The Study on Best Practices of Container Terminal Automation in the world

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IAPH
International Association
of Ports and Harbors

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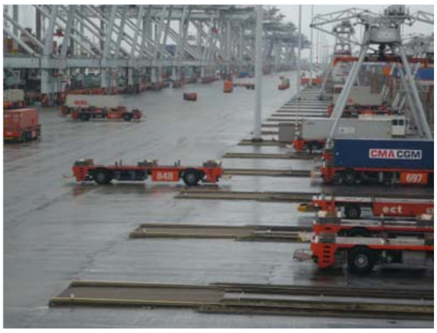


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Final Report

International Association of Ports and Harbors (IAPH)
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Contents

PREFACE

The first automated container terminal came into existence in 1993 at SeaLand Terminal in the Delta District of the Port of Rotterdam. Terminal automation has evolved and expanded steadily since then, and many successful examples can be found in major ports of the world. In the last two decades, many basic technologies underlying terminal automation have been developed and various kinds of handling systems for automated terminals have been devised. Today, automated terminals which incorporate a multitude of new technologies for all aspects of operation are expanding around the globe.

The type of handling system, layout, handling gears and vehicles employed at an automated terminal greatly vary according to each terminal's economic circumstances, geographical conditions, historical background and the nature of the project (i.e., whether it is a greenfield project or a renovation project). The technological capability of the project owner is also an important factor. As a result, many types of automated terminals can be observed throughout the world.

While there were only two (2) automated terminals in the entire world in the 1990s, nine (9) new terminals were constructed between 2000 and 2010 and an additional fifteen (15) terminals have been developed in the last five years. The speed at which automated terminals are being developed is remarkable. Although this report covers 26 automated terminals, new automated terminals are undoubtedly being planned. It has almost become the norm to consider introducing terminal automation when developing new container terminals.

In this report, an overview of the regional features and historical background of the development of twenty-six (26) terminals is provided in Chapter 1. Eleven (11) representative automated terminals are introduced in some detail in Chapter 2. Then, a comparative review of the eleven representative terminals is conducted in Chapter 3 so as to present an overview of automated terminals from the viewpoint of 1) background of terminal automation, 2) concept and basic system of automation, 3) layout in the marshaling yard, 4) handling equipment, and 5) the effect of automation. In Chapter 5, the future direction of terminal automation is discussed.

Chapter 1. Historical Overview of Container Terminal Automation Worldwide

1.1 Overview of Automated Container Terminals in Europe

Automated Container Terminals in Europe are all large-scale terminals with quay length exceeding 1000 m. Yard blocks are designed perpendicular to the quay line. Container handling on the seaside and landside is separated by container stacking blocks which ensure operators' safety and facilitate the smooth flow of traffic. In Europe, Automated Container Terminals are already highly evaluated and have been introduced in major European ports since 2000. Automated Terminals in Europe can be classified into four generation types according to their historical and technical background.

1.1.1 The First Generation of Terminal Automation

The First Generation of Terminal Automation is typified by the ECT Delta terminal of Rotterdam Port in the Netherlands which opened in 1993. Original concept of this terminal automation influenced subsequent terminals developed in Europe and this basic concept has not changed. Therefore, it can be said that basic concept of terminal automation in Europe was established by the ECT Delta terminal. This terminal is characterized by the following three technical features: (1) Yard stacking operation was fully automated by using Automated Stacking Crane (ASC) of Rail-Mounted-Gantry (RMG) type, (2) Horizontal transport of container between quay side and stacking yard was also fully automated by using Automated Guided Vehicles (AGVs), and (3) Yard blocks are designed perpendicular to the quay line. However, quay crane operation and container delivery from ASC to road trucks are not automated in this terminal. The delivery of containers between ASC and road trucks was designed to be handled by manned straddle carriers (STR) as the level of automation technology at that time did not allow for full automation due to safety concerns.

1.1.2 The Second Generation of Terminal Automation

The second generation of Terminal Automation is typified by HHLA Altenwelder Terminal (CTA) in Hamburg and Euromax Terminal (Euromax) in Rotterdam. The former started operation ten years after the 1st generation automated terminals in 2002 and the latter in 2007. These second generation terminals expanded their automation range further to reduce labor costs and adopted various new technologies to increase the efficiency of cargo handling and yard operations.

These terminals adopted the double trolley system for QGCs, which enabled operation of the No. 2 Trolley of the QGC to be fully automated. As these second generation automated terminals have already adopted twin-lift systems for their quay crane operation, the same as first generation terminals, No. 2 trolley automation meant that twin-lift container operation was also fully automated. In CTA and

Euromax, while AGV operates in twin-lift style for the horizontal transport of containers, ASC (Automated Stacking Crane) does not adopt twin-lift style for stacking operation in order to utilize container storage capacity more efficiently in limited yard space.

In addition, these terminals adopted the Diesel Electric Drive system for AGV. This Diesel Electric Drive system improved fuel efficiency and greatly reduced maintenance cost compared to the Diesel Hydraulic system, which was generally adopted in first generation automated terminals.

Finally, the enlargement of yard blocks both in block size and stacking height is another feature of these terminals. Accompanied by these enlargements, (1) ASC became larger and faster, (2) two ASCs were introduced in a single yard block, (3) remote operation system from the control room or a wireless terminal system operated by road truck drivers on site were adopted for container loading onto trucks.

① <u>ASC enlargement</u>

In ECT Delta terminal, the stacking height of ASC was raised from 6 rows 1-over-2 (Delta Terminal North) to 6 rows 1-over-3/4 (Delta Terminal East/West) during the 15 years since 1993. On the other hand, CTA adopted 10 rows 1-over-4 and Euromax introduced 10 rows 1-over-5 as their ASC block layout from the beginning of their operation.

② <u>Number of ASCs installed in yard block</u>

While one unit of ASC per block was introduced in the ECT Delta terminal, <u>two ASCs per block</u> were installed in second generation automated terminals. In terms of the number of tracks for ASC, a <u>2 track system</u> was adopted in CTA which started operation in 2002 while a <u>1 track system</u> was adopted in Euromax which started operation in 2007. While it is difficult to evaluate which track system is superior, it should be noted that all new automated terminals constructed in the 2010s have adopted a 1 track system for ASC stacking blocks.

③ <u>Automation of container transfer between ASC and road truck</u>

CTA adopted a remote operation system from the control room. ASC carries a container from its stacked location in the yard block to the delivery lane at the end of the block where a truck is waiting to receive it. ASC automatically adjusts the container to a position 30cm above the height of chassis floor of the waiting truck. Final handoff of the container onto the chassis is done by remote control from the control room. On the other hand, Euromax Terminal adopted a system in which the truck driver operates this final handoff process by himself/herself at the site using a wireless operation unit. While this method was technically successful, the final landing operation is currently being performed by Euromax dock workers for the following two reasons: 1) The handling skills of truck drivers greatly vary due lack of formal training and 2) A final agreement with labor union on this matter has not yet been reached.

1.1.3 The Third Generation of Terminal Automation

The automated terminals of the third generation, which partially came into operation in the late 2000s, are typified by HHLA Burchardkaj Terminal (CTB (2009)) in the port of Hamburg and DPW Gateway terminal (DPW-AGWT (2007)) in the port of Antwerp. It might be more accurate to categorize these terminals as modified second generation automated terminals rather than third generation automated terminals as there was not a significant evolution in applied technologies. In addition, the degree of automation was smaller compared to second generation terminals. As these terminals were converted for automation rather than newly constructed, manned straddle carriers were adopted for the horizontal transport of containers between the quay and stacking yard rather than AGV (a straddle carrier system had been employed prior to conversion). These third generation automated terminals introduced the following new technologies in order to achieve higher cargo handling performance.

1) Double trolley system with Twin-lift or Single trolley system with Tandem-lift

In 3rd generation automated terminals, a double trolley system with twin-lift & No. 2 trolley automation (CTB) and tandem-lift system with single trolley (DPW-AGWT) were introduced for quay crane operation.

In order to realize flexible container operation, a manned straddle carrier (STR) was adopted for the horizontal transport of containers in DPW-AGWT. The main reason is that horizontal transport of this terminal is very complex because of its high tandem operation rate and its combined operation of ASC and conventional STR operation. Hence this terminal adopted flexible manned STR for horizontal transport.

To leave open the possibility of AGVs being used for horizontal container transport in future, the yard layout of CTB was designed with sufficient redundancy. DPW-AGWT, on the other hand, is considering the use of an unmanned shuttle carrier (Auto-Shuttle-Carrier) for horizontal container transfer.

The issue of which system, AGV or Auto-Shuttle-Carrier (1 over 1), is best for seaside horizontal transport remains a contentious one. Each system has its own advantages and disadvantages in efficiency of operation. While the Auto-Shuttle-Carrier system has the largest advantage in decoupling works between ASC operation and Quay Gantry Crane (QGC) operation, it has yet to be introduced. Kalmar Inc., a manned shuttle carrier systems manufacturer, is now developing the required technology. On the other hand, Terex/Gottwald Inc., a leading maker of AGV systems, has developed a Lift-AGV system which can perform independent operation of ASCs and QGCs (Decoupling). Accordingly, it remains to be seen which system will prevail.

2) Mast system for crane hoisting mechanism of ASC

For shortening (or improving) the cycle time of container handling by ASC, DPW-AGWT adopted a mast guided system instead of a wire rope mechanism as the hoisting mechanism. The mast system of DPW-AGWT, the first of its kind to be introduced in automated terminals, has the following remarkable features.

① Time required to fix the position of the spreader of ASC is reduced by eliminating its horizontal deflection (sway) and rotational vibration (skew) using a simple mechanical structure guide.

② The position of the spreader can be adjusted mechanically by utilizing a self-furnished measuring mechanism of the crane gantry and trolley of ASC, without using the image processing function of a CCD camera. This mechanism allows ASC Crane to increase its adjusting speed both for acceleration and slowdown, which shortens the time cycle of handling containers by ASC.

③ The design of the stacking block can be narrow by adjusting the angle of the wire rope which runs diagonally to stop sway of the hoisting crane of ASC, which increases the efficiency of yard usage efficiency.

3) Development of full-automatic container Truck Loading/Unloading Systems

While CTB adopted a remote control system from the control room for container transfer (loading/unloading) between ASC and road trucks, the same as their second generation automated terminals, DPW-AGWT introduced a more advanced automated system for this transfer operation. They newly adopted a Fully Automated Truck Loading System of ASC which covers all operations including a) transferring a container between the stacking yard and a position one foot above the waiting chassis of a truck and b) the container final handoff on the chassis of the truck. As of 2014, the implementation rate of this Fully Automatic Truck Loading System in DPW-AGWT reached 90-95% of all handling containers. (Refer to **Figure 1.1-1**)

The above two automated terminals were built on brownfield land to convert their operation systems from the existing STR to ASC. The converting process is still underway at both terminals. Therefore, a combined operation of STR and ASC using manned STRs is employed for the seaside horizontal transport.

Figure 1.1-1 Container Yard of DPW Antwerp Gateway Terminal

On the other hand, the following three automated terminals which started operations since 2010 did not have to employ a combined operation system as they were constructed on greenfield land: TTI Algeciras (Total Terminal International Algeciras ((2010)) in the port of Algeciras, BEST (Barcelona Europe South Terminal (2012)) in the port of Barcelona, and DPW gateway terminal (London Gateway Terminal (DPW-LGWT) (2013)) in the port of London. These terminals were able to introduce the far more efficient manned shuttle carrier (Shuttle (1 over 1)) for the seaside horizontal transport.

<u>TTI Algeciras</u>

This terminal, which predominantly handles transshipment containers (representing 90% of its total handling volume), introduced automated terminal operation in 2010 and recorded a container handling volume of 1.2 million TEU in 2014. This terminal was built from scratch on greenfield land different from DPW-AGWT and CTB; its automation system has the following specific features. (1) a manned shuttle carrier system is adopted for seaside horizontal transport, (2) ASCs scheme is used for container stacking in the yard, (3) a manned shuttle-carrier is introduced for container transport between the yard block and transfer lane in the container interchange area located at the landside of the terminal. While above (1) & (2) are the same technical features adopted by other automated terminals of the third generation, (3) is almost a throwback to the system used in first generation automated terminals.

As this terminal introduced various newly developed technologies in their operation such as a) OCR system for identification of discharged container numbers, b) automated container tracking system using DPGS and millimeter-wave radar to be equipped on horizontal transfer shuttle carrier, this terminal is categorized as a third generation automated terminal.(See **Figure 1.1-2**) .

Source: Algeciras Port Authority Home Page

Figure 1.1-2 Aerial View of TTI Algeciras

BEST

This terminal which was built on greenfield land and began operations in 2012, is also categorized as a third generation automated terminal as manned shuttle carrier is adopted for the seaside horizontal transport. The following technical features have been introduced in their terminal automation: 1) manned shuttle carrier for horizontal transfer at seaside operations, 2) automated stacking system of ASC in yard block, 3) remote control system for loading containers on the external trailers and 4) internal trailer for horizontal transfer between the yard block and rail terminal (refer to **Figure 1.1-3**).

Source: Barcelona Europe South(BEST) Home Page

Figure 1.1-3 Aerial view of Barcelona Europe South Terminal

DPW-LGWT

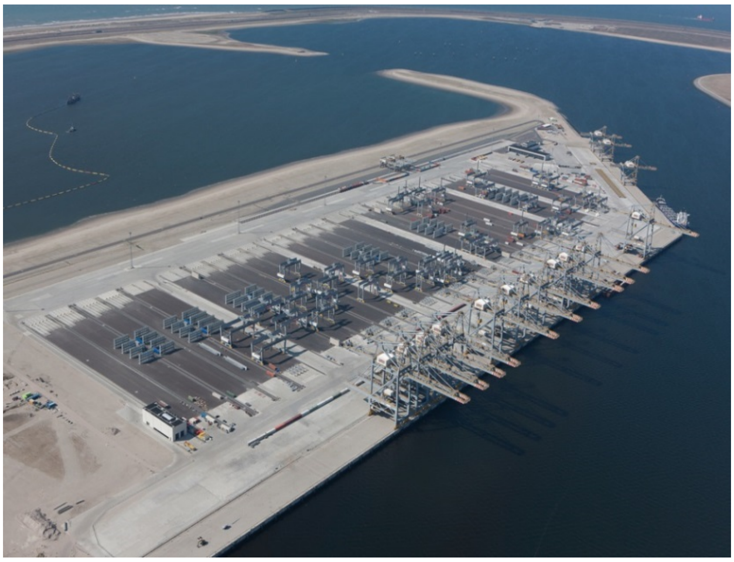
This terminal which was built on greenfield land and began operations in 201s, is also categorized as a third generation automated terminal as manned-Shuttle carrier is used for the horizontal transport of containers at seaside. The following technical features have been introduce in their terminal automation: 1) manned-shuttle-carrier for seaside horizontal transport, 2) automated stacking system of ASC in yard block, 3) Fully Automatic Truck Loading System for containers truck loading at landside end of the ASC blocks, the same as DPW-AGWT and 4) Cassette trailer system is adopted for horizontal transport of containers between the yard block and on-dock railway terminal. The success rate (successful loading/unloading rate without manual support by the remote operator) of Fully Automatic Truck Loading System has reached at 90% of all loading/unloading containers handled in the terminal within two years of starting operation (refer to **Figure 1.1-4**).

Source: DP World London Gateway Terminal Home Page

Figure 1.1-4 Aerial view of DP World London Gateway Terminal

1.1.4 The Fourth Generation of Terminal Automation

The fourth generation automated terminals, which began operation around 2015, feature the most advanced automation technologies. APMT (AP Moller Terminal (2014-15)) and RWGT (Rotterdam World Gateway Terminal (2015)), both built in Maasvlakte-2(MV-2) of the port of Rotterdam, are examples of fourth generation automated terminals. Both of these highly advanced automated terminals introduced various new technologies that weren't available when CTA in Hamburg port and Euromax in Rotterdam were developed. These fourth generation terminals aim to materialize fully-automated terminals by expanding the concept applied to second generation automated terminals. Third generation automated terminals, on the other hand, maintained the use of a semi-automated terminal system for flexible terminal operation, a concept also derived second generation automated terminals which employ a manned STR/Shuttle for the horizontal transfer of containers at seaside.



Source: Rotterdam World Gateway Terminal Home Page

Figure 1.1-5 Aerial view of MV-2 RWG Terminal (RWG Home Page)

The specific features or technical developments of the fourth generation automated terminals (APMT and RWGT) compared to second generation automated terminals are described below.

1) Realization of Remote Operation of No.1 trolley of quay crane

While automation of the No. 2 Trolley had already been realized in the second generation automated terminals 12 years ago, the remote operation of the No.1 trolley was first realized in the fourth generation terminal automation. This technical development means crane drivers no longer need to be in the cabin to operate cranes, which will lead to full automation of quay crane operation in future. In fact, quay cranes of APMT are not equipped with cabins as loading and unloading containers is fully controlled by remote control from the control room Ship loading and unloading is completely undertaken by remote control from the control room.

2) Battery Lift AGV (BL-AGV) for horizontal transport of containers

This is the first time that a battery-driven Lift-AGV (Battery Lift AGV (BL-AGV)) has been adopted for the horizontal transport of containers between the quay and yard. This system has the following two advantages: (1) reduced CO2 emissions and (2) independence (or decoupling) of ASC and QGC operations.

① Reduced CO2 emissions

The adoption of BL-AGVs for the horizontal transport means that all terminal equipment/facilities from the quay crane to the on-dock railway terminal are electric powered, thereby realizing a zero-emission terminal. While BL-AGV needs battery charging stations to be installed in the terminal, the large initial investment cost of the BL-AGV can be recovered due to lower energy costs and increased energy efficiency.

② Independence (or decoupling) of ASC and AGV operations

The required number of AGVs can reportedly be decreased by 30-40% by adopting Lift-AGVs instead of traditional AGVs. Both of the terminals above are said to be able to recover their initial investments for placing “racks” on the transfer lane of the yard blocks by the reduction of initial and running cost of AGVs.

3) Expansion of operation area of AGVs

APMT realized terminal automation in its true sense by expanding the operation area of AGVs to the whole terminal. While seaside horizontal container transport was done by AGVs in second generation automated terminals, AGVs in fourth generation automated terminals cover a much wider area and are able to transport containers onto barge terminals and rail terminals.

4) Fully Automatic Truck Loading System

Fully Automatic Truck Loading System, an early version of which was developed in DPW-AGWT, was adopted in fourth generation automated terminals from the initial stage.

In addition to the above features, terminal operation at APMT and DWGT is characterized by the extremely high ratio of transshipment containers including barge transportation. Due to the heavy traffic generated by the discharging and loading operations at the transfer lane at the seaside end of the stacking block, there was a concern that the system would not be able to efficiently handle all the transshipment cargo during peak periods. To address this issue, the layout of RWGT was designed to place the transfer lane for container handoff to AGV on the “sideline” of the stacking block.

To facilitate the above transfer operation, ASCs with Cantilever-type Automatic Rail-Mount Gantry Crane (Cantilever A–RMG) were newly introduced in RWGT to complement traditional ASCs. In addition, by using certain yard blocks only for container transfer to the barge terminal and rail terminal, APMT realized flexible container transfer operation between AGV and ASC by placing the transfer lane for Lift-AGV on both the landside and seaside end of the yard block.

The terminal layouts adopted in RWGT and APMT will inspire other terminals, which is high transshipment ratio, to introduce similarly innovative plans and technologies in future. Overview of Automated Terminals in Europe is shown in **Table 1.1-1**.

Table 1.1-1 Automated Container Terminal in Europe

No.	Port	Terminal	Operator	Year of Install-ation	Site*	Automation Concept		
						Yard Stacking	Horizontal Transport	Truck Loading
1	Rotterdam	ECT Delta Terminal	Europe Container Terminals	1992	G	ASC	AGV	Manned STR
2	Hamburg	CTA***	HHLA*****	2002	G	ASC	AGV	Remote**
3	Rotterdam	Euromax	Euromax	2011	G	ASC	AGV	Remote**
4	Rotterdam	APM Terminal (MV-2)	APM Terminals	2015	G	ASC	L-AGV	Full Auto-loading
5	Rotterdam	RWG Terminal (MV-2)	Rotterdam World Gateway	2015	G	ASC & C-ARMG	L-AGV	Full Auto-loading
6	Hamburg	CTB****	HHLA	2009	B	ASC	Manned Straddle Carrier	Remote**
7	Antwerp	Antwerp Gateway Terminal	DP World Antwerp	2007	B	ASC		Full Auto-loading
8	Algeciras	TTI Algeciras	Total Terminal International Algeciras	2010	G	ASC	Manned Shuttle Carrier	Manned STR
9	Barcelona	BEST	Barcelona Europe South Container Terminal	2012	G	ASC		Remote**
10	London	London Gateway Terminal	DP World London	2013	G	ASC		Full Auto-loading

Note: Automated | Manual Process

*Site: G: Development on the greenfield land B: Redevelopment/ Renovation Project from conventional terminal
** Remote: Remote Final handoffs between the ASC and trucks are remotely controlled from the control room.
*** CTA: Container Terminal Altenverder **** CTB: Container Terminal Burchadkai
***** HHLA: Hamburg Hafen und Lagerhaus Aktiengesellshaft

1.2 Overview of Automated Container Terminals in Australia

At present, there are two automated terminals in Australia: Patric Terminal Brisbane (PCT-Brisbane) operated by Patric Terminals Ltd. and DPW Brisbane Terminal (DPW-Brisbane), both of which are in Brisbane port. In Botany port, Patric Terminal Sydney (PTC- Sydney) is scheduled to start operation in 2015 as the third automated terminal in Australia. (Refer to **Table 1.2-1**)

Table 1.2-1 Automated Container Terminal in Australia

No.	Port	Terminal	Operator	Year of Installation	Site*	Automation Concept		
						Yard Stacking	Horizontal Transport	Truck Loading
1	Brisbane	Patric Terminal Brisbane	Patric Terminals Ltd.	2005	B	Auto-Strad		
2	Sydney	Patric Terminal Sydney	Patric Terminals Ltd.	2015	B	Auto-Strad		
3	Brisbane	DPW Brisbane Terminal	DP World (Australia)	2014	B	ASC	Manned-Shuttle	Remote**

Note: Automated | Mannual Process

*Site: G: Development on the greenfield land B: Redevelopment/ Renovation Project from conventional terminal
** Remote: Remote Final handoffs between the ASC and trucks are remotely controlled from the control room.

<u>Patric Terminal Brisbane (PTC-Brisbane)</u>

The automation concept of this terminal is completely different from that applied to European type automated terminals as it features fully automated straddle carriers (Auto-STR). Development of the Auto-STR System began in 1996 in collaboration with the University of Sydney (Robotics). A field test was conducted in 2001 and actual operation Field test started in 2001 and practical use started in 2005 using half the area of the current yard area. In 2009, Patric Brisbane Terminal began operation as a full-scale automated container terminal with three berths and a handling capacity of 800 thousand TEU.

A total of 27 units of Auto-STR were introduced to carry out the following handling work: 1) Horizontal transport of containers at seaside area, 2) Yard stacking (1-over-2), 3) Container transport between the yard and Truck Grid (container interchange area), and 4) Container transfer (loading/unloading) to/from trucks. Regarding delivery and receipt of containers, while horizontal transport and picking up a container from a trailer are automated, landing containers onto the trailer is done by a dock worker using a radio remote control system.

Basic Technology of Auto-STR system is characterized by the following two technical features: 1) Automatic Detection of Position of Straddle carriers (Positioning) and 2) Traffic Management System. Positioning relies on millimeter-wave (Extremely High Frequency) radar while the Traffic Management System controls terminal traffic based on a virtual grid in the core part of the system (Refer to **2.8**).

Figure 1.2-1 Panoramic view of Patric Termnal Brisbane

PTC-Sydney (Patric Terminal Sydney) :

According to the new concession contract concluded in 2012, Patric Terminal Sydney is developing the Expansion and Renovation Project of Patric Sydney Container Terminal. As part of this project, the terminal operation system will converted from the current manned STR operation to Auto-STR system. The concept of this terminal automation system is exactly the same as that of PTC-Brisbane. Expansion of the terminal area has already been completed and 44 units of Auto-STR are in the final stage of testing at PTC-Brisbane. PTC-Sydney is scheduled to start its automated terminal operation in 2015

DPW Brisbane Terminal (DPW-Brisbane)

The DPW-Brisbane Terminal, which began operations in 2014, is also a converted automated terminal that originally employed a traditional straddle carrier system. This terminal is modeled after the third generation automated terminals in Europe as DPW is the operator of this terminal. Namely, (1) sea-side horizontal movement is carried out by manned shuttle carrier, (2) yard stacking is done automatically by ASC, and (3) a Fully Automatic Truck Loading system is adopted for landside truck transfer (loading/unloading). An internal trailer is used to transfer containers from the yard to the on-dock railway terminal.

1.3 Overview of Automated Container Terminals in the United States

The introduction of Automated Container Terminals in the United States was 15 years behind that in Europe. The first Automated Container Terminal developed in the United States was the APM Terminal Virginia in Norfolk port in the state of Virginia, which started operation in 2008. The delay in introducing automation was mainly due to opposition from organized labor in ports.

PMA (Ports and Maritime Association), long being convinced of the economic merits of terminal automation, raised the issue every six years during labor contract negotiations with ILWU (International Long Shore and Warehouse Union). After difficult negotiations spanning a period of many years, a basic agreement on the implementation of terminal automation was ultimately incorporated into the West Coast Labor Agreement (WCLA) after certain guarantees were made to laborers in 2008. At present, there are three automated container terminals in the United States in operation or in the final stage of commissioning, namely, the aforementioned APM Terminal Virginia, TraPac Terminal which started partial operation in phase-1 area in 2014 and LBCT (Long Beach Container Terminal), which will start commercial operation in the third quarter, 2015. (Refer to **Table 1.3-1**)

Several other automated terminals are also being planned, which indicates that terminal automation in the United States will expand further in spite of the expected resistance of labor unions.

Table 1.3-1 Automated Container Terminal in the USA

No.	Port	Terminal	Operator	Year of Installation	Site*	Automation Concept		
						Yard Stacking	Horizontal Transport	Truck Loading
1	Norfolk	APM Terminal Virginia	APM Terminals Ltd.	2008	G	ASC	Manned-Shuttle	Remote**
2	Los Angeles	TraPac Terminal	Trans Pacific, LLC	2014	B	ASC	Auto-Shuttle	Remote**
3	Long Beach	LBCT (Middle Harbor)	Long Beach Container Terminal Inc.	2015	B	ASC	AGV	Full Auto-loading

Note: Automated (highlighted) / Manual Process

*Site: G: Development on the greenfield land B: Redevelopment/ Renovation Project from conventional terminal

** Remote: Remote Final handoffs between the ASC and trucks are remotely controlled from the control room.

APM Terminal Virginia

The APM Terminal Virginia was the first automated container terminal developed in the United States on greenfield land of the port of Norfolk in 2008. It was designed based on the same concept applied to third generation automated container terminals in Europe. This terminal adopted the following advanced systems: (1) Manned shuttle carriers for horizontal movement at the seaside area, (2) Automatic stacking by cranes (ASCs) for yard stacking, (3) Remote control from the central room for final handoffs between the crane and trucks, while container transfer (other than final handoff) to trucks is done automatically by ASC. An internal trailer is used to transport containers from the yard to the railway terminal (Refer to **Figure 1.3-1**).

