State of the art of handling and storage systems on container terminals

Bärbel Koppe, Birgitt Brinkmann
Leuphana University Lüneburg, Hydraulic and Coastal Engineering, Faculty Environment and Technology, Lüneburg, Germany

Abstract:

Since 1995 container traffic worldwide has increased by at least 10 percent every year and this growth rate is expected to continue. There is an increase in the number of container ships as well as in ship size. In 2006, the world's largest containership, the Emma Maersk, with a length of 397 m and a width of 56 m, was commissioned. Ships like this, with load capacities of much more than 10,000 TEU (Twenty Foot Equivalent Units), call for efficient container handling and storage systems at dedicated terminals. As a direct result, new container terminals all over the world are under construction, both on newly created port areas and in re-designation or extension of existing port areas.

Besides size and load capacity of the design vessel the choice of container handling and storage system is of major influence on terminal design. These systems affect the required floor space for transport and storage of containers as well as the handling efficiency, the required number of staff, the system reliability and the operation time.

The paper presents recent developments in container handling and stocking systems focusing on the amount of floor space required, and productivity.

I. INTRODUCTION

The growth rate in handling volume of the top 50 ranking world container ports reached 11.2 % in 2005 compared with results in 2004 [1].

Today the largest container ports are located in Asia. The container traffic in Chinese ports grew on average by 25 % in between 2004 and 2005 [1]. The largest port in Germany, both in total cargo traffic and in handled TEU, is the Port of Hamburg ranking 23rd worldwide regarding total cargo traffic and 8th regarding container cargo in 2005 [1]. The average growth rate in container handling in Hamburg was approx. 15% whereas the overall cargo handling growth rate achieved approx. 8%, both in the period 2001-2005 [1]. Therefore, most port development projects worldwide are container terminals.

With the growing demand for container cargo the dimensions of containerships are rising. In 1998, the first post-panamax containerships were launched pushing the panamax limits in all three dimensions. The largest panamax ships are able to carry 4,800 TEU [2] whereas today's largest containerships, the 397 m long and 56 m wide "PS-series"[1] of Maersk, is able to carry 11,000 full-loaded containers [3]. Under the assumption that not all containers are fully loaded (normal case) these ships are able to carry up to 14,500 containers [4].

The container freight system not only consists of large ships and ports but also of middle range and smaller containerships for the transport on less powerful trading routes and to ports offering less water depth than the large deepwater ports.

Therefore, very different container handling and stocking systems are available and are now in development to meet the different requirements. The consultant engineer planning a new, or improving an existing, container terminal has to select the best system with respect to interfaces of existing facilities, productivity, reliability, space availability, weather conditions as well as capital and maintenance costs.

II. FUNCTIONAL AREAS ON CONTAINER TERMINALS

A container terminal consists of at least four functional areas:

[1] Already put into service: Eleonora Maersk, Emma Maersk, Estelle Maersk, Evelyn Maersk [3]

1. Handling area between ship and quay (vertical handling facilities)
2. Handling area between quay and stacking area (horizontal handling facilities)
3. Stacking area (horizontal and vertical handling facilities)
4. Handling area, between stacking area and hinterland transport system, including gate and lanes for road access and rail connection (horizontal handling facilities)

For packing and unpacking of containers, as well as storage of goods in port-to-port traffic, a canopied packing area has to be established. The importance of this area decreases with the increase in house-to-house container traffic. Furthermore, a repair and maintenance area for containers and terminal equipment is another required functional area of the terminal.

III. Container Handling and Stocking Systems

A. Functional area 1

Ship-to-shore cranes are specially designed gantry cranes or conventional quay cranes equipped with a container spreader. The latter are in use on small to middle range container terminals offering comparatively low productivity of 20 to 25 moves per hour.

On middle to high range container terminals, gantry cranes are applied for efficient loading and unloading of containerships. While the crane is handling the containers directly onto and from the ship, the containers are placed onshore either on terminal tractor trailers or on the ground, depending on type of operation.

Most frequently single trolley ship-to-shore cranes are in use (Figure 1). The trolley is manually operated and a productivity of 25 to 35 moves per hour can be achieved.

Figure 1 Gantry cranes at the Burchardkai, Port of Hamburg [5]

Cranes with a double trolley system are equipped with a particular transit platform serving as interface or buffer for containers. Since 2002, this newly developed crane type is employed in the Port of Hamburg at the Container Terminal Altenwerder (CTA). The handling between transit platform and quay as well as the further onshore transport is done automatically. As a result, only short transport ways are operated manually and the productivity increases up to 45 moves per hour.

The choice between cranes with single or double trolley system depends on the required productivity and also on the automation level of the other terminal facilities. If the terminal operation system (functional area 2 and 3) is automated, the transit platform is an ideal interface between manual and automated system. The main disadvantage of the partly automated double trolley crane is an approx. 60% higher price compared to manually operated single trolley cranes.

