan has been made in order to improve overall processes and enlarge terminal capacity from 1.3 million TEU do estimated 2.0 million TEU, a 54% increase (of 700,000 TEU). The plan involves the upgrade of the terminal into Full-RTG (using cranes for both import and export stacking areas). Consequently, it focuses on acquisition of new RTG cranes, remake of pavement on RTG lanes and an increment on technology. Total terminal investment is detailed on Table 26.

EQUIPMENT	PRICE PER UNIT (US$)	UNITS TO ACQUIRED	INVESTMENT ON EQUIPMENT (US$)
RTG crane	1,520,000	37	56,240,000
RMG crane	3,800,000	1	3,800,000
Pavement remake*	36,000,000	---	36,000,000
Components replacement	3,500,000	---	3,500,000
IT (software & hardware)	1,300,000	---	1,300,000
---------------- TOTAL INVESTMENT ----------------			**100,840,000**

Table 26 – VTE investment plan for increasing capacity by 54%

* Remaking the entire surface of the yard could cost up to US$90,000,000 (as the price can reach U$80 per square meter), which represents 89% of the total investment necessary for this project plan. Therefore, only 40% of the yard is being remade (sufficient to build lanes to serve all RTG cranes).

The plan includes the implementation of an Automated Gate System, AGS, on the twelve in/out lanes. Information will be handled by the application VGS, in direct contact with the TOS COSMOS.

Yard operations will also require a low human interference, once it will be simulated and optimized by the TOS.

With a total investment of US$100,840,000 necessary to increase terminal capacity by 700,000 TEU, the cost to add each additional annual TEU will be US$144.

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ATTACHMENT A

TABELA 28
Evolução dos Preços Médios Totais
Contêineres – 2005 a 2009

PORTO / TERMINAL	2005		2006		2007		2008		2009	
	R$/u	US$/u	R$/u	US$/u	R$/u	US$/u	R$/u	US$/u	R$/u	US$/u
BELÉM										
Cais Público	443,91	189,65	387,92	181,44	325,75	183,90	430,44	184,18	508,54	292,06
FORTALEZA										
Cais Público	396,54	169,41	375,21	175,50	429,23	242,32	360,04	154,06	432,21	248,23
IMBITUBA										
Cais Público	343,86	146,90	557,74	260,87	376,70	212,67	303,79	129,99	408,35	234,52
ITAGUAÍ										
Sepetiba Tecon	-	-	-	-	-	-	-	-	475,15	272,89
ITAJAÍ										
Cais Comercial	294,34	125,75	307,62	143,88	282,33	159,39	243,08	104,01	-	-
Teconvi	254,03	108,53	330,23	154,46	302,05	170,52	318,67	136,36	247,81	142,32
MANAUS										
Chibatão	427,93	182,82	-	-	-	-	-	-	295,69	169,82
SNPH	277,29	118,46	281,06	131,46	454,44	256,56	-	-	-	-
Super Terminais	401,90	171,70	512,82	239,86	461,53	260,56	465,74	199,29	308,59	177,23
NATAL										
Cais Público	181,59	77,58	-	-	411,05	232,06	411,06	175,89	397,74	228,43
PARANAGUÁ										
TCP	379,00	161,92	514,34	240,57	337,66	190,63	339,04	145,07	370,75	212,93
RECIFE										
Cais Público	-	-	-	-	-	-	-	-	-	-
RIO DE JANEIRO										
Libra	369,46	157,84	309,03	144,54	337,39	190,48	-	-	428,50	246,09
Multirio	356,79	152,43	341,94	159,93	323,77	182,79	351,26	150,30	442,20	253,96
RIO GRANDE										
Tecon	320,45	136,90	297,21	139,01	333,42	188,23	311,02	133,09	349,14	200,52
SALVADOR										
Cais Público	245,27	104,78	694,64	324,90	-	-	619,80	265,21	-	-
Tecon	216,31	92,41	300,20	140,41	401,85	226,87	296,17	126,73	238,81	137,15
SANTOS										
Libra (T35)	282,06	120,50	331,77	155,18	261,99	147,91	359,91	154,01	369,38	212,14
Libra (T37)	300,54	128,40	252,11	117,92	259,28	146,38	233,89	100,08	295,52	169,72
Cais Público	563,20	240,61	443,23	207,31	450,08	254,10	408,82	174,93	339,83	195,17
Tecon	215,98	92,27	189,45	88,61	227,50	128,44	240,37	102,85	256,12	147,09
Tecondi	495,76	211,80	446,42	208,80	238,74	134,78	238,11	101,89	298,26	171,30
SÃO FRANCISCO DO SUL										
Cais Público	239,08	102,14	329,43	154,08	284,98	160,89	312,53	133,73	412,00	236,62
Tesc	-	-	426,74	199,60	-	-	-	-	456,79	262,34
SUAPE										
Tecon	449,40	191,99	515,14	240,94	469,02	264,79	471,40	201,71	550,08	315,92
VILA DO CONDE										
Cais Público	-	-	497,51	232,70	483,59	273,01	390,44	167,07	417,08	239,54
VITÓRIA										
Capuaba	-	-	-	-	-	-	-	-	-	-
TVV	337,44	144,16	366,57	171,45	310,88	175,51	322,61	138,04	367,58	211,11
Média Nacional	338,79	144,74	391,67	183,19	352,87	199,22	353,72	151,36	376,79	216,40