Source: APM Terminal (Virginia) Home Page

Figure 1.3-1 Aerial view of APM Terminal (Virginia)

TraPac Terminal

TraPac Terminal was the first automated container terminal to be developed on the west coast of the United States; phase-1 operations partially commenced in 2014. It was developed as a part of the Redevelopment Project of TraPac terminal, which comprises berth No. 142-147 (1,000m in length) and its backyard, terminal access flyover, and rail facilities. The goal of the Project was to expand terminal capacity and reduce operating costs by replacing its "on-chassis & RTG system" with an "ASC & Auto-STR system". While the terminal was modeled after the semi-automated terminals (third generation type) in Europe, it has realized full automation by introducing the Auto-STR which has proven effective at Patric Terminal Brisbane.

Main technical features of the terminal are summarized below.

(1) Fully Automated Container Terminal is realized through the aforementioned Auto-STR system (1-over-2) for seaside horizontal container movement.

(2) As the terminal has operational constraints due to its triangular shaped land, the following two systems are employed for yard operations, namely a) automatic stacking by ASC, and b) ground stacking of 35% of import containers by Auto-STR for transfer to intermodal railway terminal. (Refer to **Figure 1.3-2)**

(3) While transfer operation to truck is made at the landside-end of each yard block, final handoffs between the crane and trucks are controlled remotely from the control room.

(4) Movement from the Ground Stacking Yard to the rail terminal is done by the Auto-STR. Cantilever area of RMG in the rail terminal is used as buffer area (in 3 tiers) of stacking containers for rail transportation. Auto-STR in this terminal has a lifting capacity of one-over-two height as they are intended to be used both in horizontal transport in the whole terminal area and in stacking containers at the ground stacking yard and buffer area at on-dock railway terminal.

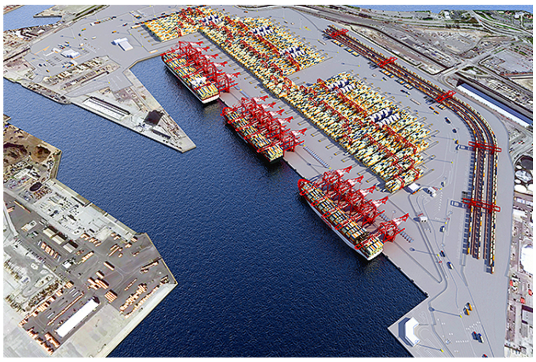
Source: Port of Los Angeles Home Page

Figure 1.3-2 Aerial view of TraPac Terminal (After completion of phase-2)

Long Beach Container Terminal (LBCT)

LBCT is now carrying out the Middle Harbor Redevelopment Project in port of Long Beach, which aims to upgrade Long Beach port by integrating Pier-E & Pier-F including reclamation of the intermediate area. The aim of the project is to expand terminal capacity, reduce operating cost and substantially mitigate the port's environmental impact by introducing automation.

Phase-1 of the planned terminal (Berth length of 420m, 16 yard blocks, terminal capacity of 1.6 million TEUs per year) is already completed and final adjustment of the operation system is now underway for commercial operation which is scheduled to start in the third quarter of 2015. This terminal adopts the basic concept employed in second generation automated terminals of Europe such as CTA and Euromax. The terminal employs the following operation systems: (1) Semi-automatic system of Double Trolley twin lift/tandem lift (1st trolley) for QGC, (2) Battery-driven AGV for horizontal movement at seaside area, (3) Automated stacking by ASCs (two identical cranes in each stacking block) for yard stacking, (4) Fully automatic truck loading system for landside truck loading by ASC's direct handling at landside-end. An internal trailer is used to transfer containers from the yard to the railway terminal Aerial view of LBCT in Middle Harbor before Rehabilitation project started (in 2010) and its completed overview picture (in 2019) are shown in **Figure 1.3-3.**



Source: Port of Long Beach Home Page

Figure 1.3-3 Aerial view of LBCT Middle Harbor (2010 (Left) and 2019 (Right))

1.4 Overview of Automated Container Terminals in Asia

There are currently 10 automated terminals in Asia (Refer to Table 1.4-1**).** While the number of automated terminals is fairly high, the level of terminal automation in Asia is quite different from that in Europe. TCB of Nagoya port in Japan is the only terminal regarded as a Fully Automated Container Terminal (fully automated operation from horizontal movement at seaside area to truck loading onto road truck). Only the yard stacking operation is automated at other terminals while horizontal movement at the seaside area is carried out either by manned trailer or manned shuttle carrier.

Pasir Panjang Terminal (Phase1) in Singapore port was the first container terminal to introduce automated terminal operation in the mid-1990s. It can be said that the introduction of terminal automation in Asia was not far behind that of Europe as ECT Delta terminal was the only automated terminal in Europe at that time.

<u>Pasir Panjang Terminal (Phase1)</u>

The Pasir Panjang Terminal (Phase1) started operation in 1997 and handled 3.5 million TEUs in 2005. The terminal has stacking yards of 4 rows (behind Berth No. 1-4) and 2 rows (behind Berth No. 5-6) which are arranged parallel to the quay line (total berth length is 2,145 m). The stacking yard (8 tiers of stacking height) is equipped with reinforced-concrete crane girder (28m height) and 44 units of automatic OHBC (Overhead bridge crane) of 45.4m (covering 10 rows) rail span on top of girders. In the back of OHBC yard, there is a row of RMG yard equipped with 15 units of manned double cantilever RMGs (covering 13 rows in width) (Refer to **Figure 1.4-1)**.

OHBC Yard was originally designed to be used for the stacking yard of transshipment containers (ration of transshipment cargoes is 80 ~ 85%) and RMG yard for the stacking yard of export and import containers. Under the original design, external truck loading operation was intended to be handled under Cantilever of landside RMG and seaside transfer operation was intended to be handled under seaside Cantilever. Therefore it was possible to separate the flow of seaside operation (transfer between RMG and AGV) from that of landside operation (transfer between RMG and manned external truck) by intermediate stacking yard.

While PSA originally planned to build a fully automated container terminal using AGVs for horizontal transfer and conducted a trial operation using five AGV prototypes, the plan was eventually abandoned due to technical and economic reasons. Instead, horizontal container transport between the quay and stacking yard is carried out by manned trailer and only the operation in OHBC yard is automated. Container transfer (loading/unloading) between trailer and OHBC is made automatically while final handoffs to the trucks are remotely operated from the control room.

In the subsequent Phase-2 & Phase-3 projects, a conventional RTG system was adopted instead of automated OHBC yard operation because the cost of building an automated stacking yard was considered to be too high.

Source: "PSA fast tracks PPT expansion plans" (PSA): Port Technology International

Figure 1.4-1 Aerial view of Pasir Panjang Terminal (phase-1)

The semi-automated terminal concept in Pasir Panjang Terminal (Phase1) had a large influence on other Asian terminals. Since 2009, many Asian ports including Hong Kong port, Kaohsiung port, Taipei port, Busan new port introduced a semi-automated operation system modeled on Pasir Panjang Terminal (Phase1). (Refer to **Table 1.4-1**).

Table 1.4-1 Automated Container Terminal in Asia

No.	Port	Terminal	Operator	Year of Install-ation	Site*	Operational Concept		
						Yard Stacking	Horizontal Transport	Truck Loading
1	Singapore	Pasir Panjang Terminal (Phase-1)	PSA	1997	G*	A-OHBC	Tractor Chassis	Remote**
2	Pusan New Port	HJNG Terminal	Hanjin New Pore Container Ltd.	2009	-	Cantilever A-RMG	Tractor Chassis	Remote**
3	Pusan New Port	HPNT Terminal	Hyundai Pusan New Port Terminal Ltd.	2010				
4	Kaohsiung	KMCT (No.6)	Kao Ming Container Terminal Co.	2011				
5	Kaohsiung	Evergreen Terminal (No.5)	Evergreen Marine Terminal Co.	2010				
6	Taipei	TPCT	Taipei Port Container Terminal	2009				
7	Hong Kong	HIT Terminals (T6/7)	Hong Kong International Terminal Ltd.					
8	Singapore	Pasir Panjang Terminal (Phase-2)	PSA	2014	G	Cantilever A-RMG	Tractor Chassis	Remote**
9	Pusan New Port	BNCT	Bussan New Port Container Terminal Ltd.	2012	G	ASC	Manned-Shuttle	Remote**
10	Nagoya	TCB	Tobishima Minami Container Berth Co.	2008	G	A-RTG	AGV	Remote**

Note: Automated Process | Manual Process
*Site: G: Development on the greenfield land B: Redevelopment/ Renovation Project from conventional terminal
** Remote: Remote Final handoffs between the ASC and trucks are remotely controlled from the control room.

<u>Semi-Automated Terminal of Hong Kong port, Kaohsiung port, Taipei port, Pusan New Port</u>,

These terminals are designed, as their top priority issue, to utilize their limited terminal space as effectively as possible.

(1) Cantilever type Auto-RMG is adopted for container stacking instead of OHBC. Their stacking blocks are designed to be larger (width of 10-14 rows and height of 6-8 tiers), compared to European type ASC (width of 8-10 rows and height of 4-5 tiers).

(2) Yard blocks are parallel to the quay line.

(3) Conventional manned trailer is used for horizontal movement between the quay and yard.

(4) Container handoff between the RMG and trailer is performed in the area under cantilever of RMG by remote control from the control room. (Refer to **Figure 1.4-2**).

As these terminals all have high transshipment ratios (50-90%), the container handling capacity at the seaside end of the stacking block would be exceeded at peak times if a European type ASC were employed. On the other hand, Cantilever type RMGs are considered to be more flexible as the horizontal transport vehicle (manned trailers) can come close to the container stacking position alongside the length of the yard block, which can alleviate handling volume tasked to RMG.

As mentioned above, Cantilever type Auto-RMG terminal has the following advantages: (1) high density yard stacking is possible, (2) crane load at peak time in high transship container operation can be alleviated, (3) low initial investment (compare with AGV system). On the other hand, this type of terminal has the following weaknesses (mainly because this operation system forces both automated-RMG and manned trailers to work on the same lane of the yard block): (1) Safety risk for truck drivers as it is not easy for them to step aside when transferring containers, (2) Less labor-saving effects compared to a fully-automated container terminal as the scope of automation is limited.

Figure 1.4-2 Ooverview of HPNT (Pusan New Port)

Pasir Panjang Terminal (Phase 4) :

PSA constructed a conventional RTG terminal served by manned trailers in both phase-2 & phase-3. However, PSA opted for semi-automated operation in their phase-4/5 terminal. The three berths of their phase-4 terminal started operation in 2014.

The technical features of the terminal are as follows:

(1) Manned trailer system was adopted for seaside horizontal movement

(2) Cantilever type Auto-RMG System (46 units) is to be adopted for yard stacking

(3) Layout of yard block (Block size: width 10 rows, height 6 tiers) was designed in parallel to the quay line.

(4) Full automated truck loading system is applied for internal transport vehicles (manned trailer)

(5) Remote control system from control room was adopted for container transfer operation between the external trailer and Auto-RMG. (Refer to **Figure 1.4-3)**.

Source: PSA Home Page

Figure 1.4-3 Aerial view of Pasir Panjang Terminal (after Phase-4/5 completed)

<u>BNCT (Busan New Container Terminal)</u>

The Busan New Container Terminal of Pusan New Port started commercial operation (Phase 1) in 2012. The terminal design is based on the third generation automated terminals of Europe mentioned above. CMA/CGM took the lead in drafting the terminal plan. Main technical features of the terminal are as follows: (1) Manned shuttle carrier system was adopted for seaside horizontal transport, (2) ASC auto-stacking system was adopted for yard stacking with yard layout being perpendicular to the quay line, (3) Final handoffs between the crane and trucks are controlled remotely from the control room, while landside truck transfer is directly handled by ASC. (4) Container transfer between the yard and rail terminal is done by an internal trailer. (Refer to **Figure 1.4-4)**

This Terminal began Phase-1 commercial operation (handling capacity is 1.8 million TEU/year with 19 yard blocks) in 2012 and handled 1.10 million TEUs in 2013 after a little over one year since it went into operation. Phase-2 of the terminal project is now under construction and is scheduled to be completed in 2015. The handling capacity of the terminal after completion of phase-2 is expected to reach 2.7 million TEU/year (30 yard blocks).

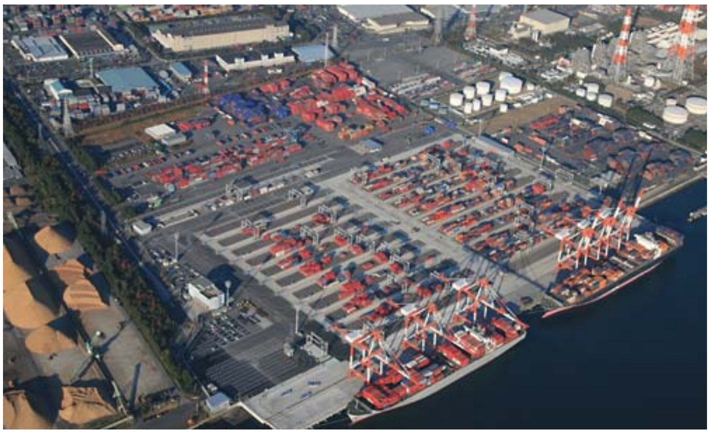
Source: Bussan New Port Container Terminal Home Page

Figure 1.4-4 Overview of BNCT (Pusan New Port)

TCB (Tobishima Container Berth)

TCB (Tobishima Container Berth) became the first fully automated container terminal in Asia in 2008. The terminal started automation of the stacking yard by introducing Automatic RTG System in 2005 and became a fully-automated terminal by introducing AGVs in 2008.

Key technical features of the terminal are as follows: 1) Fully-automated RTG is used for yard stacking operation, (2) Fully-automated AGV is used for seaside horizontal transport, (3) Final handoffs between Auto-RTG and external trucks are controlled remotely from the control room, while landside truck transfer is directly handled between trucks in each RTG-block and its corresponding A-RTG. For loading/unloading operation between seaside (AGVs) and landside transport vehicles, one AGV-lane and one Town-Chassis-lane are placed parallel under each RTG gantry (total of 8 rows). (4) Signal and blocking system is introduced for effective control of operation between AGV and external trucks as AGV and trucks are prohibited from entering a yard block at the same time for safety reasons. (Refer to **Figure 1.4-5**).



Source: Tobishima Container Berth Co. Ltd Home Page)

Figure 1.4-5 Aerial view of TCB (Nagoya Port)

Chapter 2. Major Examples of Automated Terminals

2.1 Overview

Automated Terminals currently in operation in various countries of the world can be classified into five types based on the yard stacking system; i.e. 1) ASC system, 2) Auto-STR System, 3) OHBC System, 4) Cantilever-Auto -RMG System, 5) Auto-RTG System.

Of these, 1) ASC system can be sub-classified as 1-a) ASC System with AGV, 1-b) ASC System with Manned-STR or Manned-Shuttle, and 1-c) ASC System with Auto-STR based on the difference in the type of Horizontal Transport carriers. In the 2) Auto-STR System, Auto-STR is used for both yard stacking and horizontal transport in the terminal (ex. Patric Terminal Brisbane). In both the 3) OHBC System and 4) Cantilever Auto-RMG System, Manned-trailer is used for horizontal transport between the quay and stacking yard (ex. Terminals in PSA and other Asian Terminal, i.e. Kaohsiung, Taipei, Hong Kong). In the 5) Auto-RTG System currently being operated in Nagoya Port, AGV is adopted for horizontal transport. Above classifications are illustrated in **Figure 2.1-1**.

In general, a fully-automated terminal employs an automated system which covers both yard stacking and horizontal transport, whereas in a semi-automated terminal only yard stacking is automated while horizontal transport remains a manual operation, i.e. manned STR/Shuttle or manned trailer.

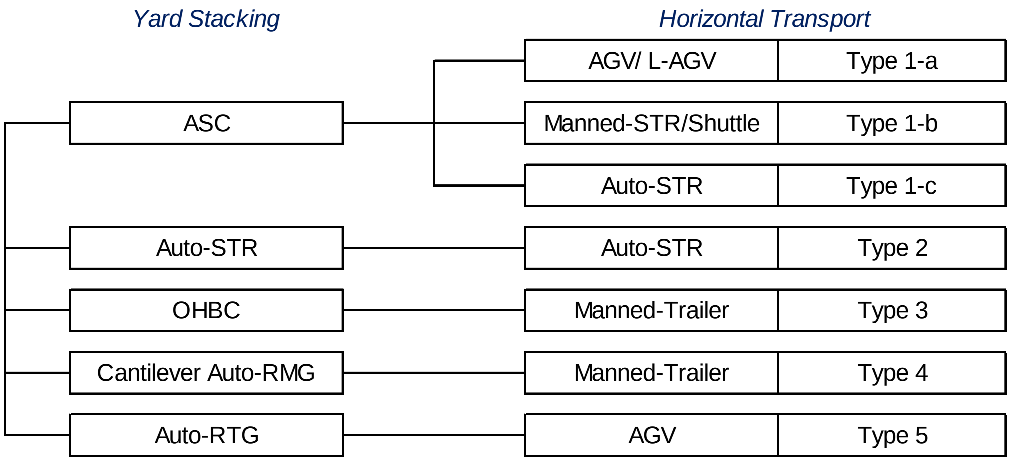


Figure 2.1-1 Classification of Automated Terminals

The Automated Terminals being operated worldwide are classified by the type and shown in **Figure 2.1-2**. Outlines of representative terminals of each category are given in this chapter.

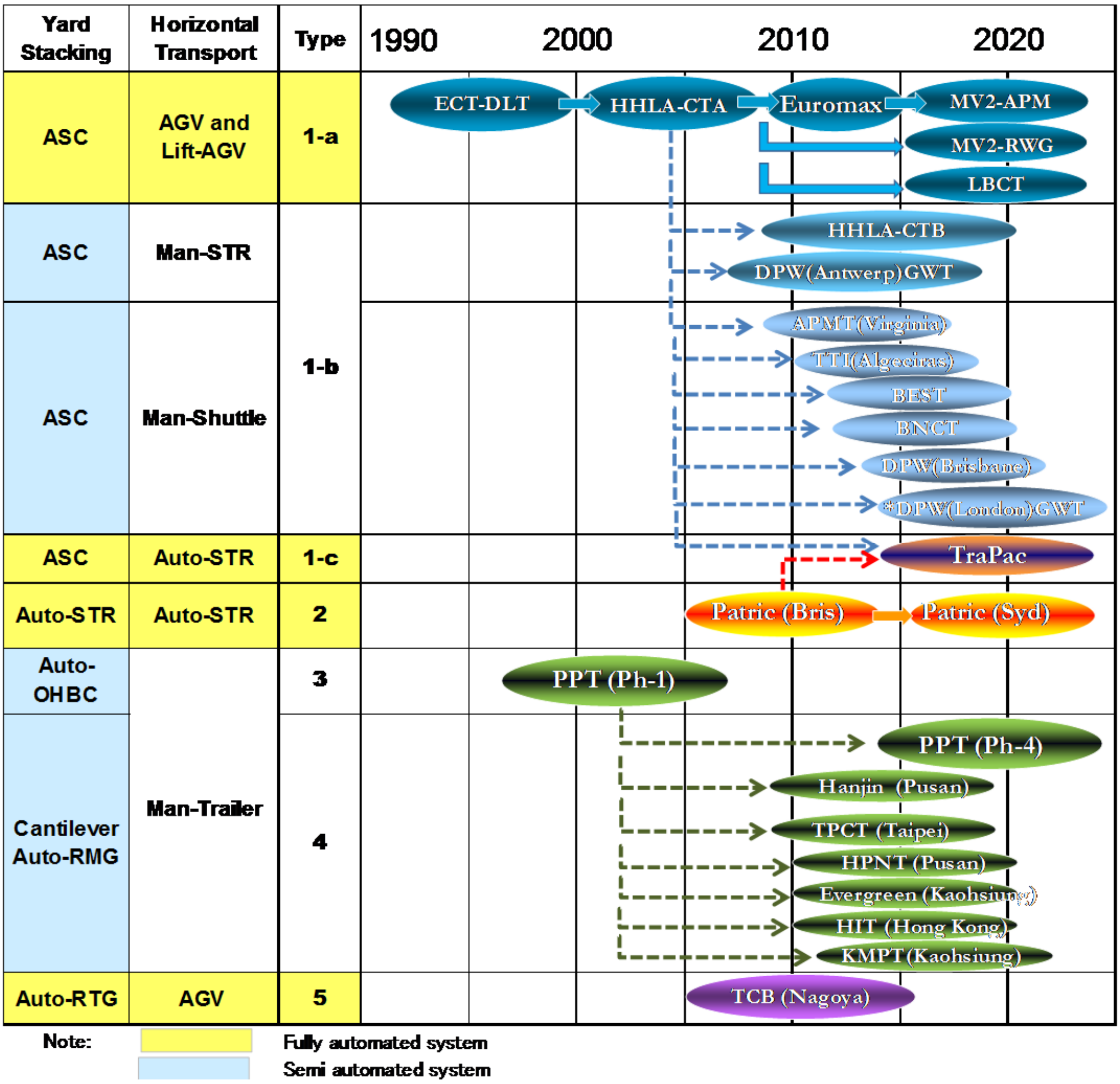
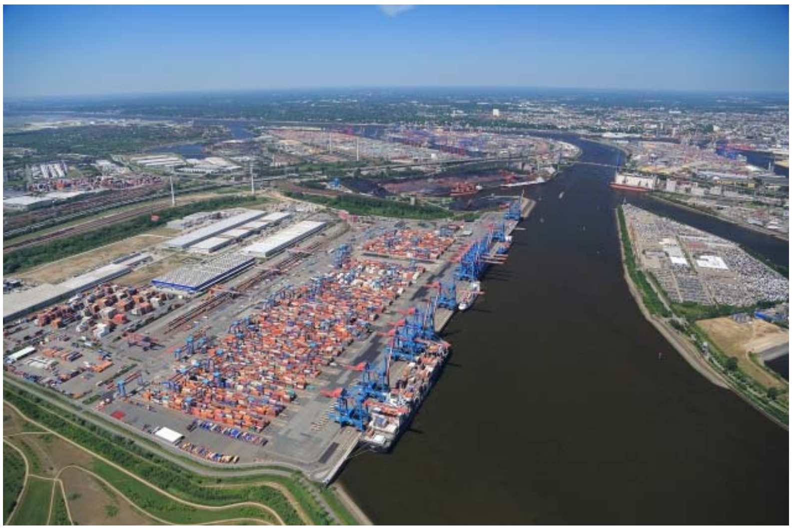


Figure 2.1-2 Evolution of Automated Terminal Development and Basic System

2.2 Container Terminal Altenwelder (CTA)

At Container Terminal Altenwelder (CTA), Phase I construction was completed (two berths along a quay of 800 m in length with a terminal capacity of 1.1 million TEUs) in October 2001 and operation began in April 2002. To accommodate the subsequent increase in container cargoes, Phase II terminal construction has also been completed. Currently, berth length is 1,400 m (three main berths) and terminal capacity is approximately 3.0 million TEUs. In 2013, 2.9 million TEUs, close to the terminal's maximum capacity, were handled here.

The concept for CTA's automation system is the same as that for the ECT-Delta Terminal at the Port of Rotterdam. At the time of commissioning in 2002, CTA became a center of attention as the world's most advanced automated terminal, surpassing even the ECT-Delta Terminal which was the first terminal in the world to introduce automated operation. CTA has had a major influence on the design and construction of subsequent automated terminals.



Source: HHLA Home Page

Figure 2.2-1 Aerial View of CTA

2.2.1 Outline of the Terminal

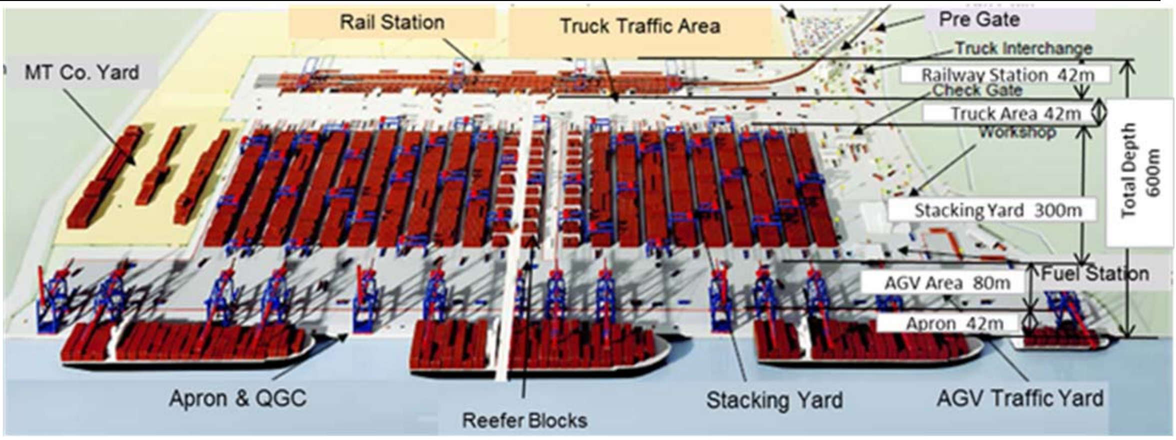
A particularly unique feature of this terminal's layout is the rail-mounted ASC loading/unloading system in the stacking yard, which is set perpendicular to the quay line. In addition, the AGV traffic lane on the ocean side and the truck traffic lane on the land side are completely separated by the automatic stacking yard. As a result, the AGV function is concentrated on transferring containers between the QGC and yard stacking cranes, thereby simplifying the traffic flow and making it easier to design an automation system for the AGVs. In addition containers unloaded on the quay can be transferred almost linearly along the shortest and most direct route with minimal detour paths, after which they are stored temporarily to await delivery to trucks from outside.

Table 2.2-1 Outline of Automated Terminal – CTA

Port Name			Hamburg Port
Terminal Name			CTA (Container Terminal Altenwerder)
Operator			HHLA (Hamburg Hafen und Largehaus Aktiengesellshaft GmbH)
Status of the Terminal Development			In Use
Starting Time of Automated Operation			2002
Main Facilities			
	Berth Length (m) (Water Depth)	Berth No.142 – 147 Berth No. 136 – 139	1,400m(-16.7m,4 Berths)
	Terminal Area (ha)		100 ha
	Yard	Yard Stacking Capacity (TEUs GS)	9,620
	Yard	Yard Stacking Capacity (Total TEUs)	38,480
	Yard	Yard Block Orientation	Perpendicular
	Yard	Number of Yard Stacking Blocks	26 Blocks
	Yard	Stacking Block Size (H x W x L(TEU))	4 Tiers (H) x 10 Rows (W) x 37 TEUs (L)
Equipment			
	QGC	Quantity (sets)	15 (14 Over Panamax + 1 Feeder)
	QGC	Outreach (row)	
	Yard Equipment (set)	ASC RMG (Cantilever)	52 (26 Larger Cranes + 26 Smaller Cranes) (on Double Track Rails)
	Yard Equipment (set)	STR	-
	Yard Equipment (set)	Shuttle	-
	Yard Equipment (set)	AGV	84 (Twin carrying system)
	Rail Terminal Crane		On site Rail Terminal: Cantilever Manned RMG 4 sets (6 Track)
Terminal Capacity / Throughput / Modal Split			
	Terminal Capacity (Million TEU/Year)		3.0MTEU
	Annual Throughput (Million TEU/Year)		2.9MTEU (in 2013)
	Modal Split	Transship (Feeder Vessel) (%)	Transship 42% + Berge 2% (Port of Hamburg in 2013)
	Modal Split	Railway (%)	22% (Port of Hamburg in 2013)
	Modal Split	Truck (%)	34% (Port of Hamburg in 2013)

2.2.2 Layout

CTA is constructed on rectangular-shaped land of 1,400m in length and 600m in depth. The apron (114m), AGV running area (42m), container stacking yard (300m), truck traffic area (64m) and intermodal railway terminal (114m) are located from seaside to landside (east to west). On the south-side of the stacking yard, empty container, special container and damaged container storage yards are allocated, which are not incorporated in the automated stacking system. On the north-side of the yard, terminal gate, AGV workshop, fuel station and administration office are laid out. Refueling of AGV is fully automatic. AGV test field is located in front of the AGV workshop (Refer to **Figure 2.2-2**).