The main interferences in developing a fully automated ship-to-shore crane are ship movements at the quay and very small tolerances in the storage frame onboard. All currently employed ship-to-shore cranes are fully manual, or, partly automated operations. Fully automated systems are still in development.

B. Functional area 2

Functional area 2 equipment interfaces with both the waterside and the stacking operating procedure. Some equipment is used in all three landside areas 2, 3 and 4. Then it must be able not only to provide horizontal, but also vertical, transportation.

Generally, manually operated and automated systems can be distinguished. The use of one of these systems is dependant on the automation level of the adjacent operating system.

The simplest equipment used for horizontal transport is a truck and chassis system. This system shows advantages on spacious terminals because of its high driving speed. For container loading and unloading, additional equipment like straddle carriers are required at least in the storage area, whereas the ship-to-shore crane can put the container directly onto the chassis or pick it up from it. Because of the laborious connecting procedure often specially designed tractors equipped with a gooseneck enabling an easy coupling with a roll trailer are in use (Figure 2).

Figure 2 Tractor equipped with gooseneck and roll-trailer [6]

Straddle carriers (Figure 3), also called van carriers, are providing horizontal as well as vertical transport. A total stacking height of 1 over 4 containers is possible. This multi-purpose equipment is widely in use on all terminal sizes. Besides manually operated straddle carriers, automatic guided straddle carriers are also currently in use, like on the terminal Fisherman's Island, Brisbane, Australia.

Figure 3 Straddle carrier on the Burchardkai, Port of Hamburg, Germany [5]

Shuttle carriers (Figure 4) are especially designed for high performance terminals with fast ship-to-shore cranes and dedicated stacking equipment. It is a low-height straddle carrier driving on high speed between stacks, quay and interchange areas.

Figure 4 Shuttle carrier [7]

Reach stackers (Figure 5) are also able to provide horizontal and vertical transport. Because the container is transported crosswise to the center-line of the vehicle, the driving lanes have to be wider than when using straddle carriers. As a result, reach stackers are seldom used on spacious terminals. They are advantageous, however, on terminals with small distances and high stacking rates. Additionally, reach stackers are also applicable for other purposes than container handling and are often favored on smaller terminals. The stacking height is up to 1 over 5 containers.

Container stackers are a type of big fork-lift working similar to reach stackers and reaching 5-high stacking heights.

Since the 1980s automatic guided vehicles (AGV) have been in use. This technology was applied first on the Europe Container Terminals (ECT) Rotterdam (Figure 6). Since 2002, it has also been employed in Hamburg on the Container Terminal Altenwerder (CTA). The AGV is a sort of automated chassis with own engine enabling horizontal transport. It is operated with high position accuracy via computer control system on the basis of management and navigation software. The automated part of the terminal is prohibited area for personnel and even the refueling takes part automatically.

Figure 5 Reach stacker [8]

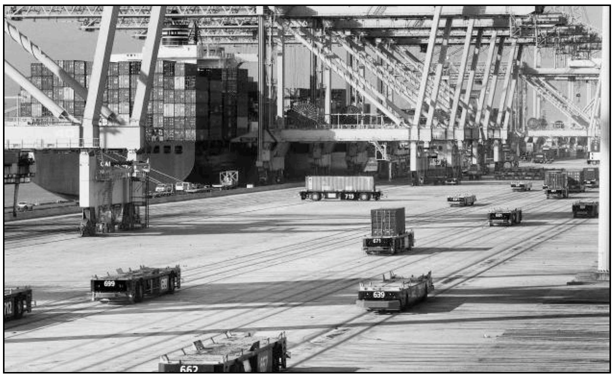

Figure 6 Automatic guided vehicles on the Europe Container Terminal Rotterdam [9]

C. Functional area 3

Straddle carriers, reach stackers or container stackers, can be deployed in all three landward functional areas bringing the containers directly from the shore into the stacking yard and further to the hinterland interface or vice versa.

Special equipment for stacking are rubber-tired-gantry-cranes (RTG) and rail mounted gantry cranes

(RMG) (Figure 7), both also called transtainer. They enable high storage capacity because of block storage with only small ratio of driving lanes in the stacking yard. The stocking height is up to 1 over 7 containers.

Whereas the RTG offers higher flexibility especially on terminals in conversion, RMG systems can be built wider than RTG even optimizing the stacking ratio. Furthermore, RMG offers easy automation possibilities.

Figure 7 Rail mounted gantry crane in the Port of Antwerp [9]

D. Functional area 4

For the transport of containers from the stacking yard to the hinterland infrastructure (roads and railways) straddle carriers, reach stackers or container stackers can be used. In case of a transtainer system, truck driven chassis can also be applied directly at the landward end of the stacking yard. For efficient container handling at long railway lines rail mounted wide span gantry cranes are suitable (Figure 8).