Fonte dos dados básicos: Pesquisa de campo ANTAQ

Cotações: US$ 1 para R$

Dezembro/2005: 2,3407
Dezembro/2006: 2,1380
Dezembro/2007: 1,7713
Dezembro/2008: 2,3370
Dezembro/2009: 1,7412

- **Source: http-//www.antaq.gov.br/Portal/DesempenhoPortuario/2010/tabelas/tabela28**

ATTACHMENT B

Voltri Terminal Europa
A member of the PSA Group

EQUIPMENT TECHNICAL INFORMATION

1. Navigational Details

• Approach channel:	Width:	280 m
	Depth:	21 – 16 m
• Turning basin:		700 m
• Distance pilot station - berth:		1,5 n.m.
• Water depth alongside:		15 m
• Requested under keel clearance:		0,5 m

2. Terminal Data

2.1 Quay and Yard

• Quay length:	1.400 m
• Depth:	15 m
• RoRo Berth:	300 m
• Yard surface:	116 HA stacking area (6 modules)
• Stacking capacity (ground slots):	12.000 TEU
• Reefer plugs:	500
• DG storage:	500 slots

2.2 Equipment

2.2.1 Quay cranes

• 4 x Reggiane post-panamax	SWL under spreader	50.0 tons
	SWL under spreader Twin Lift	48.0 tons
	SWL heavy lift (under hook)	57.0 tons
	Outreach from fender	40.8 m (16 Rows)
	Lifting height above rail	31.5 m
	Lifting height above water level	34.1 m
	Buffer to buffer distance:	24,6 m
	Crane minimum separation:	3 x 20' bays
	Available inside gantry space:	24.0 m
	Clearance between legs:	16.0 m
• 4 x Ansaldo - Reggiane post-panamax	SWL under spreader	40.0 tons
	SWL heavy lift (under hook)	47.0 tons
	Outreach from fender	40.8 m (16 Rows)
	Lifting height above rail	31.5 m
	Lifting height above water level	34.1 m
	Buffer to buffer distance:	24,6 m
	Crane minimum separation:	3 x 20' bays
	Available inside gantry space:	24.0 m
	Clearance between legs:	16.0 m
• 2 x Reggiane C. & P. post-panamax	SWL under spreader	50.0 tons
	SWL under spreader Twin Lift	48.0 tons
	SWL heavy lift (under hook)	57.0 tons
	Outreach from fender	44.0 m (18 Rows)
	Lifting height above rail	35.0 m
	Lifting height above water level	37.6 m
	Buffer to buffer distance:	27,3 m
	Crane minimum separation:	4 x 20' bays
	Available inside gantry space:	24.0 m
	Clearance between legs:	16.0 m

2.2.2 RTGs

• 4 x Ansaldo	4 + 1, 8 wheels	
	Stacking height:	4 x 9'6"
	SWL under spreader:	35 tons
• 9 x TechInt - Ansaldo	4 + 1, 8 wheels	
	Stacking height:	4 x 9'6"
	SWL under spreader:	45 tons
• 6 x ZPMC	4 + 1, 8 wheels	
	Stacking height:	4 x 9'6"
	SWL under spreader:	40 tons
• 4 x Kalmar	5 + 1, 8 wheels	
	Stacking height:	5 x 9'6"
	SWL under spreader:	41 tons

2.2.3 RMGs

• 2 x Ceretti / Reggiane	SWL under spreader	45.0 tons
• 1 x Reggiane	SWL under spreader	45.0 tons

2.2.4 Forklifts

• Container handling:	CVS	1 x 16 tons
	Fantuzzi	2 x 10 tons (ECH)
• Others:	Kalmar	1 x 32 tons
	Linde	1 x 3.5 tons
	Linde	1 x 2.5 tons
	Linde	1 x 4.5 tons
	Still	3 x 2.5 tons
	Detas	1 x 5 tons

2.2.5 Reach Stackers

• Container handling:	CVS	23 x 45 tons
	Fantuzzi	2 x 45 tons
	Kalmar	2 x 45 tons
	Hyster	1 x 45 tons