Source: "Container Terminal Altenwerder Awaits First Container Giant"(HHLA) Port Technology International

Figure 2.2-2 CTA Terminal Facility Layout

2.2.3 Background of the Terminal Automation

The Port of Hamburg is a river port, located 100 km upstream from the mouth of the River Elbe. The original port was developed in the 14^{th} century as the shipping base for the Hanseatic League. Located on the eastern seaboard of the North Sea, this port has been serving as an important relay point for marine transport to and from Central and Eastern Europe, and also the Baltic States. It is also located at the intersection of some of Europe's main arteries for land transportation, such as railways and roads. The port has flourished as a result of maximizing these geographical advantages.

Container cargo traffic through this port has grown substantially since the 1980s because (1) Central and Eastern European countries were incorporated into the West's economy as the EU expanded, (2) the economies of countries bordering the Baltic Sea have expanded, (3) a number of European industrial capitals have successively started investing in East Asia, especially China, in pursuit of low-wage production bases, and (4) as a result, the container cargo traffic of European shipping lines has increased rapidly, with East Asia as the starting point.

On the other hand, this port's weak point was the limited land area available for its operations in the harbor, because this river port is located close to Hamburg City. It was forecast that considerable time and substantial costs would be incurred in carrying out reclamation and development work for a new terminal. This was the main reason for introduction of an automation system in the terminal development planning for the Port of Hamburg, according to a source who was involved in the CTA project. That is, the primary objective of terminal automation at this port was to realize an efficient operation system for high-density yard stacking by making more effective use of the limited space..

So-called "Nord Range" gateway ports in North-western Europe, including Hamburg, Bremen, Rotterdam and Antwerp, are constantly engaged in fierce competition for freight volume. In order to survive the tough competition, a key concern was achieving an efficient terminal that would be able to withstand price- and service-based competition for customers while being able to afford higher-waged dock workers.

Furthermore, as noted above, there were issues to be overcome such as the ever-increasing container freight demand and the limited port area at the Port of Hamburg. Accordingly, it was determined that integrating old terminals and constructing a large-scale terminal would be a driving factor in strengthening the port's competitive edge.

In order to fulfill the three objectives of (1) realizing a high-density yard stacking system by effectively utilizing the limited port space, (2) efficiently managing high labor costs, and (3) accommodating growing demand with a large-scale terminal, HHLA considered all relevant technological factors and carried out economic evaluations. Consequently, an automated terminal was planned with dual-trolley type QGCs, AGVs, and RMG type ASCs as its components, and the new terminal was constructed at Altenwrelder.

With respect to the Altenwerder Terminal (CTA), the first automated terminal at the Port of Hamburg, the Bundestag gave approval for a development study to be undertaken and information sessions for community residents were initiated. It took a long time, 16 years in all, to coordinate the interests of local residents, with the last resident finally vacating the planned construction site in 1998. In 1997, HHLA was selected by public tender as the operator for this project. Construction started in 1999 and the terminal opened in 2002.

2.2.4 Outline of the Automated System

Although the concept for this automated terminal was basically the same as that for the ECT-Delta Terminal (the first generation automated terminal) which started ten years before, the ECT system was comprehensively studied and its technical issues were resolved (See **Figure 2.2-3** and **Figure 2.2-4)**.

First, a dual-trolley system was adopted for QGCs in order to improve quay loading/unloading productivity compared to the ECT system, and to simplify the AGV traffic lanes. The second trolley is fully automated and a system whereby containers for QGCs and AGVs are transferred under the back reach was adopted.

Second, the stacking height was increased to a maximum four layers (1-over-4/5) to improve the yard's storage efficiency compared to the ECT system. Also, two automatic stacking cranes (ASCs) were placed for each block, and each crane can freely load/unload independently of the other crane's operation within the yard block, under a parent-and-child (2 tracks and 2 ASCs) system. Compared to the ECT system, in which containers are stored horizontally in an extensive yard, the yard is utilized more vertically for loading/unloading and storage under this system.

Third, containers are directly transferred to/from outside trucks at the transfer points closest to the land side in stacking blocks through remote operation of ASCs. This eliminates an extra process (in the ECT system) of moving containers from the landside end of the stacking block to the outside trailers at the transfer gates in manned-straddle carriers. At CTA, one operator remotely operates four or five ASCs, which substantially reduces labor compared to the ECT system, in which an operator must drive each straddle carrier.

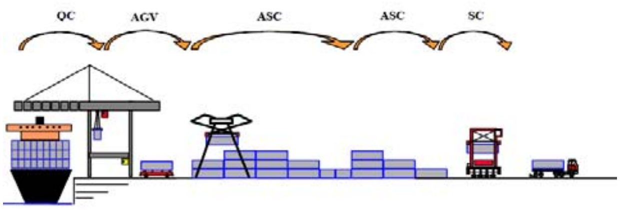


Figure 2.2-3 Container Flow in ECT-Delta Terminal

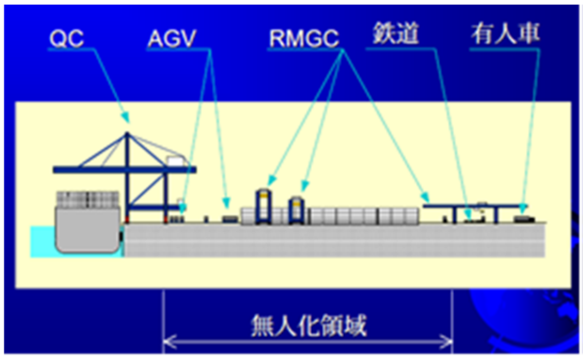


Figure 2.2-4 Container Flow in HHLA-CTA

Table 2.2-2 Outline of Automation System – CTA

Port Name				Hamburg Port
Terminal Name				CTA (Container Terminal Altenwerder)
Concept and Basic System of Automation				
	Basic System		Category	Full Automated
			Type of System	ASC System with AGV
	Details	QGC (Loading and Unloading)	Manual or Automation	(1st trolley) Manual , (2nd trolley) fully automated.
			Trolley System	Dual Trolley
			Lift System	Twin lift
			Container transfer point	under the back reach (4 lane)
		Horizontal Transport	Manual or Automation	Automated
			Vehicle	Conventional AGV
		Yard Stacking	Manual or Automation	Automated
			Stacking Crane	ASC (Larger Crane:1 over 5, Smaller Crane:1over 4)
		Truck Loading	Manual or Automation	Automatic (final hand off to the truck is controlled from the operator in the control center)
			Equipment	ASC (One Operator covers 3 -4 cranes)
	linkage to on-dock Rail Station			Manned Trailer
	Linkage to Barge Terminal			No dedicated barge berths

2.2.5 Effect of the Automation

Expected effects of terminal automation generally include: (1) reduction in terminal labor costs through labor saving (improved labor productivity), (2) maximized handling capacity in the limited space available at the port (high utilization of port area), (3) realization of stable container handling productivity (improved process predictability), (4) improved process liability (reduction in damage to terminal facilities and containers), (5) reduction in the number of industrial accidents, and (6) reduced labor costs during times when it is difficult to arrange workers, such as at night and on holidays. The extents of these factors' effects and priorities depend on a port's geographical and socio-economic environments.

Effects of Automation at CTA, Port of Hamburg

As previously noted, the Port of Hamburg has been developed over many centuries by utilizing its excellent location as a gateway to the Baltic States and to Central and Eastern European countries. (The port is also located at the heart of major consumption and production areas and at a strategic point for land transport, including both railways and roads). However, since it is a river port close to a major city, the space available for the port area is limited. In order to fully utilize its superior location while overcoming its weaknesses, it was imperative to maximize land productivity. Therefore, the automated terminals at CTA and CTB use an automated RMG system with a high-density stacking capacity instead of the conventional STR system. This is the most important benefit of automation at the Port of Hamburg.

CTA has a 1,400 m quay (15 QGCs and terminal area of 100 ha) and an annual capacity of 3.0 million TEUs. It is targeting annual berth productivity of 2,140 TEUs/m and annual yard productivity of 30,000 TEU/ha. In 2013, the actual volume was 2.9 million TEUs, very close to the planned capacity.

The second benefit of CTA's automation is the reduction in labor costs due to labor saving. With introduction of the totally automated terminal, the number of loading/unloading personnel was reduced to approximately 30-50% compared to a conventional manned-terminal with an STR system, according to a source who is involved with CTA.

2.3 Terminals in Maasvlakte-2 (APMT- MV2 and RWGT-MV2)

APMT (AP Moller Terminal) and RWGT (Rotterdam World Gateway Terminal) which were constructed at the Maasvlakte-2 (MV-2) District of Rotterdam port are state-of-the-art automated container terminals. Each terminal is introducing new technologies that were not available when CTA of Hamburg and the Euromax terminal in Rotterdam port went into service 12 years and 6 years ago, respectively.

2.3.1 Outline of the Terminal

Design aspects of APMT and RWGT such as scale, container handling capacity and concept of automation are similar. Outline of each terminal facility is summarized in **Table 2.3-1.**

（１） APMT

APMT has a quay of 1000m in length and a water depth of 20m and is equipped with twelve (12) Super Panamax QGCs with a 25-row outreach. The barge berth, which lies perpendicular to the main quay wall line, is 500m in length, 9.65m in depth and is equipped with two (2) barge QGCs. The terminal area is 86 ha and its annual container handling capacity is 2.7 million TEUs. Twenty-seven (27) yard stacking blocks are arranged perpendicular to the quay line, while 54 sets of ASC with one over five tier height are deployed. Container storage capacity is about 53,460TEUs. There are two railway cranes in the on-dock rail terminal located behind the terminal. Horizontal movements between the berth and the yard, and the yard and the railway terminal are operated by AGV.

（２） RWGT

RWGT has a quay of 1,150 m in length, a water depth of 20 m, and is equipped with eleven (11) Super Panamax QGCs with a 25-row outreach. The adjacent barge berth is 500m in length, 11m in depth and is equipped with 3 units of barge QOCs. The terminal area is 108 ha and its annual container handling capacity is 2.35 million TEUs. Twenty-five yard stacking blocks are arranged perpendicular to the alignment of the berth while 32 sets of ASC (one over five tier height) and 18 sets of Cantilever-RMG (also one over five) are deployed. Container storage capacity is about 47,880 TEUs. There are two railway cranes in the on-dock rail terminal located behind the terminal. Horizontal transport between the berth and the yard is operated by AGV, and that between the yard and the railway terminal is operated by “manned trailer with Cassette System.”

Table 2.3-1 Outline of Automated Terminal – Terminals in Maasvlakte-2

Item			Rotterdam World Gateway	APM Terminal
Port Name			Rotterdam (Maasvlakte-2)	
Terminal Name			Rotterdam World Gateway Terminal (RWG-MV2)	APM Terminal Rotterdam Maasvlakte-2 (APMT-MV2)
Operator			RWG (Rotterdam World Gateway) Terminal (DPW 40%)	APMT (AP Moller Terminals B.V)
Status of the Terminal Development			Commissioning Stage	in Operation
Starting Time of Automated Operation			2015	2015 (1st deep-sea Vessel called in February 2014)
Main Facilities				
	Berth Length (m)	Main Berth	1,150 (-20m)	Phase-1:1,000 (-20m) Final: 2,800m
		Barge Berth	550m (-11m)	500 m(-9.65m)
	Terminal Area (ha)		108 ha	86ha (Final 180 ha)
	Yard	Yard Stacking Capacity (TEUs GS)	9,576 (5,472 ASC+4,104 RMG)	10,692 (27 Blocks)
		Yard Stacking Capacity (Total TEUs)	47,880 (25 Blocks)	53,460 (27 Blocks)
		Yard Block Orientation	Perpendicular	Perpendicular
		Number of Yard Stacking Blocks	25 Blocks (16 ASC+9 RMG) (Final Stage:40 Blocks)	Phase-1: 13 Blocks (2015/E: 27 Blocks)
		Stacking Block Size (H x W x L)	ASC: 5 Tier x 9 Row x 38 TEU RMG: 5 Tier x 12 Row x 38 TEU	5 Tier x 9 Row x (43-44) TEU
Equipment				
	QGC	Quantity (sets)	11 sets +3 Barge Cr. (Final 19+4)	8 sets + 2 Barge Crane
		Outreach (row)	25 Rows	25 Rows
	Yard Equipment (set)	ASC	32 sets (Final 80 including RMG)	26 sets (2015/E: 54 sets)
		A-RMG (Cantilever)	18 sets	-
		STR	-	-
		Shuttle	-	-
		Battery Lift-AGV	AGV 59 sets	AGV: 37 sets (2015/E: 62 sets)
	Rail Terminal Crane		On site rail Terminal C-RMG 2 sets (6 tracks)：Manual	On site rail Terminal C-RMG 2 sets (4 tracks)：Manual
Terminal Capacity / Throughput / Modal Split				
	Terminal Capacity (1000 TEU/Year)		2.35 MTEU	2.7 MTEU (Final: 4.5 MTEU)
	Annual Throughput (1000 TEU/Year)		-	-
	Modal Split	Transship and Barge (%)	45%	45%～50%
		Railway (%)	20%	20%～15%
		Truck (%)	35% (35%超はPenalty)	35% (exceeding 35%:Penalty)

2.3.2 Layout

Layouts of both APMT and RWGT are comprised of the yard blocks perpendicular to the berth line and on-dock railway station behind the block, which is standard in the ASC System (Refer to **Figure 2.3-1** and **Figure 2.3-2**).

It is assumed that ratio of transshipment containers including barge transportation is extremely high in

APMT and RWGT. The government of the Netherlands controls the modal split of container terminals in Maasvlakte district as a part of the Sustainability Program in Rotterdam port which is aimed at realizing a sustainable and environmentally friendly port. The concession contract stipulates that each terminal must ensure that volume of cargo transported by trucks is less than 35% of the total or be subject to fines.

Based on the above, both terminals are designed on the condition that transshipment containers including barge transportation will account for more than 45% of the total. Hence, seaside container handling volume (which consists of containers discharged from an ocean going vessel and then stacked in the yard, and containers delivered from yard and then loaded onto a barge and vice versa) could exceed ASCs' handling capacity at the seaside end of the stacking blocks during peak times. To resolve this issue, RWGT introduced Cantilever Auto-RMGs at 9 of the 25 block instead of ASCs to increase the area of the interchange zone alongside the Cantilever-RMG blocks.

In these RMG blocks, as AGVs can move deeply into the stacking yard along the interchange zone under the cantilever, RMG can concentrate on stacking and interchange operation. Therefore, the workload of the stacking cranes is expected to be lessened by this new combined system.

In APMT, on the other hand, three (3) stacking blocks beside the barge berth are dedicated to barge container stacking operation. In these blocks, interchange of barge containers between AGVs and ASCs is possible at both ends (landside and seaside) of stacking blocks. Thanks to this design, the workload at the seaside end can be lessened. In addition, some stacking blocks close to the railway station are dedicated to railway container stacking operation. Landside end of these blocks is designed for interchange zones between ASCs and AGVs moving between the stacking yard and railway terminal for railway containers. (See **Figure 2.3-1**)

Source: APM Terminal (Rotterdam MV-2) Home Page

Figure 2.3-1 Layout Plan of APMT-MV2

Source: RWG Terminal Home Page

Figure 2.3-2 Layout Plan of RWGT-MV2

Source: RWG Terminal Home Page

Figure 2.3-3 ASC and Cantilever A-RMG with Racks at RWGT-MV2

2.3.3 Outline of the Automated System

A similar automation system has been introduced at each terminal. Features of the system are summarized below;

（１） Remote Operation of QGCs

In both AMPT and RWGT, double-trolley system is applied to QGCs with the 2nd trolleys being fully automated. For the 1st trolley, semi-automatic operation is realized by a combination of partially automated operation and remotely controlled operation from the central control room for the final handoff of containers at the hold. In these QGCs, crane operators are completely released from cabin work. It can be said that the remote control of the 1st trolley marks an evolutionary step in the development of QGC automation. This remote control system of 1st trolley will pave the way for full automation of the 1st trolley, which has been a longstanding issue.

In APMT's case, operator's cabins are not installed on the QGCs.

The primary aim of this system is to release operators from cabin work and increase the efficiency of loading and unloading productivity by reducing operator's physical stress. As of now, one operator is assigned to one quay crane (first trolley) as a remote controller at both terminals.

（２） Introduction of Lift AGV System

Lift-AGV (L-AGV) is introduced for horizontal transport between the quay and yard in APMT and RWGT, the first time an L-AGV system has been introduced in the world. The advantage of the L-AGV system is that ASC and AGV operations are independent of each other (Decoupling). Compared to conventional AGV operation, a 30%~40% reduction in the AGV's idling time while waiting at the transfer lane of a stacking block can be expected by introducing the L-AGV system. Accordingly, the cost for installation of racks at the transfer lanes at the seaside end of yard blocks can be recovered (see **Figure 2.3-3**).

（3） Connection to the On-dock Railway Terminal

In addition to the above, APMT-MV2 adopted the L-AGV system between the stacking yard and on-dock railway terminal. By introducing the L-AGV system to this transportation process, all the horizontal transport in the APMT-MV2 is fully automated by connecting activities; i.e. loading and unloading from/ to ship or barge at the quay, 2) yard stacking and 3) block train loading/ unloading operation by railway crane, and so on. In RWGT, horizontal transport between yard and railway station is done by a Cassette Manned-trailer System.

（4） Green Terminal

Battery-driven Lift-AGV system (BL-AGV) is adopted in both APMT-MV2 and RWGT-MV2. Particularly at APMT, all the container handling equipment from quay cranes through AGV, ASC and AGV till railway crane are automated, resulting in a zero emission container terminal (Green Terminal). There are two Battery Charging Stations in each terminal and thus the initial investment cost in introducing the BL-AGV system is prone to be high. However, it is considered that the initial cost will be recovered due to savings in energy costs and increased energy efficiency of the battery driven system.

（5） Introduction of Fully Automated Truck Loading System

Fully Automatic Truck Loading System (FATL System) was adopted in both APMT and RWGT. FATL System was first introduced in Antwerp Gateway Terminal in 2007 which is now over 90% fully automated. By application of this system, APMT plans to conduct all the truck loading operation for 13 yard blocks by 2 operators, and RWGT plans to do it in 25 blocks by 3 operators.

Outline of automation terminal in APMT and RWGT is given in **Table 2.3-2.**

Table 2.3-2 Outline of Automation – Terminals in Maasvlakte-2

Port Name			Rotterdam World Gateway Terminal (RWG-MV2)	APM Terminal Rotterdam Maasvlakte-2 (APMT-MV2)
Terminal Name			RWG (Rotterdam World Gateway) Terminal	APMT (AP Moller Terminals B.V)
Concept and Basic System of Automation				
Basic System		Category	Full Automatic	Full Automatic
		Type of System	ASC System with Lift-AGV	ASC System with Lift-AGV
Details	QGC (Loading and Unloading)	Manual or Automation	Main Crane: 1st trolley is partially automated and remote controlled, and 2nd trolley is fully automated. Barge Crane: Manual operation (Single Trolley and single lift system).	
		Trolley System	Main Crane: Dual trolley, Barge Crane: Single trolley	
		Lift System	Main Crane: Twin, Tandem (future plan), Barge Crane: Single	
		Container transfer point	under the back reach (7 lane)	under the back reach (6+1 lane)
	Horizontal Transport	Manual or Automation	Automated	
		Vehicle	Battery and Lift- A G V	
	Yard Stacking	Manual or Automation	Automated	
		Stacking Crane	ASC/A-RMG (1-over-5:Single Lift)	ASC (1-over-5 :Single Lift)
	Truck Loading	Manual or Automation	Fully automated truck loading (full automatic rate 90%)	
		Equipment	ASC (3 Remote Operators for 25 Blocks)	ASC (2 Remote operators for 13 blocks in Phase-1)
Linkage to on-dock Rail Station			Manned cassette trailer are used to/from on site rail terminal	AGVs are used for transportation to/from on-site rail terminal
Linkage to Barge Terminal			Lift-AGVs are used for horizontal transportation to/from Barge Berths	

2.3.4 Effect of the Automation

Four automated terminals in the Port of Rotterdam, EDT-Delta Terminals, Euromax Terminal, APMT-MV-2 and RWGT-MV2, are all mega-terminals which have been constructed on Greenfield. From the viewpoint of investment recovery, these mega terminals have an advantage over relatively medium scale automated terminals. In Rotterdam, these automated terminals have been expanded to offshore due to a shortage of land resources caused by the rapid increase of container traffic between Europe and Asia. Difficulty for large numbers of workers to commute to the increasingly distant terminals is one of the important driving forces for terminal automation.

The major effects of automation in the Port of Rotterdam are considered to be the following;

(1) Elimination of huge labor costs required to run a large-scale container terminal
(2) Effective management of a large-scale container terminal
(3) Increased cargo handling efficiency
(4) Less damage to containers
(5) Improved safety conditions for laborers
(6) Better working environment

Without automation, it would be necessary to hire many laborers in order to manage such a large-scale terminal. Loading and unloading works take place both day and night and labor costs in Holland are high. Due to the introduction of automation, labor costs have been greatly reduced.

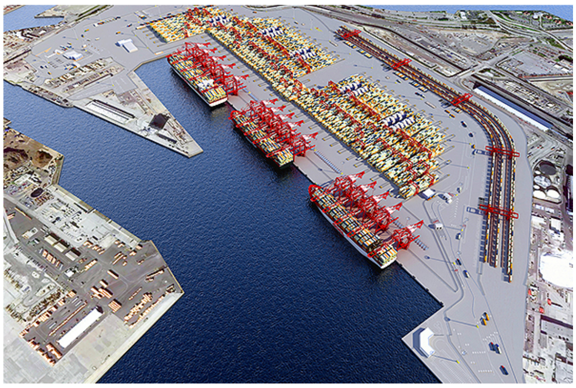
If manual operation were adopted for these large-scale terminals in Rotterdam, the availability of a large number of workers is also another concern for sustaining these mega terminals in the Port, as well as limiting labor costs in countries such as Holland where wages are high. This would be particularly true during nighttime operations and holidays when yard marshaling is done and workers would be paid overtime rates. However, operators in the Port of Rotterdam were successfully able to reduce their labor needs and prevent exorbitant labor costs by introducing automation at their terminals.

Terminal operators in the Port of Rotterdam are now focusing on ways to improve the technical or management aspects of their automated systems, rather than whether or not automation should be implemented.

2.4 Long Beach Container Terminal (LBCT)

Automation of LBCT (Long Beach Container Terminal) was introduced under the Middle Harbor Redevelopment Project to integrate and upgrade the aging, irregularly shaped marine container terminals into one regular-shaped facility by reclaiming Pier E and Pier F of the Port of Long Beach. This project LBCT was also upgraded from a traditional on-chassis system and RTG system to a fully automated system using ASC supported by battery driven AGVs to increase terminal capacity, and reduce both operational costs and the impact on the environment (See **Figure 2.4-1)**.

Operational rights to this integrated facility, which had previously been leased to Hyundai Merchant Marine (Pier E) and the Orient Overseas Container Line (OOCL: Pier F), were newly granted as a 40-year concession to OOCL and its subsidiary in the Long Beach Container Terminal (LBCT). The lease agreement was signed between the parties concerned in 2012. In this contract, infrastructure investment (landfill, land reclamation and quay upgrade, improvement of water access, significant expansion such as on-dock rail yard) is the responsibility of the Port of Long Beach (POLB) whereas OOCL provides part of the investment funds for automated terminal facilities including cargo handling equipment. Phase-1 of the project will begin operation in the 3rd quarter of 2015 while the final stage (Phase-2) is planned to be completed by 2019.



Source: Port of Long Beach Home Page

Figure 2.4-1 Aerial View of LBCT Middle Harbor in 2012 (Left) and 2019 (Right)

2.4.1 Outline of the Terminal

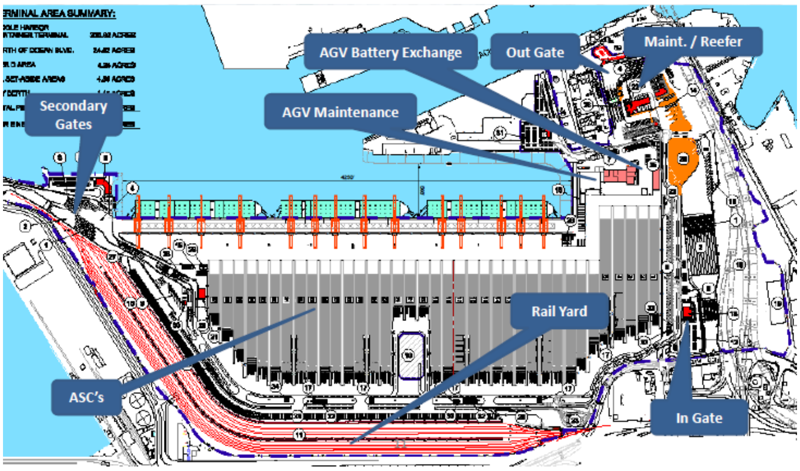
Facilities related to Phase-1 of the project have already been completed, and commissioning of the entire system is scheduled for the 3rd quarter of 2015.

The terminal facilities of Phase-1 include a 420m quay wall (final 1,275m) with a water depth of 16m, and are equipped with 6 units (18 units will eventually be available) of Super Panamax Cranes with a 24 row outreach. Terminal area is 108 ha, and container handling capacity is 1.6 million TEUs (Final3.3 million TEUs). Sixteen (16) yard stacking blocks (eventually there will be 37 blocks) are laid at right angles to the quay wall line while there are thirty-two (32) sets of ASC (70 sets will be available in the final stage) with one over five (1 over 5) tier height. Container yard has a storage capacity of approximately 34,000TEUs (final target is 79,000TEUs) (Refer to **Table 2.4-1**).

Table 2.4-1 Outline of Automated Terminal-LBCT

Port Name			Long Beach Port (Middle Harbor)
Terminal Name			LBCT (Long Beach Container Terminal)
Operator			Long Beach Container Terminal, LLC
Status of the Terminal Development			Commissioning Stage
Starting Time of Automated Operation			The 3rd quarter in 2015 (Phase1)
Main Facilities			
	Berth Length (m) (Water Depth)	Current Status	420m (-15.2m / -16.8m)
		Final Stage	1,275m (3 berths for 13,000TEU Vessels)
	Terminal Area (ha)		108 ha
	Yard	Yard Stacking Capacity (TEUs GS)	about 6,912 TEUs (Phase-1), about15,984 TEUs (Phase-2)
		Yard Stacking Capacity (Total TEUs)	about 34,560 TEUs (Phase-1), about 79,920 TEUs (Phase-2)
		Yard Block Orientation	Perpendicular
		Number of Yard Stacking Blocks	16 Blocks (Phase-1), 37 Blocks (Phase-2)
		Stacking Block Size (H x W x L(TEU))	5 Tiers x (9~10) Rows x 48 TEUs(varies depend on blocks)
Equipment			
	QGC	Quantity (sets)	6 sets (Ph-ase-1), 18 sets(Phase-2)
		Outreach (row)	24 Rows
	Yard Equipment (set)	ASC	32 sets（Ph-1), 70 sets (Ph-2)
		RMG (Cantilever)	-
		STR	-
		Shuttle	-
		AGV	38 sets (Ph-1), 72 sets (Ph-2)
	Rail Terminal Crane		6 sets x 8 tracks wide span Cantilever RMG (manual)
Terminal Capacity / Throughput / Modal Split			
	Terminal Capacity (1000 TEU/Year)		1.6 MTEU(Ph-1), 3.3MTEU (Ph-2)
	Annual Throughput (1000 TEY/Year)		-
	Modal Split	Transship and Barge (%)	0
		Railway (%)	35% (1.1MilTEU capacity)
		Truck (%)	65%

2.4.2 Layout



Source: "Middle Harbor Terminal" (TOC-Europe: June 24,2014)

Figure 2.4-2 Yard Layout of Old Middle Harbor (upper) and New Berth (lower) of LBCT

2.4.3 Outline of the Automated System

The terminal is designed based on the same concept applied in 2nd generation European-type Automated Terminals such as CTA and Euromax. In contrast to the recently developed terminals in Rotterdam Maasvlakte 2 (the 4th generation), which adopted an Lift-AGV system, LBCT applied a conventional AGV system. Basic concept of LBCT's automated system is as follows (Refer to **Table 2.4-2**):

(1) <u>Semi automated QGCs have double trolley with tandem/ twin lift.</u>
The 1st trolley can load/ unload containers from a ship to the lashing platform in tandem or twin lift operation by exchanging each type of spreader. The twin or single lift operations of the 2nd trolley, which transfers a container from the lashing platform to AGV under the back-reach (4Tracks), are fully automated. On the raised lashing platform, checkers undertake container identification for unloading containers and corning.

(2) <u>Conventional AGV (battery driven) has been used for seaside horizontal transport.</u> Battery charging for AGV is self-propelled into one of two battery charging stations in the terminal, where a used battery set is automatically replaced with a charged one. AGVs in this terminal are used only for horizontal transport between the quay and yard.

(3) <u>Yard stacking is carried out automatically by ASC (1 over 5).</u> ASC's rail is a one-track system modeled after Euromax. Except for extremely short blocks, 2 identical cranes are installed in each stacking block. The Twin System is reportedly planned for the ASC. Considering its rated load at 41Tons, the scope of the twin lift operation is considered to be limited (i.e. only for empty containers).

(4) <u>Fully automatic truck loading system is applied for truck loading / unloading</u> at the land-side edge

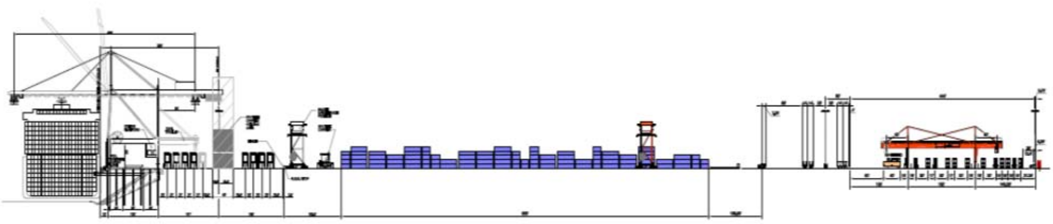
of the ASC. Transportation between the stacking yard and train terminal is planned to be done by internal manned trailers.

Table 2.4-2 Outline of Automation System - LBCT

Port Name				Long Beach Port (Middle Harbor)
Terminal Name				LBCT (Long Beach Container Terminal)
Concept and Basic System of Automation				
	Basic System		Category	Full Automated
			Type of System	ASC System with AGV
	Details	QGC (Loading and Unloading)	Trolley System	Dual Trolley (1st Trolley: Manual (partially automated), 2nd Trolley: fully automated
			Lift System	1st Trolley: Tandem/Twin, 2nd Trolley: Twin/Single
			Container transfer point	Under the back reach
		Horizontal Transport	Manual or Automation	Automated
			Vehicle	Battery Conventional AGV (twin container transport)
		Yard Stacking	Manual or Automation	Automated（Single Lift: Future plan Twin-Lift）
			Stacking Crane	ASC (1over 5)
		Truck Loading	Manual or Automation	Full Automatic Truck Loading
			Equipment	ASC (at the landside end of stacking block)
	linkage to on-dock Rail Station			Manned Trailer (380 Buffer slots at Railway Terminal)
	Linkage to Barge Terminal			No barge operation

Basic concept of container movement in LBCT is shown in **Figure 2.4-3**.

As can be seen from this figure, the concept of the automated system follows the European-type automated terminals of the 2nd generation.



Source: "Middle Harbor Terminal" (TOC-Europe: June 24,2014)

Figure 2.4-3 Basic Concept of Container Movement in LBCT

2.4.4 Effect of the Automation

The major effects of the automation of LBCT are considered to be 1) terminal capacity and efficiency improvement, 2) reduction of labor costs, 3) reduction of impact (carbon emissions) to the environment. Capacity and productivity targets in future are shown below;

（1） Target of Terminal Capacity：3.3MTEUs

（2） Target of Container Handling Productivity：

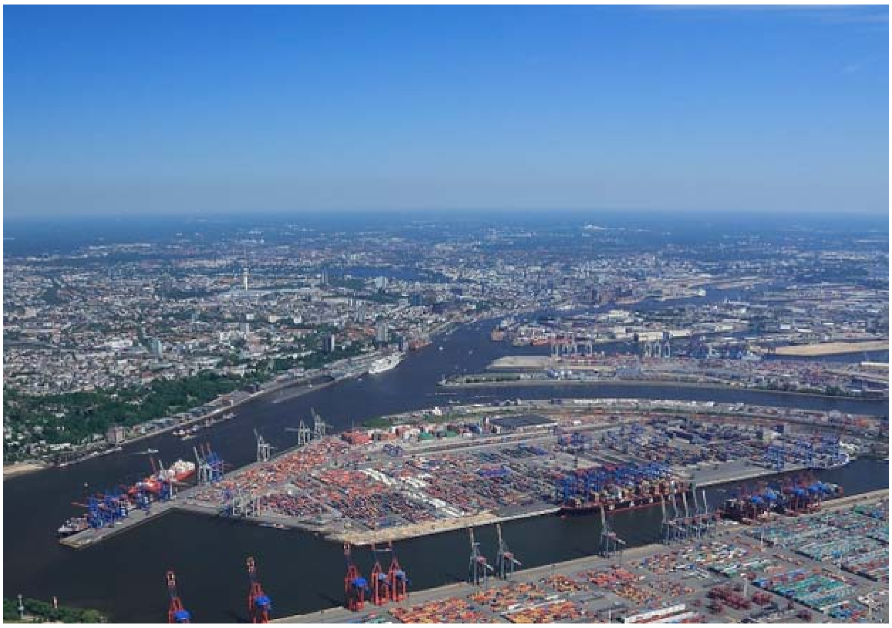
1) Seaside Productivity：2 Vessels: 200 net moves per hour (each vessel), 1 Vessel: 100 net moves per hour, and total 500 net moves per hour
2) Landside Productivity：487 net moves per hour (Outside Truck and Rail)

2.5 Container Terminal Burchardkai (CTB)

Container Terminal Burchardkai (CTB) is the second automated terminal developed in the Port of Hamburg. Unlike the CTA, which is a highly automated terminal constructed as a Geenfield Project, CTB was developed as a large-scale Renovation project (brownfield project) using an existing terminal; hence, the two terminals are noticeably different in form.

2.5.1 Outline of Terminal and Background of the Terminal Automation

CTB has a total quay length of 2,850 m and a total area of 140 ha. In 2005, before automation, the annual container handling capacity was 2.6 million TEUs and the actual volume reached 2.57 million TEU. The container handling system in place prior to automation of the terminal was a conventional STR system with 120 STRs in use. On the southern side of the terminal (lower side in the photo below) is a 1,400 m long deep-water quay. Two quays (1,000 m and 450 m) are located on the northern side (upper side and left side in photo below).



Source: HHLA Home Page

Figure 2.5-1 Panoramic View of CTB

Since the 2000s, HHLA container handling volume at the Port of Hamburg has been increasing by 20% a year. In light of these circumstances, HHLA needed to increase the container handling capacity of the port similar to the CTA, and it began considering a plan for substantially expanding CTB, which was the oldest terminal in service at that time. The feasibility study, which took three years, was completed in 2002, and the project plan was finished at the end of 2004.

The ultimate objective of the CTB expansion plan was to increase handling capacity to 5.2 million TEUs, or double the current capacity of 2.6 million TEUs without having to expand the existing site. For this purpose, the STR system had limitations. Thus, it was decided to create a high-density yard stacking system by adopting the RMG-type ASC system; the same system adopted at CTA. The existing CTB layout would have to be substantially modified to enable installation of an automated stacking yard. Improvements were gradually implemented from 2005, leading to partial use by 2009. To date, Phase 1 of the project has been completed. The automated section in Phase 1 included eight (8) blocks of the yard. Currently, combined use of these automated blocks and the existing STR areas is employed for operating the terminal. The expansion project's key objectives are to (1) make the quay deeper, expand it outward, and install large-scale quay cranes to cater for larger vessels, (2) move and reinforce the railway terminal, (3) relocate terminal facilities such as the yard, gates, and CFS, and (4) install the automated stacking yard and introduce the automation equipment.

As of 2013, the railway terminal had been reinforced, CFS had been relocated, the empty container yard had been moved and the automated stacking yard and related handling equipment (ASCs) had been installed (for eight blocks). Together with the Tollerot Terminal, the container handing capacity is 5.5 million TEU and the container handling volume had reached 4.1 million TEU (Drewry: Global Container Terminal Operators (2014)).

Outline of terminal facilities is shown in **Table 2.5-1.**

Table 2.5-1 Outline of Automated Terminal - CTB

Port Name			Hamburg Port
Terminal Name			CTB (CT Burchardkai)
Operator			HHLA (Hamburg Hafen und Largehaus Aktiengesellshaft GmbH)
Status of the Terminal Development			In Use together with STR Terminal
Starting Time of Automated Operation			2009
Main Facilities			
	Berth Length (m) (Water Depth)	Main Berth	2,850m (-15.2m Draft)
		North Berth	n.a.
	Terminal Area (ha)		140 ha
	Yard	Yard Stacking Capacity (TEUs GS)	Total 17,000 (including ASC and STR Yards)
		Yard Stacking Capacity (Total TEUs)	51,000 (Average: 3 tiers)
		Yard Block Orientation	Perpendicular
		Number of Yard Stacking Blocks	8 (final 30)
		Stacking Block Size (H x W x L(TEU))	5 Tiers (H) x 10 Rows (W) x 44 TEUs (L)
Equipment			
	QGC	Quantity (sets)	25
		Outreach (row)	
	Yard Equipment (set)	ASC	24 sets (final 90 sets)
		RMG (Cantilever)	-
		Manned STR	n.a.
		Shuttle	-
		AGV	-
	Rail Terminal Crane		7 sets
Terminal Capacity / Throughput / Modal Split			
	Terminal Capacity (Million TEU/Year)		final 5.2 MTEU
	Annual Throughput (Million TEU/Year)		4.1MTEUs (in 2013 including Tollerot Terminnal)
	Modal Split	Transship (Feeder Vessel) (%)	Transship 42% + Berge 2% (Port of Hamburg in 2013)
		Railway (%)	22% (Port of Hamburg in 2013)
		Truck (%)	34% (Port of Hamburg in 2013)

2.5.2 Outline of the Automated System

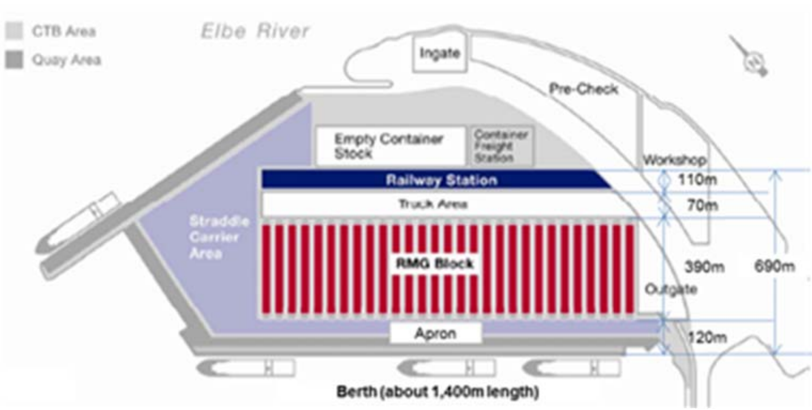
Although CTB's automated system was basically designed based on the CTA automation concept, several design features are different due to differences in available the land shape and size, required terminal capacity, quay location and operational environment (See **Table 2.5-2)**.

Difference of design features can be seen in; 1) Layout of the terminal, 2) Horizontal transport between the quay and yard, 3) Container loading to the external trucks and linkage to the railway terminal, 4) Size of ASC yard blocks, and 5) Dual use of ASC and conventional STR operations. Short explanation of each item is given below:

Table 2.5-2 Outline of Automation System - CTB

Port Name			Hamburg Port
Terminal Name			CTB (Container Terminal Burchardkai)
Concept and Basic System of Automation			
Basic System		Category	Semi Automated
		Type of System	ASC System with Manned STR
Details	QGC (Main Berth)	Manual or Automation	Total 25 sets (Main Berth 12 Sets)
		Trolley System	Dual Trolley
		Lift System	1st Trolley: Tandem/Twin, 2nd Trolley: Twin/Single
		Container transfer point	under the back reach / under the Gantry
	Horizontal Transport	Manual or Automation	Manual
		Vehicle	Manned Straddle Carrier (STR)
	Yard Stacking	Manual or Automation	Automated
		Stacking Crane	ASC (3 ASCs per Block)
	Truck Loading	Manual or Automation	Automatic (final hand off to the truck is controlled from the operator in the control center)
		Equipment	ASC
linkage to on-dock Rail Station			Manned Straddle Carrie (STR)
Linkage to Barge Terminal			No dedicated barge berths

(1) Layout of Terminal



Source: HHLA

Figure 2.5-2 CTB Layout Plan (Final Stage)

<u>**The most prominent** feature of CTB's automated system is its layout</u>. In CTB's layout, placed behind the front 1,400 m (-16.5 m water depth) quay are (1) an apron approximately 120 m from the quay line (scheduled to be converted into an AGV traffic area in due course), (2) ASC yard with a depth of approximately 390 m (including block length: 280 m (40 TEU), seaside transfer area length: 70 m, landside transfer area length: 40 m on the land side), (3) approximately 70 m of the truck traffic area and (4) approximately 110 m of the railway terminal. The basic arrangement of the layout is the same as that of CTA. However, this is the only area to be automated at CTB. The north quay and the yard behind it will remain as an STR terminal. Thus, CTB represents a unique automated terminal plan which combinesan automated terminal with a conventional STR terminal.

After the renovations are completed, CFS, the empty container yard and gate facilities will be located behind the railway terminal at CTB (see **Figure 2.5-2)**.

(2) Horizontal Transport between the Quay and Yard

The second feature of CTB is that seaside horizontal transport is undertaken by the existing manned STR instead of AGVs in the initial stage. This is assumed to be due to several reasons, including effective use of the existing STR, and the union's resistance to any rapid labor reduction by converting the conventional system to an automated system. However, according to HHLA, the most important reason for adopting the STR system for seaside horizontal transport in the early stage of the project is that it is the most efficient way to convert the existing STR system to the automated system. First the yard stacking process is converted to the ASC system when that is completed the horizontal transport process will be converted to the AGV system. If both processes were carried out berth by berth, it would take six months to wind down operation in each berth for installation of transponders inside the traffic area and for adjusting the AGV system.

Going forward, HHLA plans to use AGVs and has secured the traffic area for them (approximately 120 m from the quay to the yard block) in the new CTB layout, which is similar to that of CTA (see **Figure 2.5-2**).

Source: HHLA Home Page

Figure 2.5-3 Quayside Operation by Manned STR

(3) Container Truck Loading and Link to the Railway Terminal

The third feature is that containers are loaded on outside trucks (vice versa) through remote operation from the control room, the same as CTA. However, unlike the situation at CTA, containers are transported to the railway terminal using the manned STR. Hence, on the land side end of each yard block, there are four lanes for outside trucks loading and three lanes for interchange STR. This arrangement requires drivers to take special care since the STR carrying containers to the railway and the traffic for outside trucks intersect.

Source: HHLA Home Page

Figure 2.5-4 ASC in CTB Automated Yard

(4) Concept of the Yard Block Design

The fourth feature is the design concept for the yard blocks. For CTB, a total of 30 stacking blocks will be constructed in due course, with a total length of 44 TEU (approximately 380 m) and height of five tiers (1-over-5), which will be larger and higher than those at CTA. Therefore, three ASCs will be allocated for each block to handle a large number of containers for stacking.

(5) Automated Stacking Cranes and Safety Measures

For CTB, 90 ASCs are planned to be installed across all 30 blocks at the final stage. Since the stack height will be increased, the ASCs' overall height will be greater. Regarding total weight, the inside crane weighs 300 tons, heavier than CTA's ASC. Capabilities such as traveling speed, traversing speed and hoisting speed will be the same as those of CTA's ASCs.

As explained above, manned STRs are used for horizontal transport at CTB, and comprehensive safety measures are implemented. In the container transfer area at the seaside end of ASC blocks, traffic signals are installed at points where STR drivers can see them. When an ASC is handling containers in a lane within the transfer area, or if an ASC is preparing to enter the transfer area, a signal turns red, preventing an STR from entering the transfer lane. Even within the same transfer area in a block, if an ASC is working in, or seeking to enter, a different lane, the signal does not turn red. If an STR is in the lane, the ASC is blocked from entering that lane. As a safety measure on the land side transfer area at the landside end of the ASC block, the same methods are used.

(6) Implementation Procedures of the CTB Renovation Project

The fifth feature of CTB is that this is not a Greenfield construction but Redevelopment project for updating an existing terminal. Therefore, full attention was paid to gradually converting the container handling system without substantially impairing the terminal's operation and capacity during the project implementation process. For this purpose, relocation of railway facilities, CFS, empty container yard, etc. was implemented in the early stage of the project so as to secure the construction site for the automated stacking blocks.

2.5.3 Current Status of CTB Automation

Installation of quay facilities, relocation and reinforcement of the railway terminal, relocation of CFS and the empty container yard, as well as installation of the automated stacking yard and related handling equipment were completed in 2014, as noted above. With respect to automation of container stacking in the yard, the first eight (8) of a total thirty (30) blocks have been constructed. Currently-twenty-four (24) ASC are in use.

2.5.4 Effect of the Automation

For CTB, the plan is to double handling capacity from the 2.6 million TEUs (with terminal area of 140 ha) under the current STR system to 5.2 million TEUs by introducing the ASC system. With this capacity increase, the berth's annual productivity rate will reach 1,825 TEUs/m/year.

Regarding reduction of the terminal's labor costs, the effect is limited to labor saving due to automation of yard stacking because the STR system is still being used for seaside horizontal transport for the medium term. The labor cost reduction is not expected to be as large as that achieved at CTA with its full automation.

2.6 DPW London Gateway Terminal (London GWT)

DPW-LGWT, which started commercial operation in 2013, is the latest semi-automated terminal which adopts a manned shuttle carrier system for sea-side horizontal transport. Located 20 km upstream from the Thames River estuary, the port literally serves as the gateway to the city of London. On the site of the former petroleum refining plant of Royal Dutch Shell, DPW invested 1.5 Billion Pounds for infrastructure (land reclamation, dredging access channel, replacement of contaminated soil, pulling railway, construction of highway interchange) and for large-scale container terminal development. This massive investment was undertaken entirely by DPW. According to the master plan of the port, a huge Logistics Park will be constructed directly behind the terminal.

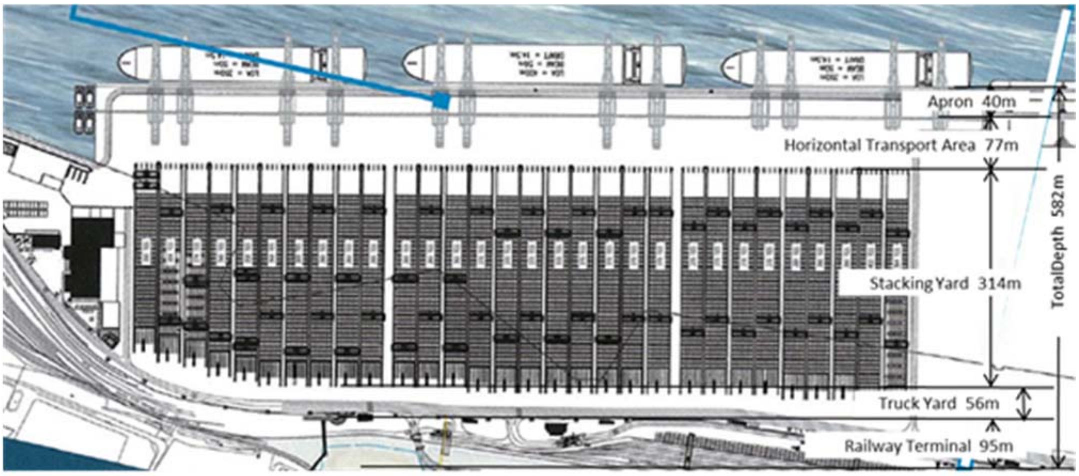
2.6.1 Outline of the Terminal

As of January 2015, DPW-LGWT has a quay length of 1,250m (3 Bath) with a water depth of 17m, and is equipped with 12 Super Panamax QGC (24 row outreach). Terminal area is 55 ha, and container handling capacity is 1.6 million TEUs per annum. Outline of facilities in the final stage is shown in **Table 2.6-1.** Stacking yard has 20 blocks arranged at right angles to the quay line. Each block has 2 ASCs (1 over 5); in total 40 ASCs are equipped in the yard. Twenty-eight (28) manned shuttles (1 over 1) circulate between the quay and stacking yard. Container storage capacity is approximately 40,000 TEUs (Refer to **Table 2.6-1**).

Table 2.6-1 Outline of Terminal Facilities

Port Name			Londo Port
Terminal Name			DPW London Gateway Terminal (DPW-LGWT)
Operator			DPW (Dubai Port World) (100%)
Status of the Terminal Development			In Operation (Phase-1)
Starting Time of Automated Operation			2013 (Phase-1)
Main Facilities			
	Berth Length (m)	Fhase-1	1,250m (3 berth(-17m))
		Final Stage	2,700m (6 Berth(-17m))
	Terminal Area (ha)		55 ha (Final 170 ha)
	Yard	Yard Stacking Capacity (TEUs GS)	about 8,000
		Yard Stacking Capacity (Total TEUs)	about 40,000
		Yard Block Orientation	Perpendicular
		Number of Yard Stacking Blocks	20 (Phase-1)
		Stacking Block Size (H x W x L)	5 Tiers x 10 Rows x (37-40)TEUs
Equipment			
	QGC	Quantity (sets)	12 sets (Final 24 sets)
		Outreach (row)	24 Rows
	Yard Equipment (set)	ASC	40 sets (1-over-5)
		A-RMG (Cantilever)	-
		STR	-
		Manned Shuttle	28 sets (1-over-1)
		Battery Lift-AGV	-
	Rail Terminal Crane		On site Rail Terminal: Cantilever Manned RMG 3 sets (4 Track)
Terminal Capacity / Throughput / Modal Split			
	Terminal Capacity (1000 TEU/Year)		1.60MTEU (Final 3.50TEU)
	Annual Throughput (1000 TEY/Year)		227,000 TEU (2014)
	Modal Split	Tranship and Barge (%)	3% (Transship)
		Railway (%)	20%
		Truck (%)	77%

2.6.2 Layout



Source: DP World London Gateway Terminal Home Page

Figure 2.6-1 Aerial View and Layout Plan of DPW-LGWT

2.6.3 Background of the Terminal Automation

Since its first successful development of a semi-automated terminal in Antwerp Gateway Terminal, DPW holds a basic policy of introducing automation for newly developed large-scale terminals on the green field in order to achieve high productivity, efficient yard stacking capability and significant cost savings. Automation at DPW-LGWT has been introduced as part of this policy.

2.6.4 Outline of the Automated System

DPW-LGWT has been designed to achieve high container handling productivity (40 to 45 Box/ Hour / Crane) by adopting tandem lift handling in the terminal (40%~50%). Basic concept of the automated system is to maintain flexibility, by using manned shuttles, in horizontal transport operation connecting QGC and yard operations. For this reason, exchanging of spreader for tandem lift and twin lift in a short time is a key technology. In this terminal, raised spreader replacement platform is installed on the sea-side portal of the QGC, and replacement of the spreader can be carried out there in three (3) minutes (See **Figure 2.6-2**).

A raised lashing platform is installed on the land-side portal of each QGC. At present, assigned field workers undertake identification of unloaded containers and seals, and affix/remove stacking corns. OCR system is planned to be installed in the near future (See **Figure 2.6-2**).

Figure 2.6-2 Spreader replacing platform and container transfer lane under the back reach

Basic system of automation can be summarized in the following four points:

① For seaside horizontal transport, the aforementioned manned shuttle-carrier system is adopted. Container handoff between QGC and the shuttle is performed on the six (6) transfer lanes arranged under the back reach of QGC. Manned shuttle tracking is done by the transponder embedded on the ground along the running path.

② Yard stacking is performed by ASCs (1 over 5) while the container handoff between ASC and manned shuttle is carried out by placing a container directly on the partitioned ground located at the landside edge of the stacking block.

③ For deposit/pick up containers between ASC and land side trailer a Fully Automated Truck Loading System (Full ATLS) is adopted, which is the same system used at the DPW-Antwerp Gateway Terminal. Success rate of this Fully ATLS has reached 90%, although this terminal has been in operation for less than two years.

④ Cassette trailer system is adopted for the horizontal transport between the yard and railway terminal and customs warehouse. (See **Figure 2.6-3**).