2.2.6 Terminal Tractors

• Terberg	22 x 42 tons
• CVS	50 x 42 tons

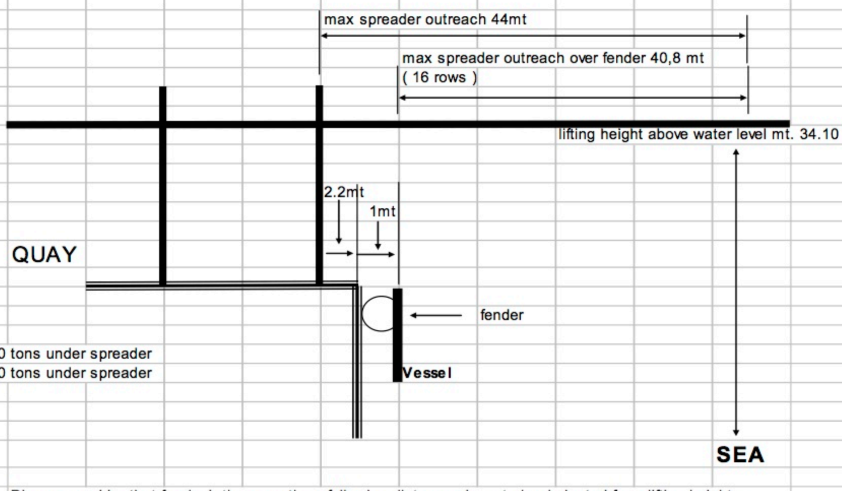
2.2.7 Terminal Châssis

• Gaussin	23 x 50 tons
• CVS	21 x 35 tons
• Inta - Eimar	32 x 60 tons
• Buiscar	7 x 50 tons

3. IT Systems

• Server:	2 Application / Data Base clustered servers 2 WEB server, EDI server, internally managed infrastructure servers
• System:	INTEL -Win servers, IBM -AIX servers, I-series –As/400 Servers Oracle Data Base, SQL Server Data Base, DB2 Database Network Protocol TCP/IP, LAN,WAN Computer Rooms in two different sites
• Facility:	Documentation CTCS Cosmos system SHIPS/SPACE/TRAFIC/ COSMOS systems linked-up with fully computerized Radio Data SystemTEKLOGIX, GATE automation SN5 Cosmos system for E.D.I./ EDIFACT STANDARD, WEB Custom Documentation on web site portal (www.vte.it) E-PORT Customs link Global Financial System (Oracle application)

VTE QUAY CRANE PARTICULARS (Q.C. 01-08)



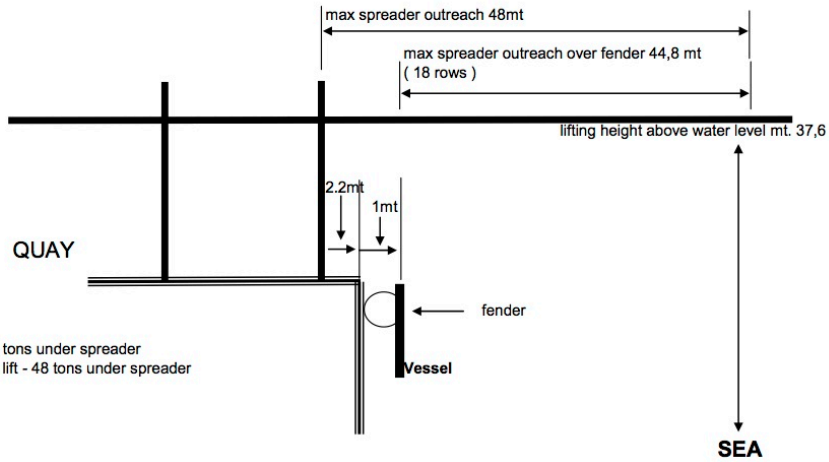
CR 01-04 50 tons under spreader
CR 05-08 40 tons under spreader

Please consider that for deck tier operations following distances have to be deducted from lifting height:

1) lashing cage height (to be placed on top the last deck tier): 2,8 mt.
2) clearance between last deck tier and the lashing cage: 0,3 mt

Therefore, max operational deck height is about 31 mt above water level.

VTE QUAY CRANE PARTICULARS (Q.C. 09-10)



CR 09-10 50 tons under spreader
twin lift - 48 tons under spreader

Please consider that for deck tier operations following distances have to be deducted from lifting height:

1) lashing cage height (to be placed on top the last deck tier): 2,8 mt.
2) clearance between last deck tier and the lashing cage: 0,3 mt

Therefore, max operational deck height is about 34.5 mt above water level.