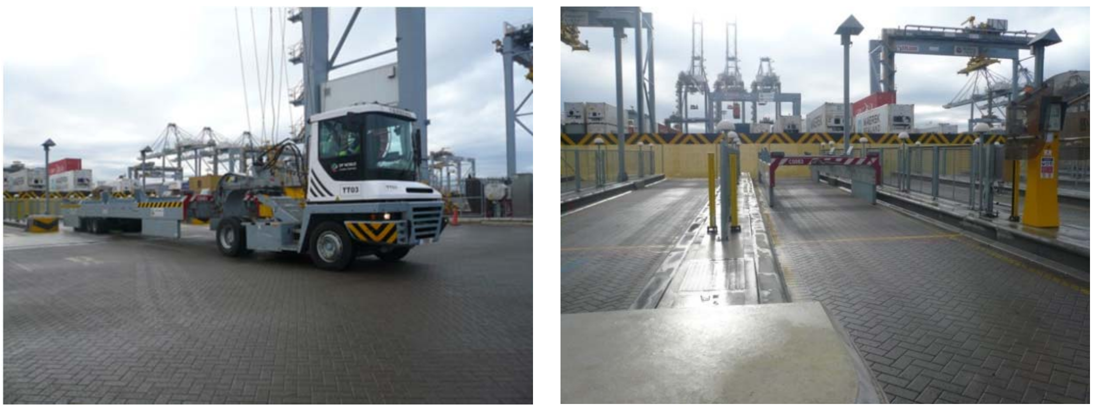


Figure 2.6-3 Trailer and Cassette at the land-side end of yard blocks

Table 2.6-2 Basic System of Automated Terminals : DPW - LGWT

Port Name				Londo Port
Terminal Name				DPW London Gateway Terminal (DPW-LGWT)
Concept and Basic System of Automation				
	Basic System		Category	Semi Automated
			Type of System	ASC System with Manned Shuttle Carrier
	Details	QGC (Loading and Unloading)	Manual or Automation	Manual
			Trolley System	Single Trolley
			Lift System	Twin, Tandem
			Container transfer point	under the back reach (6 lane）
		Horizontal Transport	Manual or Automation	Manual
			Vehicle	Manned Shuttle (1 over 1)
		Yard Stacking	Manual or Automation	Automated
			Stacking Crane	ASC (1 over 5) (Single lift) (travelling speed: 200m/min)
		Truck Loading	Manual or Automation	Fully automated truck loading (full automatic rate 90%)
			Equipment	ASC (3 Remote Operators for 20 Blocks)
	Linkage to on-dock Rail Station			Cassete Trailer System (10 Manned Trailer + 115 Cassette)
	Linkage to Barge Terminal			No dedicated barge berths

2.6.5 Effect of the Automation

The main effect of automation in DPW-LGWT is 1) reduction of labor cost, 2) realization of high and consistent productivity, and 3) improvement of yard stacking efficiency. In particular, 2) and 3) are essential for the realization of a mega terminal.

1) **Labor Cost**: Compared with the conventional STR system, the number of yard stacking workers can be reduced as their functions are replaced by ASCs. Truck loading workers can also be reduced as their functions are replaced by the Fully Automated Truck Loading System. Current number of workers per gang is ten (10), including Crane Operator (1), Checker (2), Carrier Driver (3), Lasher (3), and Foreman (1).
2) **Productivity:** Compared with the conventional STR system, current automated system has greater yard capability for receiving containers from the quay. As a result, QGC productivity has already reached 40 Box/Hour/Crane and the future target is set at 48 Box/Hour/Crane.

2.7 TraPac Terminal（TraPac）

The TraPac terminal, the first automated container terminal on the west coast of the United States, started Phase-1 commercial operation in 2014. Automation was introduced as part of the "Redevelopment Project of Berth Nos.142-147 of the Los Angeles Port". The Redevelopment Project which include rehabilitation of intermodal railway facilities and the access road (flyover), and redevelopment of the terminal facilities in order to increase terminal capacity and reduce operational costs. The new system employs Automated Stacking Cranes (ASCs) and Automated Straddle Carriers (Auto-STRs) which have multi functions for both yard stacking and horizontal transportation including waterside transport and landside transport between the stacking yard and railway station. Although this automated terminal is modeled after the European-type semi-automated terminal (the 3rd generation), full automation was realized by applying the Auto-STR System which was first introduced at Patric Terminal in Brisbane.

2.7.1 Outline of the Terminal

This terminal has two groups of berths; Berth Nos. 136-139 (L=600m, D=15m) and Nos.142-147 (L=1,000m, D=15~16m). Total yard area is about 90 hectares and the annual container handling capacity is 800,000 TEUs (before redevelopment), which will be extend to 1,200,000 TEUs (after Redevelopment). Berth Nos.136-139 and its backyard are not automated but operated by a conventional RTG and Wheel system. In this area, 6 QGCs and some RTG blocks are arranged. One of 6 QGC is planned to be shifted to Berth Nos.142-147.

Berth Nos. 142-147 and their backyard area were partially converted to an automated terminal (Phase-1). These berths are equipped with four (4) Over Panamax QGCs (21-22-row outreach) at present. In this automated stacking yard, nineteen (19) ASC stacking blocks and Auto-STR stacking area (Auto-STR yard) is planned to be installed under Phase-1 to Phase-4.

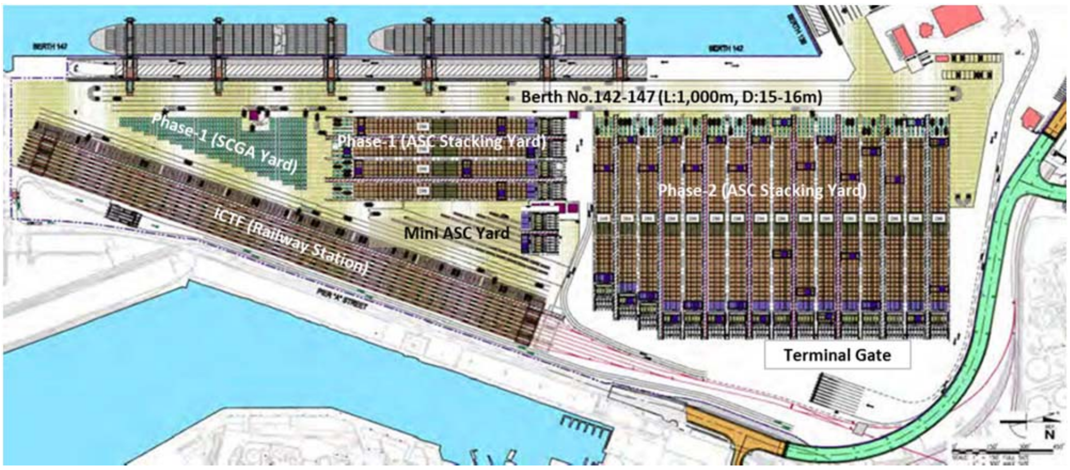
Due to its triangular land shape, four (4) of nineteen ASC blocks are arranged parallel to the quay, whereas fifteen (15) ASC blocks are planned to be laid out perpendicular to the quay. Each ASC block has two (2) identical ASCs (1 over 5); in total, 38~40 ASCs are planned to be installed. The Auto-STR Yard is an automated stacking yard using Auto-STR (1 over 2) designed based on the same concept of Patric Terminal Brisbane.

Under Phase-1, four (4) ASC blocks (parallel to the quay line) and the Auto-STR yard were constructed and commercial operation commenced in 2014. Remaining ASC blocks will be constructed in Phase-2/4. Storage capacity of the automated container terminal is estimated at approximately 25,000TEU in the final stage (Phase-4) including ASC yard, Auto-STR yard and on-dock railway terminal yard. Facilities in the automated container terminal are summarized in **Table 2.7-1**.

Table 2.7-1 Outline of Automated Terminal - TraPac Terminal

Port Name			Los Angeles Port
Terminal Name			TraPac Terminal
Operator			TraPac, LLC
Status of the Terminal Development			In operation Phase-1
Starting Time of Automated Operation			2014
Main Facilities			
	Berth Length (m) (Water Depth)	Berth No.142 – 147	1,000 m (-15 to -16m)
		Berth No. 136 – 139	600m (-12m)
	Terminal Area (ha)		70 ha
	Yard	Yard Stacking Capacity (TEUs GS)	-
		Yard Stacking Capacity (Total TEUs)	Auto Terminal: 25,000 TEUs (Phase-4)
		Yard Block Orientation	Perpendicular 15 blocks and Parallel 4 blocks
		Number of Yard Stacking Blocks	ASC Block: Phase-1:4 Blocks (Final:19 Blocks)
		Stacking Block Size (H x W x L(TEU))	5 Tiers (H) x 8 Rows (W) x 38 TEUs
Equipment			
	QGC	Quantity (sets)	Berth No. 142-147: 4 sets, Berth No. 136-139: 6 sets
		Outreach (row)	21 - 22 Rows
	Yard Equipment (set)	ASC	Phase-1: 10 sets (Final: 40 sets)
		RMG (Cantilever)	-
		STR	Phase-1:16 sets (Auto-STR (1 over 2) Kalmar: ESC350WA)
		Shuttle	–
		AGV	-
	Rail Terminal Crane		Double Cantilever RMG: 2 sets
Terminal Capacity / Throughput / Modal Split			
	Terminal Capacity (1000 TEU/Year)		Total capacity: 1,200 (after completion of Phase-4 Project)
	Annual Throughput (1000 TEY/Year)		-
	Modal Split	Transship and Barge (%)	almost zero
		Railway (%)	35%
		Truck (%)	65%

2.7.2 Layout



Source :"Planning for the TraPac Automated Container Terminal" (ASCE 2013)

Figure 2.7-1 Yard Layout of TraPac Terminal (After completion of Phase-4)

2.7.3 Background of the Terminal Automation

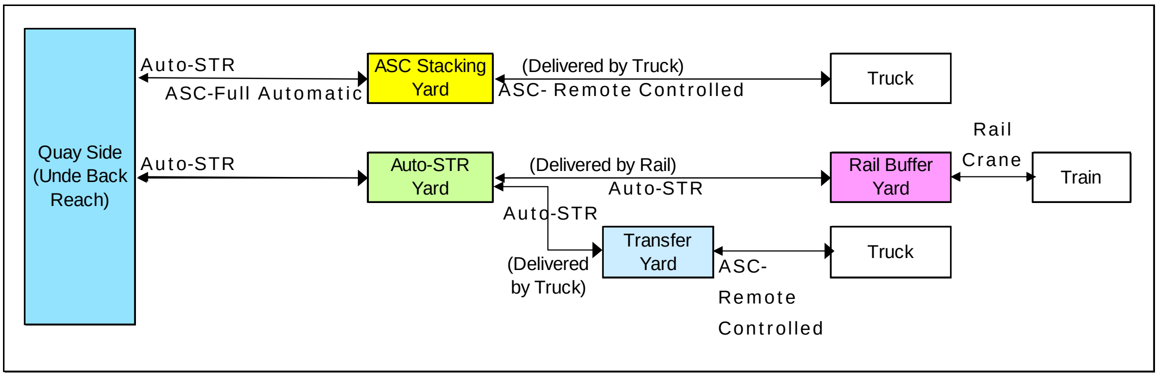
Automation of the TraPac Terminal was, as aforementioned, introduced as a part of the Redevelopment Project of Berth No.142-147 in TraPac Terminal in order to increase yard capacity and reduce operational costs.

2.7.4 Outline of the Automated System

The automated system of the TraPac Terminal is outlined below.

1) The Auto-STRs (1 over 2) are used for horizontal transport between the quay and stacking yard. Interchange area is allocated under the back reach of the QGCs (See **Figure 2.7-3)**
2) Because the terminal land area is triangular in shape, yard stacking method is comprised of two systems; a) ASC stacking, b)ground stacking using Auto-STR, where imported railway containers are handled.
3) Container deposit to the external trucks at ASC blocks is done at the landside end of the blocks automatically. However the final handoff to the truck is performed by remote control from the central control room and vice versa.
4) In container deposit to the external trucks from the ground stacking yard (Auto-STR yard), loading is not done by the AutoStrad directly but done by the remote-controlled ASC at the specially designed transfer yard (Mini Yard) (See **Figure 2.7-4**).
5) Container transport to the on-dock railway terminal from the ground stacking yard (Auto-STR yard) is performed full automatically by Auto-STR and vice versa. At the railway terminal, cantilever area of railway RMG is utilized for a buffer zone (three (3) tiers of stacking height is available).

From the reasons above, Auto-STR has one-over-two stacking height because of its multipurpose use; a) for horizontal movement in the entire terminal area, b) for container stacking at SCGA, and c) for container stacking at on-dock railway buffer area. Container movement and transport vehicles in the automated terminal are shown in **Figure 2.7-2.**



Source: Patroc Corporation Home Page

Figure 2.7-2 Container Flow in the Yard

2.7.5 Effect of the Automation

In this terminal, automation was introduced as the part of the Terminal Redevelopment Project. Therefore, the primary objective of the automation is modernization of the terminal including enhancement of terminal capacity and reduction of total terminal cost. However, the direct effect of automation is the reduction in the labor force. According to representatives of the terminal, direct labor cost (ILWU-relevant labor cost) is expected to be reduced by 40% by the automation, whereas the proportion of direct labor cost accounts for more than 50% of the total cost in the terminal.

Source: TraPac Home Page

Figure 2.7-3 Quay-side Operation at TraPac Terminal

Figure 2.7-4 Truck Loading Operation at TraPac Terminal

Table 2.7-2 Outline of Automation System- TraPac Terminal

Port Name				Los Angeles Port
Terminal Name				TraPac Terminal
Concept and Basic System of Automation				
	Basic System		Category	Full Automated
			Type of System	ASC with Auto-STR
	Details	QGC (Loading and Unloading)	Manual or Automation	Manual Operation
			Trolley System	Single trolley
			Lift System	Twin lift
			Container transfer point	under the Back Reach
		Horizontal Transport	Manual or Automation	Automated
			Vehicle	Auto-STR
		Yard Stacking	Manual or Automation	Automated
			Stacking Crane	ASC (1 over 5)at ASC Yard and Auto-STR in Auto-STR yard
		Truck Loading	Manual or Automation	Remote controlled from control room
			Equipment	ASC at ASC Yard and Transfer Yard
	linkage to on-dock Rail Station			Auto-STR
	Linkage to Barge Terminal			No dedicated barge berth (Main berths are used commonly)

2.8 Patric Terminal Brisbane (Patric Brisbane)

PTC-Patric Brisbane Terminal (Patric Brisbane) is totally different from the European-type automated terminals mentioned above. The terminal is a unique automated container terminal which employs an automated straddle carrier (Auto-STR) system. Development of the Auto-STR System originally began in 1996 by Patric Corporation Ltd. with the collaboration of Sydney University (Robot Engineering) while Kalmar Co. Ltd developed the actual machine. Field test started in 2001 and practical use started in 2005 using half the area of the current yard area. In 2009, Patric Brisbane Terminal began operation as a full-scale automated container terminal with three berths and a handling capacity of 800 thousand TEUs.

2.8.1 Outline of the Terminal

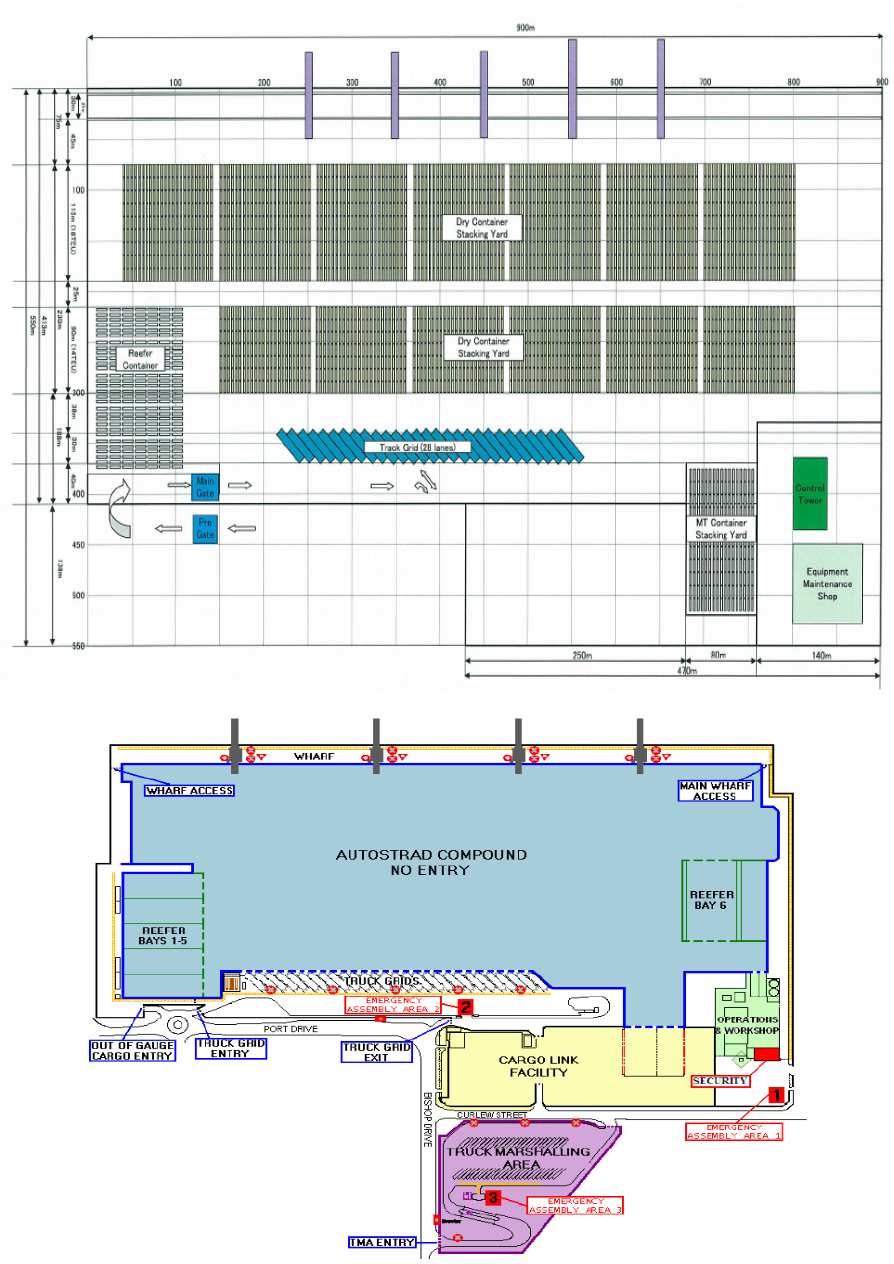
The terminal is comprised of three berths over a total quay length of 900m, water depth of 14m and six over panamax gantry cranes (five are able to reach across 22 rows of containers, and one can reach across 19 rows). The terminal area is 39 ha and container handling capacity is 800 thousand TEUs. Equipped with 28Auto-STR, the terminal has 15 blocks of stacking yard which are placed at a right angle to the quay line; container stacking capacity is 11,500 TEUs (Refer to **Table 2.8-1**).

Table 2.8-1 Outline of Automated Terminal – Patric (Brisbane)

Port Name			Brisbane Port (Australia.)
Terminal Name			Patric Terminal Brisbane
Operator			Patrick Corporation Ltd.
Status of the Terminal Development			in Operation
Starting Time of Automated Operation			2005
Main Facilities			
	Berth Length (m) (Water Depth)	Current Status	900m (3 Berths -14m)
			(Berths No. 8 to No.10)
	Terminal Area (ha)		39.27 ha
	Yard	Yard Stacking Capacity (TEUs GS)	about 5,766
		Yard Stacking Capacity (Total TEUs)	about 11,532 (2 Tiers/ Ground Slot)
		Yard Block Orientation	Perpendicular
		Number of Yard Stacking Blocks	15
		Stacking Block Size (H x W x L(TEU))	2 Tiers (H) x 24 Rows (W) x 18/14 TEUs (L)
Equipment			
	QGC	Quantity (sets)	6 sets
		Outreach (row)	13 Row x 1 set, 18 Row x 5 sets
	Yard Equipment (set)	ASC	-
		RMG (Cantilever)	-
		STR	28 (AutStrad (1 over 2) Kalmar-ESC35)
		Shuttle	-
		AGV	-
	Rail Terminal Crane		-
Terminal Capacity / Throughput / Modal Split			
	Terminal Capacity (1000 TEU/Year)		800
	Annual Throughput (1000 TEY/Year)		50万TEU (2009)
	Modal Split	Transship and Barge (%)	-
		Railway (%)	-
		Truck (%)	100%

2.8.2 Layout

The layout of this terminal is the same as an ordinary STR terminal with containers being placed at a right angle to the quay line. Size of block is 24 rows in width, 14 TEUs and 18 TEUs in length and two tiers in height. Seven blocks of 18 TEUs in length are placed behind the quay and six blocks of 14 TEUs in length are placed behind it. Additionally, a reefer container stacking block and an empty container stacking block are placed, thus there are 15 blocks in total (Refer to **Figure 2.8-1**).



Source: Patric Home Page

Figure 2.8-1 Yard Layout of Patric Terminal (Brisbane)

2.8.3 Background of the Terminal Automation

Automation of Patric Terminal was envisaged in 1996, and full-scale operation started in 2009. Before introducing automation, manned straddle carrier system was adopted in the terminal. Patric Corp.'s basic policy on automation is to use the existing straddle carriers rather than introduce new automated machines in the terminal. Driving force for developing an automated terminal was to reduce the skyrocketing labor costs in the port.

Terminal automation was introduced firstly in the Port of Brisbane because it was considered an unwise idea to develop an innovative and full-scale automated terminal in a large-scale terminal such as Sydney or Melbourne. In addition, the Port of Brisbane was judged as the most suitable port to introduce automation from the standpoints of container handling volume, the terminal area and various other conditions. Thus, in 2001, field tests were implemented in CSX world Terminal, an American operator located next to Patric Terminal. Later in 2005, half the area of the present yard area went into operation and finally Patric Brisbane Terminal started operation as a full-scale automated container terminal in 2009.A total of 250 terminal jobs were eliminated by automation and some were transferred to another terminal (Timber) while others received a special payment without compulsory dismissal.

2.8.4 Outline of the Automation System

Scope of automation is as follows;

1) Horizontal transport in seaside
2) Yard stacking (1-over-2)
3) Delivery and receipt of containers between a Auto-STR and a trailer from outside

The operation is conducted by 28 Automatic Straddle Carriers (Auto-STR). Regarding delivery and receipt of containers between an Auto-STR and a trailer from outside, horizontal movement of Auto-STR and picking up a container from a trailer are automated, but the final handoff of a container to a trailer is done by a dock worker using a radio remote control system (Refer to **Table 2.8-2**).

Table 2.8-2 Outline of Automation –Ptaric (Brisbane)

Port Name				Brisbane Port (Australia.)
Terminal Name				Patric Terminal Brisbane
Concept and Basic System of Automation				
	Basic System		Category	
			Type of System	Auto-Straddle Carrier System
	Details	QGC (Loading and Unloading)	Manual or Automation	Manual operation
			Trolley System	Single Trolley
			Lift System	Twin lift
			Container transfer point	Under the back reach
		Horizontal Transport	Manual or Automation	Auto-Strad (Kalmar ESC 350A)
			Vehicle	Lifting height 9,800 mm (1 over 2 x9'6" container)
		Yard Stacking	Manual or Automation	Lifting weight 65 ton (20' container twin lift)
			Stacking Crane	Running speed 27 km/h (same as manual STR)
		Truck Loading	Equipment	Auto-Strad
			Site	Final handoff of import containers in the Truck Grid
	linkage to on-dock Rail Station			Manned trailer
	Linkage to Barge Terminal			No dedicated barge terminal

Auto-STR system is characterized by the following two technical features: 1) Automatic Detection of Position of Straddle carriers (Positioning) and 2) Traffic Management System. Positioning relies on millimeter-wave (Extremely High Frequency) radar while the Traffic Management System controls terminal traffic based on a virtual grid in the core part of the system.

1) Automatic Position Detection of Straddle Carriers

Position of Auto-STR is detected using a millimeter-wave radar system on a real time basis. Accurate position of Auto-STR is detected using reflecting signals from the three most appropriate wave-reflecting-boards in the yard. Three units of reflecting boards are attached to thirty lighting poles located in the yard. If these lighting poles are not sufficient to cover all the required Auto-STR running area, additional poles are installed for collecting sufficient reflecting signals for detection. In the original plan, both millimeter-waves radar and DGPS were considered to be used for the position detection. Currently, only the millimeter-waves radar system has been adopted due to concerns with the reliability and accuracy of DPGS. The millimeter-waves radar positioning system is accurate within +/- 2 cm regardless of weather conditions.

2) Traffic Management System

Traffic management system employs a mechanism to autonomously determine what routes can be taken at any given moment based on its forefront safety distance information (Nose Path) collected from each vehicles' front laser detection devices, rather than assigning a pre-fixed entire route to be followed by each Auto-STR from the start. Namely, four units of laser detection devices attached on the front end of the vehicles confirm the safety of its front area (Nose Path) by detecting obstacles in front of the straddle carrier. Based on such Nose Pass information collected by each Auto-STR, the central system computes 50 model routes every second in the order of most recommended. Each straddle carrier selects the most suitable path from the recommended routes. For efficient yard operations, Virtual Grid is used to grasp the status of terminal activities such as situation of stacking containers and location of each Auto-STR with its destination and running route. As explained above, each straddle carrier continuously selects its route based on the recommendations from the central system.

Source: Patric Home Page

Figure 2.8-2 Quay-Side Operation Overview

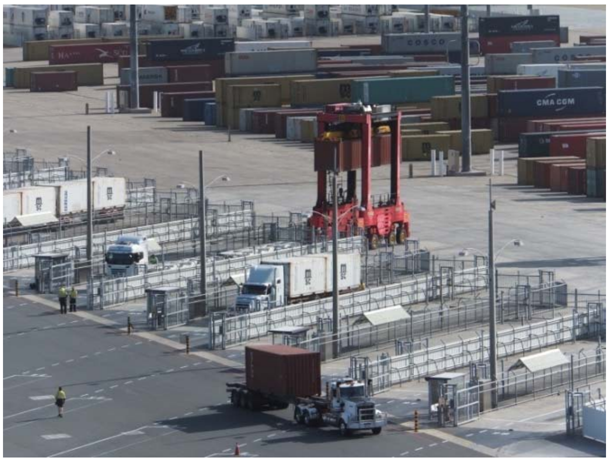


Figure 2.8-3 Truck Grid Operation Overview

2.8.5 Effect of the Automation

In the Patric Terminal, yard automation brought the following benefits;

1) <u>Reduction of labor cost</u>

In the yard, there are four gantry cranes and four workers per one crane (one chief, one crane operator, two twist lock operators). A total of only 16 workers are needed in the yard, which enabled the terminal operation workforce to be greatly reduced. When automation was first introduced, the number of workers was cut by 50%. Today the size of the workforce is two-thirds smaller than it was before automation was introduced.

2) Improvement of work safety

Accidents causing injury or death have greatly decreased because fewer workers enter the yard area due to automation. In 2002 there were 141 accidents but in recent years that figure has been reduced to 1 or less.

3) Reduction of operation costs

Various costs have been reduced. For example, insurance cost decreased from 1 million AUD/year to 0.3 million AUD/year as the number accidents causing injury or death plummeted. Also, energy costs for yard lighting decreased by 100 thousands AUD/year as there is no longer any need for intense lighting at night. Electricity costs for straddle carriers decreased by 20% because hybrid-type Auto-STRdle Carriers were introduced. Finally, painting cost for traffic lanes fell by 20 thousands AUD/year due to automation.

2.8.6 Extension of Auto-STR Terminal- Patric Terminal Sydney

Based on a new concession contract signed in 2012, Patric Corp. is going forward with Sydney Container Terminal Expansion and Redevelopment Project. As a part of the project, Patric Corp. plans to convert the manned straddle carrier system into an Auto-STR system in the terminal. The concept of the automated terminal is the same as Patric Terminal Brisbane. Expansion of facilities has already been completed and 44 Auto-STRs were delivered to Patric Corp. A test run is ongoing at Patric-Brisbane. This automated terminal is scheduled to start operation in 2015 (See **Figure 2.8-4**).

Source : "Redeveloping Port Botany Container Terminal" (Asiano Presentation: IAPH Conference, 2014 Sydney)

Figure 2.8-4 Yard Layout of Patric Terminal (Sydney)

2.9 PSA Pasir Panjang Terminal Phase-1 (PPT Phase-1)

PSA Pasir Panjang Terminal Phase-1 (PPT Phase-1), the first automated terminal in Asia, started operation in 1997 and handled 3.5 million TEUs of containers in 2005. PSA began to study the development of an automated container terminal in the mid-1990s making it one of the pioneers in this field. At that time, the only automated container terminal in the world was the Delta Terminal in the Port of Rotterdam.

2.9.1 Outline of the Terminal

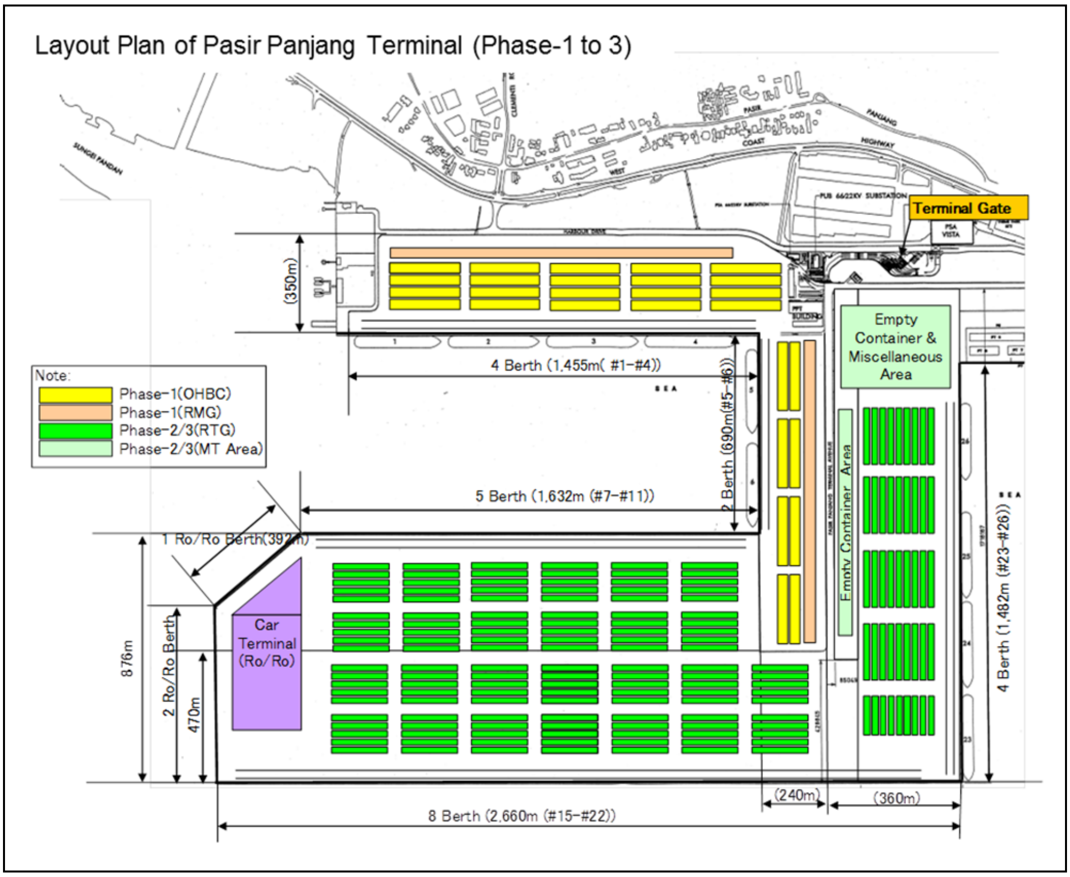
The terminal is comprised of six berths over a total quay length of 2,145m, water depth of 15m and 24 over panamax gantry cranes able to reach across 18 rows of containers. The terminal area is 84 ha and container handling capacity is 5.4 million TEUs. Among the six berths, four berths (No.1-No.4) are 1,455m in length and two (No.5-No.6) are 690m in length, and form a right angle configuration (See **Figure 2.9-1**). Behind each there are two kinds of container yards: OHBC yard and RMG yard. In OHBC yard, there are four blocks of 28m height crane girders behind the No.1 to No.4 berths, and two blocks behind the No.5 to No.6 berths which are all located parallel to the quay; 44 OHBCs with a rail span of 45.4 m are installed in the yard. The RMG yard is located behind the OHBC yard and has 15 RMGs which are operated manually. Its stacking yard has 14,024 ground slots (Refer to **Table 2.9-1**).

Table 2.9-1 Outline of Automated Terminal – PSA Pasir Panjang

Port Name			Singapore Port	
Terminal Name			PSA Pasir Panjang Terminal (Phase-1)	
Operator			PSA Singapore Terminals	
Status of the Terminal Development			in Operation	
Starting Time of Automated Operation			1997	
Main Facilities				
	Berth Length (m) (Water Depth)	Current Status	2,145m (6 Berths: -15m)	
		Final Stage	-	
	Terminal Area (ha)		84 ha	
	Yard	Yard Stacking Capacity (TEUs GS)	14,024	
		Yard Stacking Capacity (Total TEUs)	112,192 (8 Tier)	
		Yard Block Orientation	Parallel	
			OHBC (Automatic)	Cantilever RMG (Manual)
		Number of Yard Stacking Blocks	Behind Berth Nos.1-4: 20 Blocks	Behind Beth Nos.1-4: 1 Block
			Behind Berth Nos. 5-6: 8 Blocks	Behind Berth Nos.5-6: 1 Block
		Stacking Block Size (H x W x L(TEU))	8 Tiers x 10 Rows x (38~35)TEUs	8 Tiers x 13 Rows x (190~154)TEUs
Equipment				
	QGC	Quantity (sets)	24 sets (Behind Berth No.1-No.4: 14 sets + Behind No.5-No.6 Berth: 10 sets)	
		Outreach (row)	18 Rows	
	Yard Equipment (set)	OHBC	44 sets (Behind Berth Nos.1-4: 32 sets + Behind Nos.5-6 Berth: 12 sets)	
		Double Cantilever RMG	15 sets (Behind Berth Nos.1-4: 9 sets + Behind Berth Nos.5-6: 6 sets)	
		STR	-	
		Shuttle	-	
		AGV	-	
	Rail Terminal Crane		No on-dock Rail Station	
Terminal Capacity / Throughput / Modal Split				
	Terminal Capacity (1000 TEU/Year)		5,400	
	Annual Throughput (1000 TEY/Year)		n.a.	
	Modal Split	Transship and Barge (%)	80% to 90%	
		Railway (%)	-	
		Truck (%)	20% to 10%	

The OHBC yard was originally planned as a stacking yard for transshipment containers (Transshipment Ratio of PSA is 80 to 85%) and the RMG yard was planned as a stacking yard for import/export containers. Delivery and receipt of containers between RMG and external trucks is done under the landside cantilever and a container interchange between seaside transport vehicles (initially planned to be done by AGV) and RMG is done under the seaside cantilever. Therefore, it is possible to separate those two traffic lanes, for seaside AGV lanes and for landside manned external truck lanes, with stacking blocks.

2.9.2 Layout



Source: PSA

Figure 2.9-1 Yard Layout of Pasir Panjang Terminal (Phase-1 to -3)

2.9.3 Background of the Terminal Automation

When PSA began to study the development of a new terminal in the Pasir Panjang district, they focused on the concept of an automated terminal in order to cope with labor shortages. Initially, PSA planned to develop an full-automated terminal adopting AGV system for seaside horizontal movement, and conducted a test run after purchasing five AGVs.

However, due to technical and economic reasons, PSA abandoned that idea and instead opted for a semi-automated terminal in which only the yard stacking is automated. As a result, container transportation between quay side and stacking yard is done by manned trailers; only the OHBC yard stacking is automated.

For Pasir Panjang Terminal Phase-2 and Phase-3, PSA adopted an ordinary manual RTG system. Automated yard system by OHBC was not adopted due to the exorbitant construction cost of the crane girder. In addition it took a year and half for commissioning of Phase-1. By adopting an ordinary RTG system, a commissioning period of only six weeks was required. As the development of Phase-2 and Phase-3 was urgently required, PSA did not adopt the OHBC system.

2.9.4 Outline of the Automation System

The concept of Auto-OHBC with manned trailer system is summarized in **Table 2.9-2**.

Table 2.9-2 Outline of Automation – PSA Pasir Panjang

<table>
<tr><td colspan="4">Port Name</td><td colspan="2">Singapore Port</td></tr>
<tr><td colspan="4">Terminal Name</td><td colspan="2">PSA Pasir Panjang Terminal (Phase-1)</td></tr>
<tr><td colspan="4">Concept and Basic System of Automation</td><td>A-OHBC</td><td>Cantilever RMG</td></tr>
<tr><td rowspan="14"></td><td colspan="2" rowspan="2">Basic System</td><td>Category</td><td>Semi Automated</td><td>Manual</td></tr>
<tr><td>Type of System</td><td>Auto-OHBC System with Manned Trailer</td><td>-</td></tr>
<tr><td rowspan="10">Details</td><td rowspan="4">QGC (Loading and Unloading)</td><td>Manual or Automation</td><td colspan="2">Manual</td></tr>
<tr><td>Trolley System</td><td colspan="2">Single trolley</td></tr>
<tr><td>Lift System</td><td colspan="2">Single lift</td></tr>
<tr><td>Container transfer point</td><td colspan="2">Under the Gantry</td></tr>
<tr><td rowspan="2">Horizontal Transport</td><td>Manual or Automation</td><td>Manual operation</td><td rowspan="2">Manned trailer</td></tr>
<tr><td>Vehicle</td><td>Manned trailer</td></tr>
<tr><td rowspan="2">Yard Stacking</td><td>Manual or Automation</td><td>Automated</td><td rowspan="2">Manual</td></tr>
<tr><td>Stacking Crane</td><td>A-OHBC (1 over 8)</td></tr>
<tr><td rowspan="2">Truck Loading</td><td>Manual or Automation</td><td>Remote controlled</td><td rowspan="2">Manual</td></tr>
<tr><td>Equipment</td><td>Auto-OHBC (under the gantry)</td></tr>
<tr><td colspan="3">linkage to on-dock Rail Station</td><td colspan="2">No on-dock railway station.</td></tr>
<tr><td colspan="3">Linkage to Barge Terminal</td><td colspan="2">Manned trailer (Main Berths are used for Feeder Vessels and Barges)</td></tr>
</table>

2.9.5 Effect of the Automation

PSA introduced automation to reduce labor cost; Initially, PSA's target was to keep the transportation cost between the quay and yard under three Singapore dollars per box. However, based on the results of the AGV test run, it seems they determined that this would be difficult to achieve.

2.9.6 Pasir Panjang Terminal (Phase4/5)

PSA introduced an ordinary manual RTG system in Pasir Panjang Terminal Phase-2 and 3. However, in Pasir Panjang Terminal Phase4/5 PSA decided to introduce an automated terminal again. In Phase-4, a semi-automated terminal with three berths started operation in 2014. Those terminals adopted

Cantilever type Auto-RMG System with manned trailer the same system that has been adopted at other Asian terminals since 2009.

An outline of the system is as follows;

(1) Yard blocks are arranged parallel to the quay.

(2) Seaside horizontal transport is done by manned trailers

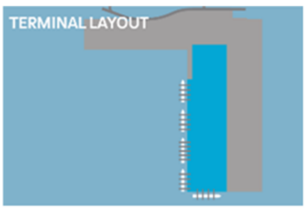
(3) Yard stacking is done by the Cantilever-type Auto-RMG System (46 RMGs in 2014) In this system, container stacking operation in the block is done automatically by the Auto-RMG.

(4) Container transfer between Auto-RMG and internal trailer is done using Fully Automated Truck Loading System.

(5) Delivery and receipt of a container between Auto-RMG and external trailer is done using a remote control system from the control room.

Main specifications of Pasir Panjang Terminal (Phase4/5) are shown in **Table 2.9-3.**

Table 2.9-3 Main Features of Pasir Panjang Terminal Phase 4/5

Operation Starting Time		August in 2014		
		By the end of 2014	By the end of 2015	Final Stage
Facilities	Number of Berths	3 Berths	5 Berths	15 Berths
	Quay Length (Water Depth)	n.a.	1,850 m (-18m draft)	6,000 m
	Terminal Area	n.a.	110 ha	Layout 
	Number of Yard Blocks	20	40	
	Orientation of the Yard Blocks	Parallel to the main Quay Lines		
	Size of Yard Stacking Block	6 Tiers (H) x 10 Rows (W) x 40 TEUs (L)		
Equipment	QGC	14 sets	22 sets	
	Cantilever Auto-RMG	46 sets	about 80 sets (2 sets/Block)	
Automation System	QGC	Manual		
	Horizontal Transport	Manned trailer		
	Yard Stacking	Automatic		
	Truck Loading/Unloading	Remote Control and Full Automation		

2.10 Hyundai Pusan New Port Terminal (HPNT-Pusan)

HPNT is a terminal in Pusan New Port, which is capitalized 100% by Hyundai, a Korean shipping company. Commercial operation started in 2010, and by 2013 the terminal recorded a container handling volume at 2,392 thousand TEUs. HPNT adopted Cantilever Auto-RMG system with horizontal transportation by manned trailer, the same as other Asian terminals.

2.10.1 Outline of the Terminal

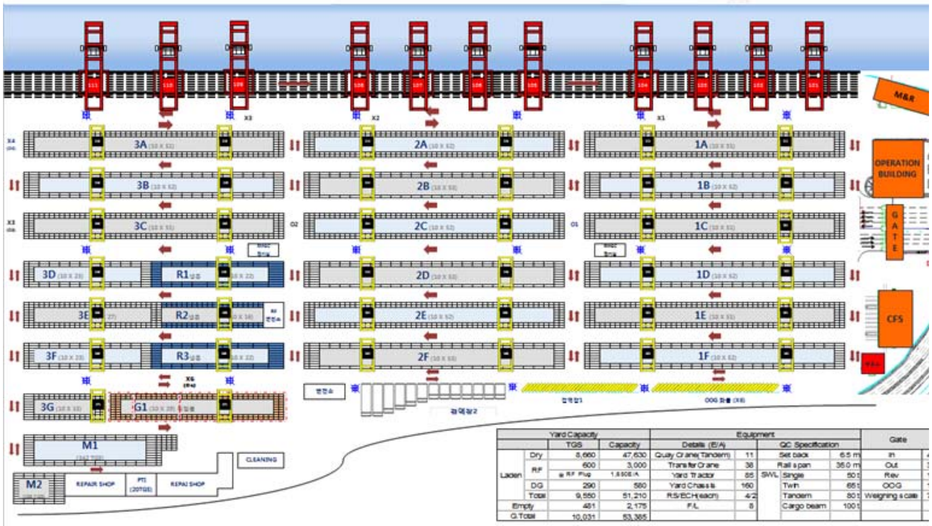
The terminal has a quay length of 1,150m with three berths, water depth of 16 to 17m and is equipped with 12 over panamax QGCs which can reach across 24 rows of containers. Total area of the terminal is 55.3ha and container handling capacity is 2.45 million TEU. There are 19 stacking blocks which are placed parallel to the quay line having two Cantilever Auto-RMGs in each block or 38 in total. Capacity of stacking containers is 53,385 TEU. (Refer to **Table 2.10-1**)

Table 2.10-1 Outline of Automated Terminal - HPNT

Port Name				Busan New Port
Terminal Name				HPNT (Hyundai Pusan New port Terminal)
Operator				Hyundai Pusan New-Port Terminal Co., Ltd.
Status of the Terminal Development				in Operation
Starting Time of Automated Operation				2010
Main Facilities				
	Berth Length (m) (Water Depth)		Current Status	1,150 m (-16m to -17m)
			Final Stage	-
	Terminal Area (ha)			55.3 ha
	Yard	Yard Stacking Capacity (TEUs GS)		10,031
		Yard Stacking Capacity (Total TEUs)		53,385
		Yard Block Orientation		Parallel
		Number of Yard Stacking Blocks		19
		Stacking Block Size (H x W x L(TEU))		6 x 10 x 48
Equipment				
	QGC		Quantity (sets)	12 sets
			Outreach (row)	24 Raw
	Yard Equipment (set)		ASC	-
			RMG (Cantilever)	38 (2 sets /block)
			STR	-
			Shuttle	22 (Shuttle)
			AGV	-
	Rail Terminal Crane			No Railway Station on dock
Terminal Capacity / Throughput / Modal Split				
	Terminal Capacity (1000 TEU/Year)			2,450
	Annual Throughput (1000 TEY/Year)			2,392,000 (in 2013)
	Modal Split	Transship and Barge (%)		50% (in 2014)
		Railway (%)		-
		Truck (%)		50% (in 2014)

2.10.2 Layout

Yard layout of the HPNT is shown in **Figure 2.10-1.** The yard is 1,050m wide with a depth of 600m; RMG blocks are placed parallel to the quay line. (Refer to **Figure 2.10-1** and **Figure 2.10-2**)



Source: HPNT

Figure 2.10-1 Yard Layout of HPNT

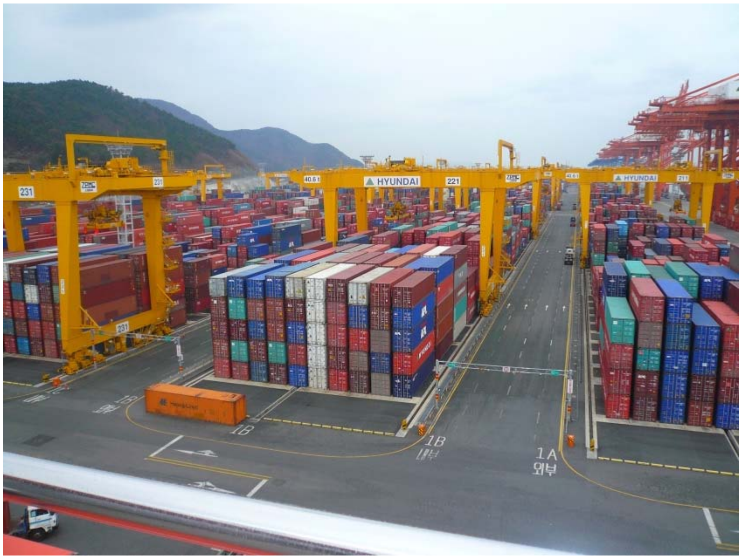


Figure 2.10-2 Stacking Yard in HPNT

2.10.3 Background of the Terminal Automation

Terminal automation was introduced at Pusan New Port to enhance competitiveness and efficiency in order for the port to be a container hub port in North East Asia, and to keep pace with world trends. HPNT decided to adopt Cantilever type Auto-RMG system which was adopted in the Port of Singapore and other Asian ports. HPNT selected this terminal automation system because a large stacking capacity can be secured even in terminals with limited space (the depth of HPNT terminal is only 400m-450m), and effective operation is possible even with a transship ratio of 45% to 50%.

2.10.4 Outline of the Automation System

As mentioned above, this terminal is designed to handle as many containers as possible in a limited yard area. Outline of the system is as follows;

a) Cantilever type Auto-RMG system is adopted for container stacking. The block size is 10 rows in width and 6 tiers in height making it bigger than the European style ASC blocks.
b) The layout in the yard block is arranged parallel to the quay line
c) Horizontal transfer between quay and yard is performed using manned trailers, the same as in a conventional container terminal
d) Delivery and receipt between a trailer and RMG is done under Cantilever by remote control from the control room (Refer to **Table 2.10-2** and **Figure 2.10-3**)

Table 2.10-2 Outline of Automation - HPNT

Port Name				Busan New Port
Terminal Name				HPNT (Hyundai Pusan New port Terminal)
Concept and Basic System of Automation				
	Basic System		Category	Semi Automated
			Type of System	Cantilever A-RMG System with Manned Trailer
	Details	Loading and Unloading	Manual or Automation	Manual operation
			Trolley System	Single Trolley
			Lift System	Twin, Tandem lift
			Container transfer point	Under the Gantry
		Horizontal Transport	Manual or Automation	Manual operation
			Vehicle	Manned trailer
		Yard Stacking	Manual or Automation	Automated
			Stacking Crane	Cantilever A-RMG (1 over 6)
		Truck Loading	Manual or Automation	Remote controlled
			Equipment	A-RMG (under the cantilever)
	linkage to on-dock Rail Station			No on-dock railway station.
	Linkage to Berge Terminal			No dedicated barge terminal

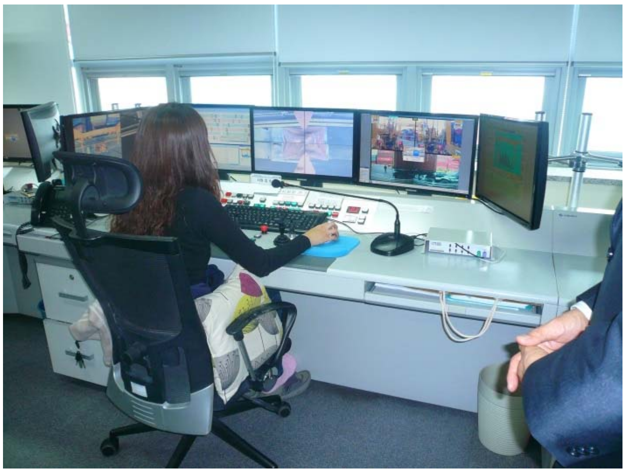


Figure 2.10-3 Container Truck Loading from Control Room

2.10.5 Effect of the Automation

The purpose of introducing terminal automation is to realize a) efficient cargo handling operation and b) lower labor costs.

1) Efficient cargo handling operation by automation

Improvement in the efficiency of cargo handling operation after introducing automation is show in the following Table.

Table 2.10-3 Operation Efficiency in the HPNT

Item	2013	2014
QGC Productivity (GWP)	31 box/hr	30.5 box/hr
Berth Productivity (GBP)	88 box/hr/berth	91.8 box/hr/berth
Truck Turnaround Time	17 min.	16.5 min

Source：HPNT Document

In the North Port Terminal in the Port of Busan (which is not an automated terminal), QGC productivity was less than 30 box/hr, berth productivity was 60 – 70 box/hr/berth and turnaround time of a truck was about 20 minutes. Operational efficiency at HPNT is far superior to the conventional terminal. Loading and unloading time of 3,000TEU class container ship takes 18 hours in the North Port, but only 10 hours in HPNT.

2) Reduction of labor cost

At the North Port, 171 transfer crane operators were working in three shifts, but at HPNT only 23 workers are needed (in the control room). The drastic reduction in labor greatly reduced labor costs.

2.10.6 Automation and the Labor Union

There is one union at the Port of Busan with members working at both the north port and the new port. When the HPNT started as an automated terminal, negotiations were held with the labor union but there were no serious issues. The lack of resistance can be attributed to two reasons; first, Bussan New Port was a newly constructed port and the union welcomed the increase in jobs and second, the Bussan new port project is a national policy which had the backing of BPA (Busan Port Authority).

2.11 Bussan New Port Terminal (BNCT)

MKIF (Macquarie Korea Infrastructure Fund), a Korean investment company, holds a 30% interest in BNCT, making it the largest shareholder. Other shareholders include Terminal Link which is a subsidiary of CMA/CGM, a French shipping company, NYTP (Bouygues Travaux Public) as well as Korean companies. Terminal Operator is I&K Newport which employs 420 workers and undertakes stevedoring and container handling work in the terminal.

This terminal is designed based on the 3rd generation European semi-automated terminal mentioned above (Refer to **Chapter1**), as CMA/CGM took the lead in drafting the terminal plan.

The terminal operation (Phase-1) began in 2012 with 19 yard blocks and a container handling capacity of 1.8 million TEUs per year. However, by 2013, the handling volume had already reached 1.1 million TEUs. Yard construction works under the Phase-2 program are currently underway and are scheduled to be completed in 2015. After completion, the handling capacity will reach 2.7 million TEUs per year with 30 yard blocks.

2.11.1 Outline of the Terminal

The terminal has four berths along its 1,400m quay and a water depth of 16 – 17m. The terminal is equipped with eight Over Panamax QGCs with an outreach across 24 container rows. Terminal area is 69.8 ha and the container handling capacity is 1.83 million TEUs. There is a stacking yard composed of 19 blocks at a right angle to the quay line equipped with 38 ASCs (1 over 5). Container stacking capacity is 37,507 TEUs. (Refer to **Table 2.11-1**)

Presently, 20 Manned –Shuttles (1 over 1) are used for horizontal transportation at seaside which have the following main specifications; 40t hoisting load, 24m/min hoisting speed, 32km/hr maximum moving speed. Three Manned-shuttles are provided for one quay crane.

Table 2.11-1 Outline of Automated Terminal - BNCT

Port Name			Busan New Port
Terminal Name			BNCT(Busan New Port Container Terminal)
Operator			Busan New Container Terminal Ltd.
Status of the Terminal Development			in Operation
Starting Time of Automated Operation			2012
Main Facilities			
	Berth Length (m) (Water Depth)	Current Status	1,400 m (-16m to -17m)
		Final Stage	-
	Terminal Area (ha)		69.8 ha (final 84 ha)
	Yard	Yard Stacking Capacity (TEUs GS)	8,563 (final: n.a.)
		Yard Stacking Capacity (Total TEUs)	37,507 (final 63,222)
		Yard Block Orientation	Perpendicular
		Number of Yard Stacking Blocks	19 (final 30)
		Stacking Block Size (H x W x L(TEU))	5 x 8 x 45
Equipment			
	QGC	Quantity (sets)	8 (final 12 sets)
		Outreach (row)	24 Raw
	Yard Equipment (set)	ASC	38 (final 60) (2 sets /block)
		RMG (Cantilever)	-
		STR	-
		Shuttle	20 (final 33)
		AGV	-
	Rail Terminal Crane		2 sets
Terminal Capacity / Throughput / Modal Split			
	Terminal Capacity (1000 TEU/Year)		1,830 (final 2,700)
	Annual Throughput (1000 TEY/Year)		1,099,000 (in 2013)
	Modal Split	Transship and Barge (%)	50% (in 2014)
		Railway (%)	-
		Truck (%)	50% (in 2014)

2.11.2 Layout

Source: BNCT

Figure 2.11-1 Yard Layout

2.11.3 Background of the Terminal Automation

The Busan New Port introduced terminal automation to bolster its competitiveness and efficiency as part of its plan to become a hub port in North East Asia. In the competition of BTO (Build-transfer-Operate) scheme at Pusan New Port, BNCT proposed and a automated terminal along to the policy, to establish a competitive hub port in the area.

2.11.4 Outline of the Automation System

The concept of this terminal automation is the same as the 3rd generation European semi-automated terminals as mentioned above. Main features are as follows;

(1) Horizontal transport at seaside is done by manned shuttle-carrier (1 over 1).
(2) Yard stacking is done automatically by ASC system (1 over 5) and yard blocks are arranged at a right angle to the quay line.
(3) Container transfer from QGC to shuttle carrier is done under the back reach of the gantry and vice versa.
(4) Container interchange between the shuttle carrier is performed at the transfer grids laid out on the ground of the seaside end of ASC blocks.
(5) Delivery and receipt of a container to/from external trailers is done at landside end of the ASC block automatically. However, the final handoff of containers to the external trailer is done by remote control from the central control room (Refer to **Table 2.11-2)**.

Table 2.11-2 Outline of Automation - BNCT

Port Name				Busan New Port
Terminal Name				BNCT(Busan New Port Container Terminal)
Concept and Basic System of Automation				
	Basic System		Category	Semi Automated
			Type of System	ASC System with Manned Shuttle
	Details	QGC (Loading and Unloading)	Manual or Automation	Manual operation
			Trolley System	Single
			Lift System	Twin
			Container transfer point	Under the back reach
		Horizontal Transport	Manual or Automation	Manual operation
			Vehicle	Manned shuttle
		Yard Stacking	Manual or Automation	Automated
			Stacking Crane	ASC (1over5)
		Truck Loading	Manual or Automation	Remote controlled
			Equipment	ASC
	linkage to on-dock Rail Station			Manned trailer
	Linkage to Barge Terminal			No dedicated barge terminal

2.11.5 Effect of the Automation

Effects of terminal automation at BNCT are considered as; 1) reduction in labor costs, 2) enhancement of work safety and 3) enhancement of operation performance.

1) Reduction in labor costs by automation

One of the largest benefits of automation at this terminal was the reduction in labor costs. Labor costs related to crane operator and vehicle drivers decreased by about 30%. Under a transfer crane system, 38 transfer cranes and 171 workers are needed in three shifts, but by introducing automation, only 15 workers are needed in the remote control room. Also, introducing the straddle carrier system led to a reduction of 72 drivers compared with the yard tractor system. Thus a total of 228 workers were trimmed from the workforce.

2) Realization of 24-hour operation

Automation allowed 24-hour operation to be introduced without adversely affecting the quality of port operations and services. If automation had not been introduced, additional time and cost would have been required to train workers on the various technical aspects of operation.

3) Yard layout of right angle arrangement to quay line

As the stacking yard is configured at a right angle to the quay line, the stacking capacity is increased by approximately 19% (For reference, the area needed for stacking one container is 39.9 m2 in the case that yard is arranged parallel to the quay line, but only 33.6 m2 when it is arranged at a right angle to the quay line.) Turnaround time of a trailer decreased to 12 or 13 minutes due to the shortened transfer distance, while the waiting time of trailers for loading and unloading containers was virtually eliminated. In addition, as trailers need not go into the yard the risk of accidents has been reduced and shortened transfer distance has resulted in reduce carbon dioxide emissions of cargo handling equipment.

2.12 Tobishma Container Berth, Nagoya (TCB-Nagoya)

TCB (Tobishima Container Berth) is the first fully-automated container terminal in Asia. The terminal started automation of the stacking yard by introducing RTGs in 2005 and became a fully-automated terminal by introducing AGVs in 2008. To date, this remains the only fully-automated terminal in Asia.

2.12.1 Outline of the Terminal

The terminal is comprised of two berths over a total quay length of 750m, water depth of 16m and 6 over panamax gantry cranes able to reach across 22 rows of containers. The terminal area is 36.7 ha and container handling capacity is 600 thousand TEU. There are 22 stacking blocks which are placed parallel to the quay line having 24 Auto-RTGs (1 over 4). Capacity of stacking containers is 17,668 TEU (Refer to **Table 2.12-1**).

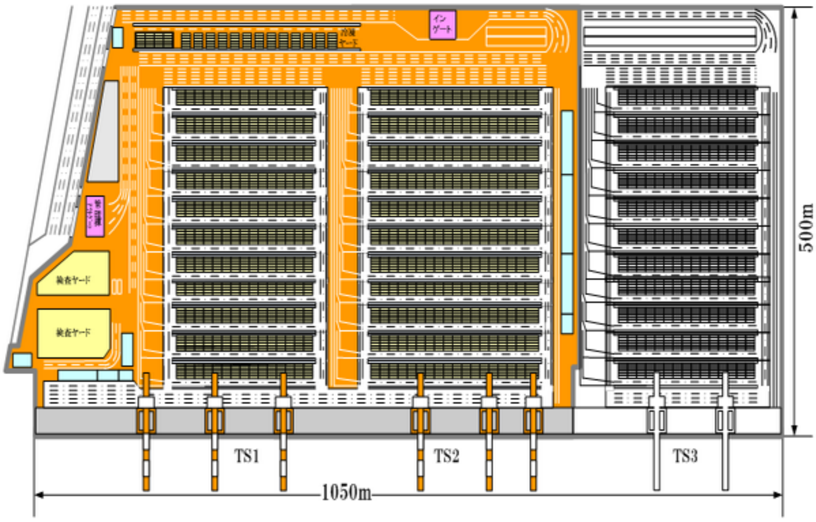
Table 2.12-1 Outline of Automated Terminal - TCB

Port Name			Nagoya Port
Terminal Name			TCB (Tobishima South Berth)
Operator			Tobishima Container Berth Co. Ltd.
Status of the Terminal Development			in Operation
Starting Time of Automated Operation			2008
Main Facilities			
	Berth Length (m) (Water Depth)	Current Status	750 m (2 berths -16m)
		Final Stage	Final 1,050m (3 Berths -16m)
	Terminal Area (ha)		36.7 ha
	Yard	Yard Stacking Capacity (TEUs GS)	4,422
		Yard Stacking Capacity (Total TEUs)	17,688
		Yard Block Orientation	Parallel
		Number of Yard Stacking Blocks	22
		Stacking Block Size (H x W x L(TEU))	4 X 6 x (30-37)
Equipment			
	QGC	Quantity (sets)	6 sets (final 8 sets)
		Outreach (row)	22 Raw
	Yard Equipment (set)	ASC	RTG 24 (sets)
		RMG (Cantilever)	-
		STR	-
		Shuttle	-
		AGV	33 (sets)
	Rail Terminal Crane		No Railway Station on dock
Terminal Capacity / Throughput / Modal Split			
	Terminal Capacity (1000 TEU/Year)		n.a.
	Annual Throughput (1000 TEY/Year）		471.000 (in 2014)
	Modal Split	Transship and Barge (%)	-
		Railway (%)	-
		Truck (%)	almost 100%

2.12.2 Layout

Yard layout of TCB is shown in **Figure 2.12-1.**

The site is 1,050 m wide with a depth 500 m; RTG blocks are placed parallel to the quay line.



Source: TCB Home Page

Figure 2.12-1 Yard Layout of TCB Terminal

2.12.3 Background of the Terminal Automation

Automated terminal was introduced using the latest technology at that time to cope with the future increase of containers at the Port of Nagoya and also as part of national policy to realize competitive ports which can accommodate large container vessels. After extensive study, the RTG system was finally selected as the automation system since it was thought to offer the most efficient operation.

2.12.4 Outline of the Automated System

Automation system in TCB is totally different from other terminals in Europe and Asia. The basic concept of the terminal is to use automatic RTGs for the yard stacking operation. Seaside horizontal transport is undertaken by AGVs which was developed by Japanese manufacturer. An outline of the automated terminal is as follows;

1) Fully-automated RTG system is adopted for yard stacking.
2) Fully-automated AGV system is adopted for horizontal transport at seaside
3) On the landside, delivery and receipt of a container between Auto-RTG and trailers coming from outside (Town Chassis) is done automatically except for the release of a container from Auto-RTG which is done manually using a remote control system from the control room. And an AGV-lane and a Town-Chassis-lane are placed parallel to each other under the gantry of Auto-RTG (total of eight lanes; 6 stacking lanes, 1 AGV-lane and 1 town-chassis—lane).
4) For safety reasons, an AGV and a Town Chassis are prohibited from entering a block at the same time. Thus, traffic lights and crossing bars system is introduced to facilitate a safe and efficient traffic flow **(**Refer to **Table 2.12-2**).

Table 2.12-2 Outline of Automation - TCB

Port Name				Nagoya Port
Terminal Name				TCB (Tobishima South Berth)
Concept and Basic System of Automation				
	Basic System		Category	Full Automated
			Type of System	A-RTG System with AGV
	Details	Loading and Unloading	Manual or Automation	Manual operation
			Trolley System	Single trolley
			Lift System	Twin lift
			Container transfer point	Under the back reach
		Horizontal Transport	Manual or Automation	Automated
			Vehicle	AGV
		Yard Stacking	Manual or Automation	Automated
			Stacking Crane	A-RTG (1 over 4)
		Truck Loading	Manual or Automation	Remote controlled
			Equipment	A-RTG
	linkage to on-dock Rail Station			No on-dock railway station.
	Linkage to Berge Terminal			No dedicated barge terminal

2.12.5 Effect of the Automation

The effects of automation in TCB are considered to be as follows;

1) Reduction of terminal operation costs by decrease of dock workers

2) Night time operation in the yard became easier resulting in enhancement of overall terminal efficiency

3) Enhancement of work safety

Among the above effects, the 30% reduction in labor cost was the largest.

Chapter 3. Comparative Review of Container Terminal Automation

In this chapter, a comparative review of terminal automation throughout the world will be carried out from the following standpoints; 1) background of terminal automation, 2) concept and basic system of automation, 3) layout in the marshaling yard, 4) handling equipment, and 5) the effect of automation.

3.1 Background of Terminal Automation

3.1.1 Modernization of Terminal

The objective of terminal automation (driving force) is primarily to reduce labor costs. However, terminals which have promoted automation as the direct goal (i.e., Brisbane Patric Terminal) are rather rare.

The majority of automated terminals are also being built for the purpose of modernizing terminal facilities and operations. Modern, large-scale automated terminals are typically constructed on Greenfield land to cope with increases in container ship size and cargo demand (Greenfield project), while in other cases aged terminal facilities are refurbished into modern high-capacity terminals by integration of old terminals or redevelopment of aged infrastructures (Redevelopment Project). In both of the above development scenarios, “Job Creation” or “Green Terminal” is the most often used as catch-phrases. Reducing the labor force and labor costs are obviously equally important but these matters are seldom officially discussed.

Examples of Greenfield projects include CTA in Hamburg, ECT-Delta Terminal, Euromax Terminal, APMT-MV2 and RWGT-MV2 in Rotterdam, the BNCT and HPNT in Busan, and TCB in Nagoya, etc. (Greenfield projects vastly outnumber Renovation projects.)

CTB in Hamburg, DPW Gateway Terminal in Antwerp, TraPac Terminal Los Angeles, and LBCT Long Beach, etc, are typical examples of Renovation projects.

3.1.2 Effective utilization of port area

Another driving force behind automated terminal construction is effective land utilization of the port area.

Terminals in the Port of Hamburg (CTA, CTB) are typical examples. Port of Hamburg is located 120km inland from the estuary of the River Elbe, and has evolved from the Middle Ages as a strategically important port in North European Trade. However, as this river port is located near the city, land space available for the port is limited. In order to overcome this disadvantage, improving land-side productivity is considered to be essential. Hence, Hamburg Port Authority and terminal operator (HHLA) developed automated terminals capable of high density stacking using Automated RMG (ASC) with AGV.

3.1.3 Others

There are some ports which introduced automated terminal partly to gain a competitive advantage over ports in the same region. Severe competition among Northern European Ports such Rotterdam, Hamburg and Antwerp has been an important factor in their aggressive introduction of automation.

The ability to use public funds in large-scale port infrastructure projects as a part of government policy to stimulate maritime industry has also served as a springboard for automated terminal development. Such automated terminals as Hanjin Terminal, HPNT and BNCT in the Bussan Newport and TTI in Algeciras Port are of this nature.

3.2 Concept and Basic System of Automation

The area covered by terminal automation ranges widely from ship to shore operation by QGCs to container delivery to outside trucks and intermodal railway trains. However, the combination of yard stacking and seaside horizontal transport constitutes the core of the automation system. Automation of yard stacking is performed by ASCs, Cantilever Auto-RMGs, Auto-STRs and Auto-RTGs, whereas horizontal transport is done using AGVs, Manned-STRs/Shuttles, Auto-STRs and Manned-trailers. However, while there are theoretically sixteen (4 x 4) types of combinations, only a few combinations are actually employed throughout the world as shown in **Table 3.2-1**.

Table 3.2-1 Basic System of Automated Terminal

		Yard Stacking				
		ASC	**Auto-STR**	**Auto-RTG**	**Cantilever Auto-RMG (including OHBC)**	Total
Horizontal Transport	**AGV Lift-AGV**	(Type: 1-a) ECT-Delta, CTA, Euromax, LBCT MV2-APM, MV2-RWG		(Type: 5) TCB-Nagoya		7
	Manned-STR Manned-Shuttle	(Type: 1-b) CTB, DPW-Antwerp APM-Virginia, TTI-Algeciras, BEST-Barcelona, DPW-London DPW-Brisbane, BNCT-Pusan				8
	Auto-STR	(Type: 1-c) TraPac(Los Angeles)	(Type: 2) Patric-Bris, Patric-Syd			3
	Manned-Trailer				(Type: 3, 4) PPJ-(1), PPJ-(2) Hanjin (Pusan), HPNT(Pusan) Evergreen (Kaohsiung), KMCT (Kaohsiung) TPCT (Taipei), THIT (Hong Kong)	8
	Total	15	2	1	8	26

Note: Fully automated terminal
Semi automated terminal

The most common systems in the world are 1) ASC system combined with AGV (Type 1-a), 2) ASC system combined with Manned-STR or –Shuttle (Type 1-b), and 3) Cantilever Auto-RMG (Type 4). In Type 1-a and 1-b, containers are transferred between ASC and horizontal transport vehicles at the end of the stacking block, whereas in Type 4 containers are picked up from or deposited on to yard chassis under the cantilever of RMG at the side of the yard block. Based on each core system, appropriate operation method and equipment in surrounding process is selected, i.e. ship to shore operation, truck loading, transportation between yard and on-dock railway terminal. Then, total automation system in each type is established.

The Auto-STR system (Type 2) is currently not popular in the world due to its generous use of yard space and immaturity of its technology, i.e. there is no practical way to apply a one over three straddle carrier system which is common in STR terminals worldwide. However, the potential of Auto-STR technology has been attracting attention, and TraPac terminal in Los Angeles Port plans to introduce a new generation fully automated system by combining ASC and Auto-STR.

Auto-RTG system (Type 5) is also not popular because the owner of the technology has not yet succeeded to aggressively market its merits.

OHBC (Overhead Bridge Crane) system is also unlikely to gain in popularity due to the high infrastructure cost involved.

3.3 Layout of Marshaling Yard

The layout of facilities in a container terminal is the most basic part of a terminal plan, and is usually determined by the planning parameters such as landform of the terminal site, size of the calling vessels, required capacity, employed container handling system, facilities and equipment to be installed and physical connection with the outside traffic infrastructure etc.

The main layout items of an automated terminal are the arrangement of yard blocks (direction of container stacking and block dimensions) and space for horizontal transportation vehicles and location of on-dock railway terminal. Among them, the arrangement of yard blocks is the most fundamental item for the layout.

3.3.1 Direction of Yard Block

[**ASC System** and **Auto-STR System**]

In the case of **ASC System** and **Auto-STR System**, with the exception of TraPac Terminal where a small number of ASC blocks are laid out parallel to the quay due to its land shape, almost all the stacking blocks are located perpendicular to the quay. This perpendicular design separates seaside and landside operations, thereby facilitating the use of AGV on the seaside and enhancing safety. This layout is considered to be effective for terminals handling large volumes of import and export cargo (See **Table 3.3-1**).

Table 3.3-1 Layout of Automated Terminal

		Yard Stacking				
		ASC	Auto-STR	Auto-RTG	Cantilever Auto-RMG (including OHBC)	Total
Horizontal Transport	AGV Lift-AGV	(Type: 1-a) Perpendicular		(Type: 5) Parallel		7
	Man-STR Man-Shuttle	(Type: 1-b) Perpendicular				8
	Auto-STR	(Type: 1-c) Perpendicular	(Type: 2) Perpendicular			3
	Man-Trailer				(Type: 3/4) Parallel	8
	Total	15	2	1	8	26

Note: (yellow) Full automated terminal; (blue) Semi automated terminal

[**Cantilever Auto-RMG** and **Auto-RTG System**]

In the case of **Cantilever Auto-RMG** and **Auto-RTG System,** stacking blocks are laid out parallel to the quay. In this layout, horizontal transport vehicles (Manned trailers, AGVs) can reach near the container stacking position alongside the block and RMG/RTGs do not carry every container along the block. Therefore, this design enables RMG/RTGs to concentrate on container stacking and loading/unloading operations to the vehicles, and lessens the workload of the crane, and therefore this system is considered suitable to operate the bigger yard blocks. This design is also considered to be effective for terminals handling large volumes of transshipment cargo including cargo transported by barge (See **Table 3.3-1**).

When transshipment operation is concentrated at the ASC block, container handling at the seaside end of the block reaches peak condition and could exceed the capacity of ASC. The Cantilever Auto-RMG/RTG system, on the other hand, can provide many loading points along the stacking block, thereby reducing the workload of the crane.

3.3.2 Terminal Dimensions

Dimensions of the representative Automated Terminals presented in Chapter 2 are summarized in **Table 3.3-2**.

Table 3.3-2 Dimensions of Automated Terminals

No.	Terminal	Site	Modal Sprit (%)			Berth Length (m)	Depth of the Terminal (m)						Layout Chart No. for Reference
			Tranship and Barge	Railway	Truck		Total Depth	Apron	Hirizontal Transport Area	Stacking Yard	Truck Area	Railway Station	
ASC System with AGV (Type 1-a)													
1	CTA	G	30-40	30	40-30	1,400	**600**	42	80	300	64	114	Figure 2.2-2
2	RWG Terminal (MV-2)	G	40-50	20	40-30	1,150	**590**	40	75	335	73	67	Figure 2.3-2
ASC System with Manned STR/Shuttle (Type 1-b)													
3	CTB	B	30-40	30	40-30	1,400	**690**	120		390	70	110	Figure 2.5-2
4	BNCT (Pusan New Port)	G	50	almost zero	50	1,400	**600**	43	70	348	41	98	Figure 2.11-1
5	DPW London Gateway Terminal	G	almost zero	20	80	1,250	**582**	40	77	314	56	95	Figure 2.6-1
ASC System with Auto STR (Type 1-c)													
6	TraPac Terminal	B	almost zero	35	65	1,000	**457**	36	50	315	56	(73)	Figure 2.7-1
Auto-Strad System (Type 3)													
7	Patric Terminal Brisbane	B	almost zero	No ondock-rail	100	900	**413**	30	45	230	108	-	Figure 2.8-1
Cantilever Aauto-RMG System with Manned Trailer (Type 4)													
8	HPNT (Pusan)	G	50	No ondock-rail	45-40	1,050	**409～465**	42	17	310～366	40	-	Figure 2.10-1
Auto-RTG System with AGV (Type 5)													
9	TCB (Nagoya)	G	almost zero	No ondock-rail	100	750	**450**	36	21	352	41	Other 50	Figure 2.12-1

[**ASC System**]

ASC terminals, which are constructed on rectangular- shaped land and supported by either AGV or STR/Shuttle systems, have quays of 1,110m-1,400 m in length and terminal depth of about 600 m. The following facilities are laid out from seaside to landside, 1) Berth and apron; about 120m in depth including AGV or STR/Shuttle running area, 2) Yard blocks; about 300m length including transfer zones at the seaside and landside end, 3) Trailer and intermodal transport vehicle running zone; about 70m wide, and 4) Railway terminal; about 110m wide.

ASC stacking blocks are 8 to 10 rows wide and 5 tiers high. There is a trade-off between stacking capacity and operational efficiency which is governed by the block length. It is typically about 300m including the transfer zone for ASC and seaside transport vehicles, and that for ASC and landside transport vehicles. The layout of CTA can be said to be typical (Refer to **2.2**).

In the case of TraPac in Los Angeles, where automated terminal facilities are installed on triangular-shaped land, some of ASC blocks are arranged parallel to the quay and the location of the railway terminal differs from many other examples (Refer to **2.7**) due to the exceptional land shape.

RWGT-MV2 in Rotterdam also has a special layout due its large transshipment and barge container volume. This terminal has two types of stacking cranes, ASCs and Cantilever Auto-RMGs, to cope with transshipment operation during peak times, and both types of stacking blocks are arranged perpendicular to the quay (Refer to **2.3**).

[Automated Straddle Carrier (Auto-STR) System]

Layout of the **Auto-STR Terminal ,** which is represented by Patrick Terminal Brisbane, is the same as a conventional straddle carrier terminal, except for the Truck Grid which is allocated approximately 100m deep at the landside area of the terminal. Total depth of the terminal is about 413 m, which is much smaller than ASC terminals (Refer to **2.8**).

[Cantilever Auto-RMG System]

Cantilever Auto-RMG stacking blocks are 10 to 12 rows wide and 6 to 8 tiers high. Block size is relatively larger than ASC blocks. Seaside transport vehicles' circulating area is dispersed to alongside of each block arranged parallel to the quay, and thereby this area does not require wide space. There are no examples of Cantilever Auto-RMG terminals with an on-dock railway station. Therefore, total depth of the terminal is typically only 400m to 450m, similar than that of ASC terminals (Refer to **2.10**).

3.4 Handling Gears and Vehicles

Handling gears and vehicles of automated terminals are addressed in this section. Main features of this equipment are summarized in **Table 3.4-1** and **Table 3.4-2**.

3.4.1 QGC

① Full automation of QGCs

A fully automated QGC has yet to be realized. Vessel sway during operation, instability and damage risks to the vessel structure are the main difficulties which many terminals and crane manufacturers have been struggling to overcome.

The 2nd trolley was already automated at CTA in 2002, and semi-automation of the 1st trolley started at Euromax Terminal in 2011. This semi-automated system includes robotic operation in some part of the total stroke between a ship and the lashing platform, whereas the final hand off or pick- up of containers in the hold remains a manual operation.

At the latest automated terminals in Rotterdam Maasvlakte-2, APMT and RWGT, which started commercial operation in 2015, a remote control system in the 1st trolley operation is adopted, in which the 1st trolley is remotely controlled by the operator in the central control room. Thereby, whole stroke of the 1st trolley is operated in combination system of automation and remote controlled manner, the same as the yard stacking crane adopted at CTA more than ten years ago. At APMT-MV2, operator's cabin is not equipped on the QGCs.

② Selection of Trolley System

[AGV Terminal]

In every AGV terminals (Type 1-a and Type 5), except for ECT Delta Terminal which opened at an early date (1993), QGCs have a **dual trolley system**. The dual trolley is the remarkable feature of this type of terminal. The advantages of the dual trolley are follows;

1) QGC productivity is improved by dividing the container loading/unloading stroke into two parts using the 1st and 2nd trolleys. Usually the 1st trolley undertakes container movement from a ship to the raised lashing platform on the gantry and vice versa. The 2nd trolley, which is fully automated, undertakes container movement from the lashing platform to the interchange position under the back reach of the gantry and vice versa. In this way, total loading/unloading cycle time of QGC is shortened.

2) The crane operator (1st trolley) is able to easily deposit a container on the interchange point of the lashing platform which is installed on the middle level of the gantry. At the ECT Delta Terminal, crane operators have to adjust the spreader to the AGV on the ground.

[STR/Shuttle Terminal]

In every STR/Shuttle terminal (type 1-b and 1-c), except CTB which plans to convert its seaside transportation to AGV system in future, QGCs adopt a **single trolley system.** Design policy of this type of terminal, which includes DPW Antwerp Gateway Terminal and London Gateway Terminal, is "to improve QGC productivity by increasing the Tandem-lift (or twin lift) ratio". For this purpose this type of terminal maintains flexibility by adopting a manned STR/Shuttle for the key process connecting QGCs and ASCs. In these terminals, QGCs place the unloaded containers (two 40' containers at Tandem-lift operation) on the interchange zone/slot at the ground under the gantry or back reach directly, and manned STR/Shuttle pick them up and transfer them to the stacking yard and vice versa. Automated seaside transportation system which is effective for this Tandem-lift operation has not yet been developed. As a result, STR/Shuttle terminals have not yet adopted a Dual Trolley for their QGCs.

③ Tandem-lift Operation in AGV Terminals

Tandem-lift operation is attractive even at AGV terminals with Dual-trolley QGCs. Some AGV terminal operators are trying to realize fully automated tandem-lift operation. One of the successful examples can be observed at LBCT Long Beach which is currently in the commissioning stage and is scheduled to start commercial operation in the 3rd quarter of 2015. This terminal has dual trolley QGCs; the 1st trolley (manual operation) has a Tandem-lift and twin-lift convertible system whereas the 2nd trolley (automated operation) has a twin-lift and single-single lift system. Two 40' containers unloaded by the 1st trolley onto the lashing platform using Tandem-lift operation are picked up by the 2nd trolley one by one and handed off to the AGV under the back reach of the gantry and vice versa. This combination of tandem-twin/single-lift operation so far represents the cutting edge of this technology.

Table 3.4-1 QGC and Horizontal Transport Vehicle for ASC System

No.	Terminal	Year of Installation	Site	QGC					Horizontal Transport
				Trolley	1st Trolley		2nd Trolley		
					Lift System	Operation	Lift System	Operation	
ASC System with AGV (Type 1-a)									
1	ECT-Delta	1992	G	Single Trolley	Twin	Manual	-		AGV
2	CTA*	2002	G	Dual Trolley	Twin	Manual	Twin	Full Auto	AGV
3	Euromax	2011	G		Twin	Manual*	Twin	Full Auto	AGV
4	APM Terminal (MV-2)	2015	G		Twin (Tandem)	Remote	Twin	Full Auto	L-AGV
5	RWG Terminal (MV-2)	2015	G		Twin (Tandem)	Remote	Twin	Full Auto	L-AGV
6	LBCT (Long Beach)	2015	B		Twin Tandem	Manual*	Twin	Full Auto	AGV
ASC System with Manned STR/Shuttle (Type 1-b)									
7	CTB**	2009	B	Dual Trolley	Twin	Manual	Twin	Full Auto	Manned STR (1 over 3)
8	DPW Antwerp Gateway Terminal	2007	B	Single Trolley	Twin Tandem	Manual	-	-	
9	APM Terminal Virginia	2008	G	Single Trolley	Twin	Manual	-	-	Manned Shuttle (1 over 1)
10	TTI Algeciras	2010	G		Twin	Manual	-	-	
11	BEST (Barcelona)	2012	G		Twin	Manual	-	-	
12	BNCT (Pusan New Port)	2012	G		Twin	Manual	-	-	
13	DPW Brisbane Terminal	2014	B		Twin	Manual	-	-	
14	DPW London Gateway Terminal	2013	G		Twin Tandem	Manual	-	-	
ASC System with Auto STR (Type 1-c)									
15	TraPac Terminal	2014	B	Single Trolley	Twin	Manual	-	-	Auto-STR (1 over 2)

3.4.2 Horizontal Transportation Equipment

The horizontal transport system serving the Yard Stacking Crane consists of two separate logistic loops

(See **Figure 3.4-1**):

1) Landside transport: moving containers from the terminal truck gate or intermodal railway terminal to the stacking yard and vice versa
2) Seaside transport: moving containers from QGC to the stacking yard and vice versa

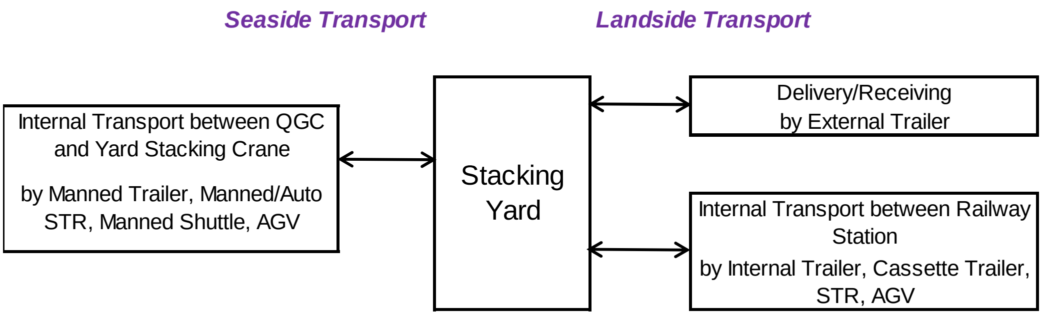


Figure 3.4-1 Concept of Horizontal Transport

Landside transport is traditionally handled by external trailers entering through the gate into the terminal area. However, recently various type of vehicles, such as STR or Cassette Trailers, and AGVs have also been employed (See **Figure 3.4-1**). Seaside transport is handled by internal terminal vehicles such as terminal tractors/chassis, straddle/shuttle carriers or AGVs.

Since street trucks entering the terminal are driven by external drivers unfamiliar with unmanned cranes, special attention needs to be paid to safety in automated terminals. The safety arrangements are considered simpler for the ASC layout than cantilever RMG layout, since the external trucks only drive to the landside end of the ASC blocks and the waterside is completely separated. For the cantilever RMG layout, external trailers drive under the cantilevers of the RMGs and such total separation is not possible. In some terminals, double-cantilevers are used so that the internal terminal vehicles and the external trucks have separate pathways.

[Manned Trailer System]

Traditionally, seaside transport for manually operated yard gantry cranes (i.e. RMG, RTG) has been handled by low cost manned trailers. However, these have the following serious disadvantages when used for an automated yard stacking system:

1) The operation of the ASC has to be synchronized (coupled) with the arrival of terminal trailers. ASCs cannot place containers directly on the ground and move onto the next tasks, significantly reducing yard productivity.
2) Having an automated stacking crane loading a container while there is a driver in the terminal tractor cabin creates safety problems.

[Manned STR/Shuttle System]

The advantage of using a straddle carrier (STR) for seaside transport is that the operation cycles of the

ASC and QGC can be made independent in this STR system (decoupled). The ASCs, QGCs and STRs all place containers directly on the ground and use the interchange areas as "buffer zones" for containers. The disadvantage of the STR system compared with the manned trailer system is the higher price. However, it should be noted that, owing to increased horizontal transport efficiency, the SRT system requires fewer vehicles than the trailer system to achieve the same production volume.

Shuttle Carrier (1 over 1) is a lower and lighter straddle carrier type used for transport only. It does not stack containers, but only transports them between the QGCs and ASCs. Combination of ASC and Manned-shuttle (Type 1-c) has been adopted as a semi-automated system in various ports since 2008 (i.e. APMT Virginia, TTI Algeciras, BEST Barcelona, BNTT Bussan, DPW Brisbane, and DPW London Gateway Terminal).

[Cassette Trailer System]

Low profile cassettes on which containers can be loaded have recently been used in a number of terminals for the transport between the stacking yard and on-dock railway station and customs warehouse. The advantage of the cassette trailer system is 1) de-coupling between tractor and containers on the cassette, which results in a decrease in the number of tractors and drivers, 2) the use of cassette rather than chassis, which reduces the initial investment and maintenance cost. DPW London Gateway Terminal and Rotterdam MV-2 RWG Terminal are the first two terminals to introduce this cassette system for their internal transportation between stacking yard and on-dock railway terminals (See **Figure 3.4-2**).

Figure 3.4-2 Cassettes and Cassette Trailer

[Auto-STR System]

The establishment of a fully automated ASC-Shuttle system by converting the manned shuttle carrier to a robotic system has been a long-standing goal of many terminal operators and STR manufactures. Automation of the STR terminal itself, including auto stacking and auto horizontal transport, has already been realized by Patric Terminal Brisbane. Hence, the remaining issue is how to realize an overall effective automated system by combining with ASC.

The first terminal which implemented this type of automation (Type 1-c) was TraPac Terminal in the

Port of Los Angeles (2014). In this terminal, Auto-STR covers not only 1) seaside horizontal transport but also 2) operation in the ground stacking yard, and 3) internal transport between yard and on-dock railway terminal. For this reason, Auto-STRs in TraPac are the same type as at Patric Terminal (1 over 2) to perform higher stacking and unmanned horizontal transport. (Refer to **2.7**).

In contrast to Patric Terminal, Auto-STR navigation system of TraPac adopts a magnet system, in which each STR detects pole direction and allocation patterns of the magnet bits buried in the ground of the STR moving area with an antenna installed in the bottom of the vehicle. The detected signals are decoded and the exact location of the STR in the terminal is pinpointed. Patric's Auto-STR navigation system adopts mm-wave radar system with more than thirty reflecting boards installed in the yard.

[AGV System]

Since the first fully automated terminal started at ECT-Delta in 1993, AGV combined with ASC (Type 1-a) has been the most prevailing and totally robotic terminal automation system in the world. Safety risks for drivers have been totally eliminated in this system.

Originally, AGVs were all of a platform-type design (Conventional AGVs), with containers loaded on top of the AGV platform by another crane (ASC, RTG or QGC). Using this design, the operation cycles of ASC, QGC and AGVs are tied together (coupled). This point is considered as a disadvantage compared to the STR/Shuttle system. Since an AGV does not have a self-loading/depositing function when carrying containers, they have to wait for this task to be performed by a stacking crane or QGC at the transfer zones of the stacking block or under the QGCs. This idling time reportedly exceeded 50% of the AGV fleet capacity.

To mitigate this disadvantage, Lift-AGV type of vehicle has been introduced to the latest fully automated terminals in the Port of Rotterdam Maasvlakte-2; APMT and RWGT. This Lift AGV is able to place the carried containers on a rack, and also to pick up containers from such racks. These racks are placed in the ASC transfer zones, thus decoupling the operation sequences between ASCs and AGVs. However, it is not feasible to use such racks under the QGC, since the QCs move while loading/ unloading the container to/from the ship. In the APMT Maasvlakte-2, the Lift AGVs expand their moving territory to the on-dock railway station (See **Figure 3.4-3)**.

Source: Terex/Gottwald Product Catalogue

Figure 3.4-3 Conventional AGV (Left) and Lift-AGV (Right)

The AGV system incorporates innovative technology for reliable navigation, positioning and perception systems.

[Navigation of AGV]

AGV recognizes its current position by detecting an electromagnetic signal from the transponders embedded in a lattice at 1.5m-20m intervals in the pavement in its travelling area. Together with the information from its own steering mechanism, AGV judges the deflection from the planned travel route and angle deviation so that it performs automatic operation while selecting the travelling route instructed by the operation control system in the central computer.

[Positioning of AGVs]

Positioning of AGVs to QGC in the quay direction (X- direction) is done by AGVs based on the QGC's position (center line of the gantry). Right angle direction (Y- direction) is adjusted by the second trolley based on the stopping position of AGV or carried container's position on the AGV with the fine adjustment system of trolley and spreader's position/angle by the laser based or IR positioning system. Stopping accuracy under QGC in AGV running direction (X- direction) is ± 50mm or less with respect to the center line of QGC (design value ± 30mm or less). In the right angle direction (Y- direction), the stopping accuracy of AGV is considered comparable with respect to the center line of the lane. AGV stop position within the ASC transfer zone is designed at a fixed point.

Table 3.4-2 Yard Stacking and land-side transportation vehicles for ASC System

No.	Terminal	Yard Stacking				Truck Loading	Connection to Railway Station		Connection to Barge and Feeder Ship	
		Yard Stacking System	ASC per Block	Rail Track	Positioning		Rail Cargo Ratio	Vehicle	Transship Cargo Ratio	Vehicle
ASC System with AGV (Type 1-a)										
1	ECT-Delta	ASC	1	1	Target	Manned STR	20%	Manned Trailer	40%~50%	AGV
2	CTA*	ASC	2	2	Target	Remote	30%	Manned Trailer	30%~40%	AGV
3	Euromax	ASC	2	1	Target	Remote	20%	Manned Trailer	40%~50%	AGV
4	APM Terminal (MV-2)	ASC	2	1	Target	Full Auto-loading	20%	L-AGV	40%~50%	L-AGV
5	RWG Terminal (MV-2)	ASC & C-ARMG	2	1	Crane	Full Auto-loading	20%	Manned Cassette Trailer	40%~50%	AGV
6	LBCT (Long Beach)	ASC	2	1	Target	Full Auto-loading	35%	Manned Trailer	almost zero	AGV
ASC System with Manned STR/Shuttle (Type 1-b)										
7	CTB**	ASC	3	2	Target	Remote	30%	Manned STR	30%~40%	Manned STR
8	DPW Antwerp Gateway Terminal	ASC	2	1	Crane	Full Auto-loading	10%	Manned Trailer	30%~40%	
9	APM Terminal Virginia	ASC	2	1	Target	Remote	n.a	Manned Trailer	n.a	Manned Shuttle
10	TTI Algeciras	ASC	2	1	Target	Manned Shuttle	2%	Manned Shuttle	90%	
11	BEST (Barcelona)	ASC	2	1	Target	Remote	n.a	Manned Trailer	n.a.	
12	BNCT (Pusan New Port)	ASC	2	1	Target	Remote	n.a.	Manned Trailer	n.a.	
13	DPW Brisbane Terminal	ASC	2	1	Target	Remote	n.a.	Manned Trailer	n.a.	
14	DPW London Gateway Terminal	ASC	2	1	Target	Full Auto-loading	20%	Manned Cassette Trailer	almost zero	
ASC System with Auto STR (Type 1-c)										
15	TraPac Terminal	ASC Ground	2	1	Target	Remote	35%	Auto-STR	almost zero	Auto-STR

Note Remote: Direct Remote
Full Auto-loading: Direct and Fully automated

3.4.3 Stacking Crane

Since automatic tacking cranes are operated unmanned and not equipped with cabin, some of the functions normally undertaken by the crane operator are required to be automated. The main functions to be automated are as follows:

1) Starting/ending a job

2) Pick-up/deposit of container from/to the horizontal transport vehicles or ground
3) Path control to move from start point to destination point
4) Controlling the spreader and container position with high accuracy (±cm)
5) Avoiding collisions
6) Compensating for changing rail conditions
7) Handling crane dynamics and deflection

For these purposes ASCs are equipped with an advanced control system; i.e. laser and/or infrared (IR) sensors, CCD camera imaging technology, sophisticated process controllers, and crane management information systems that continuously report the status of the crane.

Among these, the most important item is crane/spreader positioning which affects the accuracy of stacking and crane productivity. There are two types of positioning systems; target positioning and 2) crane positioning.

Target positioning system is to adjust the spreader position onto the container corner castings by laser and/or infrared (IR) sensors and camera imaging technology. This system is common and used in many auto stacking cranes (See **Figure 3.4-4**)

Crane positioning system has a guide mast in the trolley and stiff gantry structures so that it can make mechanical crane and trolley positioning in the yard operation. The automated terminals which have implemented this system are DPW Antwerp Gateway Terminal and RWGT-MV2. The main advantage of this system is that it enables the spreader positioning time to be shortened, especially in a strong wind environment, by preventing horizontal sway and skew of spreader/ container by means of simple mechanical structures.

Figure 3.4-4 Crane Positioning (Left) ASC and Target Positioning (Right)

① **Number of ASCs per Block and Rail Tracks**

There are generally two ASCs equipped in each stacking block (with the exception of ECT Delta

Terminal and CTB Hamburg). As yard blocks of CTB are designed much larger than that of CTA, they have three (3) ASCs in each block. However, quantity of stacking containers per ASC of CTB is designed equivalent to that of CTA. In the case of Cantilever Auto-RMG terminals, the quantity of stacking cranes per block is usually not more than two (2) sets in spite of their bigger yard block size. This is mainly due to their stacking cranes which are not designed to undertake container carrying functions along the block length.

A single rail track for each block is common for ASCs, whereas CTA and CTB have double tracks on which a Smaller ASC and a Larger ASC are installed over one pair of narrower and wider tracks respectively so as they can overpass each other and can cover the entire block.

② Introduction of Full Auto truck loading

Container loading and unloading to/from a trailer (hereinafter referred to as “truck loading”), which is manipulated remotely from the central control room, was started at Pasir Panjang Terminal (Phase-1) in 1997. Ten years later, full auto truck loading was realized at Antwerp Gateway Terminal in 2007.

Core function of this system is to recognize the shape of a trailer-chassis and twist lock pin position at the four corners of the chassis using advanced camera imaging technology and to adjust the spreader position to the target. After the implementation at Antwerp Gateway Terminal, the full truck loading system became as a standard tool for new automated terminals, and more than ninety percent (90%) of transactions are successfully performed without manual support.

3.4.4 Linkage with On-dock Railway Terminal

The most suitable container transport vehicles for transport between the stacking yard and on-dock railway station are generally selected by the distance and position of both facilities. In automated terminals, internal transport is commonly handled by manned tractors and trailers, and loading of containers onto the block train is handled by manned rail gantry cranes, usually cantilever and wide-span type with turning trolley. Due to the difficulty in synchronizing the yard delivery operation and block train loading operation, substantial buffer capacity is required at the railway station. This buffer area is usually kept under the cantilever of the rail gantry crane zone. Tractor heads and trailers are designed to be detached and joined easily to achieve a high tractor operating rate.

Wide variety of vehicles for internal transport is available throughout the world. Some of the representative alternatives are shown in **Table 3.4-3**. Lift-AGV and Auto-STR is adopted for full automation of internal land transport. Cassette trailer system is used instead of a trailer-chassis which enables the initial investment cost and maintenance cost to be reduced. Manned-STR and Manned-Shuttle can be used for both seaside and landside transport, thereby reducing equipment costs.

Table 3.4-3 Vehicles for Railway Terminal Connection

No.	Purpose	Buffer in the Railway Station	Connection to Railway Station		Terminal
			Vehicle	Rail Cargo Ratio	
1	Automation	Rack	L-AGV	20%	APM Terminal (MV-2 (2015))
2		Ground	Auto-Strad	35%	TraPac Terminal (2014)
3	Lower Cost of Trailer	Cassette	Manned Cassette Trailer	20%	RWG Terminal (MV-2 (2015))
				20%	DPW London Gateway Terminal (2013)
4	Common use of Horizontal Transport equipment	Ground	Manned Shuttle	2%	TTI Algeciras (2010)
5		Ground	Manned STR	30%	CTB (2009)

3.5 Effect of Terminal Automation

The effect of automation of container terminal is generally recognized as follows;

(1) Improving labor productivity: Reduction of labor cost which shares more than 60% of total terminal operation cost,

(2) Advanced use of port area; To gain maximize terminal capacity at the port available area,

(3) Improvement of predictability of process; Realization of consistent container loading/unloading productivity,

(4) Improvement of the reliability of the process; Reduction of damages to terminal equipment and containers/ cargoes,

(5) Reduction of labor accidents and injury,

(6) Reduction of labor costs, particularly at night and on holidays.

The impact and significance of each item is different according to each terminal's geographical position, economic and social environment. However, "reducing labor costs" is a common effect in all automated terminals.

As described in Chapter 2, a 30-50% reduction in dockworkers can be realized by automation depending on the type of system adopted. To verify this reduction rate, the following automation model is examined and reviewed.

① **Terminal Operation Model**

１) Three (3) QGCs are dedicated for each calling vessel (3 gangs per vessel)

２) Stevedoring work (quay-side operation) is performed for three days per week, and two shifts per day (16 hours per day).

３) Two Yard Stacking Cranes (i.e. RTGs) undertake one QGC's stevedoring work (2 RTGs per gang) and two operators are assigned for one RTG.

４) Six yard trailers undertake one QGC's stevedoring work (6 trailers per gang) and one driver is assigned for one trailer.

5） Land-side operation for container receiving and delivery is undertaken by RTGs, and six days of land-side operation is continued per week with one shift operation.

② **Automated System**

1） Yard stacking is automated (i.e. Automated RTGs).

2） Sea-side horizontal transportation is automated by AGV. Transfer containers between AGVs and Auto-RTGs are fully automated with one worker being assigned for monitoring.

3） Truck loading to the external vehicles is remotely controlled by the operator in the control office. One operator covers three (3) RTGs.

Table 3.5-1 Workforce Saving Model by Automation

Preconditions	Number of working days per week (day)	Sea-side	3	
		Land-side	6	
	Number of shifts per day (shift)	Sea-side	2	Day, evening
		Land-side	1	Day-shift
	Number of gangs per shift (gang)	Sea-side	3	

	Process	Conventional Terminal Operation (RTG with Manned Trailer System)			Automated Terminal Operation (ASC with AGV System)			Work Force Saving Rate
1	QGC	Workers per Gang	QGC Operator	2	Workers per Gang	QGC Operator	2	**0%**
			Deck-man	1		Deck-man	1	
			Corning	2		Corning	2	
			Lashing/Unlashing	5		Lashing/Unlashing	5	
			Sub-Total	10		Sub-Total	10	
		Total Workers (persons)	per Shift	30	Total Workers (persons)	per Shift	30	
			per Day	60		per Day	60	
			per Week	180		per Week	180	
2	Sea-side Horizontal Transportation	Number of Driver per Tractor		1	Number of Driver per Tractor			**18%**
		Number of Tractor per Gang		4	Number of Tractor per Gang			
		Total Workers (persons)	per Shift	12	Total Workers (persons)	per Shift		
			per Day	24		per Day		
			per Week	72		per Week	0	
3	Sea-side Yard Crane Operation	Number of Operators per Yard Crane		2	Number of Operators per Yard Crane		0	**17%**
		Number of Yard Cranes per Gang		2	Number of Yard Cranes per Gang		2	
		Total Workers (persons)	per Shift	12	Total Workers (persons)	per Shift	1	
			per Day	24		per Day	2	
			per Week	72		per Week	6	
4	Land-side Yard Crane Operation	Number of Operators per Yard Crane		2	Number of Operators per Yard Crane		0.3333	**15%**
		Number of Yard Cranes per Shift		6	Number of Yard Cranes per Shift		6	
		Total Workers (persons)	per Shift	12	Total Workers (persons)	per Shift	2	
			per Day	12		per Day	2	
			per Week	72		per Week	12	
Total Number of Workforce per week (1+2+3+4)				**396**			**198**	**50%**

The result of reviewing labor reduction effect based on the above conditions is summarized in **Table 3.5-1**. As a result, the effect of reducing laborers per berth is about fifty percent (50%), which is substantially the same as that obtained from the examples presented in Chapter 2.

Chapter 4. Future Trends

4.1 Expansion of automated terminal

The first automated container terminal came into existence in 1993 at SeaLand Terminal (Now ECT North Terminal) in the Delta District of the Port of Rotterdam. Terminal automation has evolved and expanded steadily since then, and many successful examples can be found in major ports of the world. In the last two decades, many technologies underlying terminal automation have been developed and various kinds of handling systems for automated terminals have been devised. Today, automated terminals which incorporate a multitude of new technologies for all aspects of operation are expanding around the globe.

Terminal automation is already common in West Europe where wage levels are high. Most newly developed container terminals in Europe in the 2010s are fully-automated (ASC system with AGV (Type 1-a)) or semi-automated (ASC system with Manned-STR/Shuttle (Type 1-b)).

On the other hand, Asian ports (typified by Singapore's PSA Terminal) have not invested in technology for full automation as labor costs are still relatively low in Asia. Moreover, establishing a fully automated terminal requires overall system integration which terminal operators in Asia have been reluctant to attempt as the benefits are not considered to be large enough.

In addition, in developing countries where labor costs are low, job creation is an important national policy while the construction of modern automated terminals runs counter to that policy.

In the near future, the rapid development of automated terminals is expected in North America. Until now, terminal automation had been delayed due to strong resistance from unions. However, barriers to introducing terminal automation were removed with the signing of the West Coast Labor Agreement of 2008 in which the union withdrew its objection to terminal automation provided there were certain guarantees to compensate for the impact on labor.

As wages of dock workers in North America are amongst the highest of any region of the world, there is great potential for terminal automation. Currently, some automation projects are being studied in the US; i.e. APL Terminal in the Port of Los Angeles. Considering that terminal automation requires not only the automated equipment and facilities but also investment in large infrastructure, the financing ability of the public sector (which generally is responsible for large infrastructure construction) is crucial for implementing these projects. In the case of APL Terminal's automation project, this point is also a key factor.

In China, an automated terminal is planned to be introduced in Yangshan (Phase 4) in the near future. The driving force behind this automation project seems to be national pride rather than economic rationality. However, as this terminal will be located offshore and far from residential areas, it would be difficult for large numbers of workers to commute back and forth; this may be one of the reasons for automation.

In recent years, Arab countries have established hub ports covering the Gulf countries or east coast of Africa which they seek to expand. Since these countries lack a sufficient workforce, the introduction of automated terminals would seem to be a logical step, especially as the public sector has the financial power to develop the required infrastructure. Accordingly, the emergence of automated terminals in this region is expected in the near future.

4.2 Technical Trends

(**1**) Automation of QGC

Full automation of the main trolley (the first trolley) of QGC has been a long-standing issue. At present, combination of a remote controlled and partially automated system has been realized at APMT-MV2 and RWGT-MV2. In both terminals, one remote operator covers one main trolley. The coverage will gradually be increased in the near future as the Fully Automated Truck Loading system of ASC is now performing, in which one remote operator covers seven (7) blocks. The complete automation of QGC will thus be substantially realized when it reaches the same level as ASC.

Sea side cargo handling gang commonly consists of QGC operator, corning personnel, checkers for unloaded containers, lashing personnel, etc. Automated equipment for corning is currently being developed by competing manufacturers and will be adopted as standard equipment in the near future. In addition, the OCR system has been implemented in some terminals to reduce the number of checkers, and this trend is expected to continue.

(2) Automation of Horizontal Transport

[AGV System]

It is noteworthy that the latest two automated terminals in Rotterdam MV2 adopted the Lift-AGV. Then, Lift-AGV system has been proceeded from development stage to commercial stage, so that added a step favorable conditions in competition with Shuttle Carrier System. The next technical issue for AGV is to develop a system capable of supporting Tandem-lift operation. This will take some time to develop as further study on AGV and the 2^{nd} trolley for horizontal transport in Tandem-lift operation will be required.

[STR/Shuttle Carrier System]

TraPac’s fully automated terminal which opened in 2014 is remarkable step for the STR/Shuttle system, which is a combination of ASC and Auto-STR (1 over 2). The same type of fully automated terminal which combines ASC and “Auto-Shuttle (1 over 1) for seaside horizontal transport will be developed as a Greenfield project in the near future on a rectangular land area.

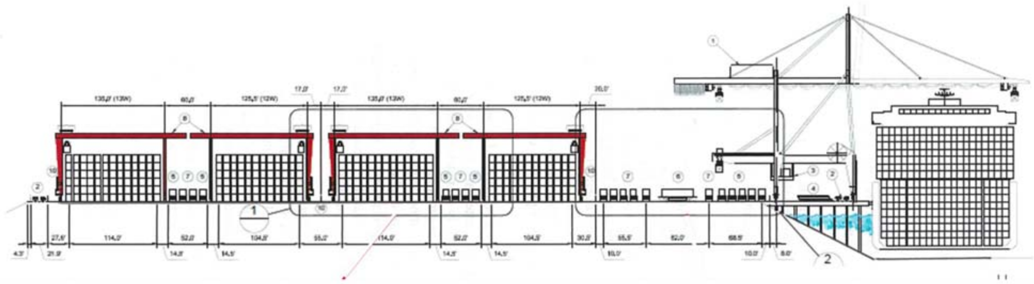
[Selection of Horizontal Transport System]
Competition between AGV and Auto-Shuttle in horizontal transport will continue for a long time. Important criteria for determining which system offers the best service will be its efficiency in supporting tandem-lift operation and to what degree the environmental load can be decreased.

[Truck Loading]
Fully Automatic Truck Loading system is currently 90% fully automated but will reach 95% -98% in the future. Full automation will thus be substantially realized.

(3) Automation of Yard Stacking

[ASC]
ASC system relies on proven technology.

[**Cantilever Auto-RMG**]
There are many examples of semi-automated terminals with a combination of Cantilever Auto-RMG served by Manned-trailer in Asian terminals. However, a fully automated system in combination with AGV has only recently been introduced at RWGT-MV2 in 2015. Based on this technology, APL Terminal is planning to develop a fully automated Cantilever RMG terminal in the Pier 300 Redevelopment Project in the Port of Los Angeles. If realized, this would be the first fully automatic Cantilever RMG terminal with AGV to be developed.



Source: Berth302-306 [APL] Container Terminal Project (The Port of Los Angeles)

Figure 4.2-1 Container Flow of APL Terminal Automation Plan

(4) Movement toward Green Terminals

The development of automated terminals throughout the world has in part been driven by the need to reduce the impact of ports on the environment. Old STR for yard stacking is replaced by the ASC, RTG is replaced by Cantilever RMG, while the Manned-trailer is replaced by the battery-driven AGV, all of which contributes to reducing CO_2 emissions and the impact on the environment. Particularly in the case of the most recently constructed APMT and RWGT in Rotterdam-MV2 and Long beach LBCT, priority has been given to reducing the environmental impact (both employ battery-driven AGVs). The future direction of automation clearly points to the development of more green terminals.

Annex: Abbreviation and Terminology

AGV	Automated guided vehicle; a robotic vehicle for horizontal transport of containers between quay and yard
ASC	Automated stacking crane; a driverless rail mounted gantry crane for container yard handling operations
Auto-RMG	Automated rail mounted gantry crane, more commonly known as an ASC and Cantilever RMG (See "RMG")
Auto-RTG	Automated rubber tired gantry crane; used for container yard handling operations (See "RTG")
Auto-Shuttle	Automated shuttle carrier; a driverless 1-over-1 straddle carrier for horizontal transport of containers between yard and quay (See "Shuttle")
Auto-STR (Auto-Strad)	Automated STR; a driverless 1-over-2 or 3 straddle carrier for container yard stacking operations and horizontal transport in the terminal (See "STR")
BL-AGV	Battery driven Lift AGV (See "L-AGV")
C-ASC	Abbreviation for side-loading cantilever automated stacking crane, an ASC designed for operation in stacking blocks laid out parallel to the quay
CCD	Charge Coupled Device: a type of semiconductor used for image sensor incorporated in digital camera
DGPS	Differential global positioning system; a technology for automated identification and tracking of vehicles in the terminal
E-ASC	Abbreviation for end-loading automated stacking crane, an ASC designed for operation in blocks laid out perpendicular to the quay
FATL	Full automatic truck loading
ITV	Internal transport vehicle; a generic term denoting vehicles used for container transport within terminals
L-AGV	Lift AGV; specially designed AGV enable to deposit carrying containers to the rack or pick them up from the rack (See "AGV")
OCR	Optical character recognition; a technology for automated identification and tracking of vehicles and containers
OHBC	Overhead bridge crane; used for container yard handling operations
PDS	Position detection system; a system for automatically detecting container, vehicle and crane location in the terminal
QGC	Quay gantry crane, also known as ship-to-shore (STS) crane, a type of crane for

	moving containers between ships and terminal berths
RMG	Rail mounted gantry crane; a type of container yard handling crane and also used for rail terminal handling operations
RTG	Rubber tire type gantry crane; a type of container yard handling crane
Shuttle	Shuttle carrier; a 1-over-1 straddle carrier designed for horizontal transport of containers between yard and quay
STR	Straddle carrier; a type of container handling equipment used for yard operation and horizontal transport in the terminal
TOS	Abbreviation for terminal operating system; computer software specially designed to facilitate container terminal operation and management