Figure 8 Rail mounted wide span gantry crane at the Port of Birsfelden, Switzerland [9]

IV. AUTOMATION LEVEL ON CONTAINER TERMINALS

Currently, terminals with different automation levels are planned or under construction. Looking at the two main German container terminals in the planning or construction stage, the Burchardkai in the Port of Hamburg (under construction) and the only German deep water port JadeWeserPort in Wilhelmshaven (in the planning stage), the automation level at the Burchardkai with automated gantry cranes at the berths and rail mounted automated gantry cranes in the stocking area is much higher than that one of the JadeWeserPort. Here the equipment consists of gantry cranes without lash platform and manned straddle carriers.

These different concepts may have originated as a result of different port operators. The Burchardkai is operated by HHLA who also operates the CTA, one of the most modern container terminals worldwide with a very high automation level. The JadeWeserPort will be operated by Eurogate, a company currently running only manual operated terminals.

Eurogate adheres to the straddle carrier system at the JadeWeserPort due to excellent operational experience with respect to costs, productivity and eco friendliness [10]. Additionally, Eurogate stresses that van carriers are very flexible and less sensitive to rough marine environments than automated systems [11]. In addition, conventional systems provide more jobs showing positive social effects in the economically less developed region Wilhelmshaven.

Generally it can be said that automated systems are only cost effective on middle-size to large terminals because of high initial costs for required information technology. In addition, automated systems need more vehicles than manned systems for handling the same number of TEUs. According to a comparative analysis [12] there is a need of much more AGV than manned straddle carriers to meet the same productivity, e.g. 65 to 27 according to selected port properties. Nevertheless, over the years the investigated automated systems are less expensive than the manned ones despite of higher capital costs [12].

On the other hand, there exist also less positive experiences with automation. On the basis of high transshipment ratio of 80% and high labor costs, the Port of Singapore installed automated overhead cranes for ship-to-shore container handling. These cranes showed good productivity but the costs are still high. The automated crane is not more cost effective than conventional RTGs [13].

In the stacking yard one major advantage of automated systems is the possibility of running 24/7 shifts without high labor costs enabling densely packed stacking yards.

V. REQUIRED SPACE IN CONTAINER TERMINALS

In many ports fast growing container transportation leads to space scarcity. Terminals are often operating at full capacity. Long storage periods of containers cause severe problems and expansion areas are often difficult to obtain.

Therefore, terminal systems have to be designed space-effective. A comparative calculation of space consumption of a manually operated and an automated terminal operation system is done on the basis of selected design parameters (Table I). The terminal and stacking systems are the following:

1. Straddle carrier system (SC)
2. Automated rail mounted gantry cranes with automated guided vehicles (RMG-AGV)

Both systems require different lane widths and stacking features, see [14]. The lane widths of automated systems are much larger because of high number of vehicles on the terminal and larger clearance width between vehicles. On the other hand, the stacking height of SC is only 4-high whereas the ARMG is able to stack 7-high. Based on these figures space consumption of both systems is calculated exemplarily. The result is shown in Figure 9.

In general, it can be stated that the difference in space consumption of both systems is small. In the case of less than approx 4 Mio TEU handled per year, the SC-systems requires less space than the automated system. In case of higher quantities of handled containers it is the reverse.

In general, automated equipment needs broader terminal sizes than manually operated facilities due to wider lane requirements on both stacking yard sides, seaward and landward.

Table I Selected design parameters

Ratio 20ft/40ft	30% / 70%			
Transshipment	25%			
Container type	Standard	Reefer	Dangerous	Empty
Container mix	80%	4%	1%	15%
Storage period	4 days	4 days	4 days	15 days
Storage height	4-SC 7-ARMG-AVG	2-high	2-high	5-high

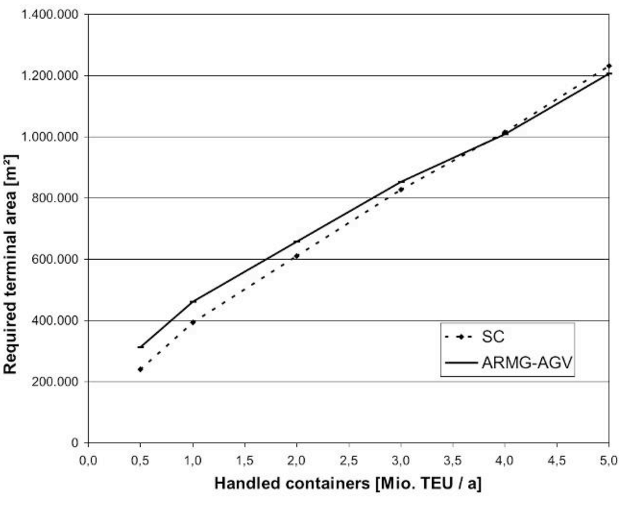

Figure 9 Comparison of space consumption of manned and unmanned terminal handling and stacking systems

VI. SUMMARY

Container handling and stacking facilities influence strongly the layout, productivity and costs of container terminals.

The decision for or against unmanned terminal facilities has to be made individually for each planning task based on terminal size, space availability, labor costs, weather conditions and cost-effectiveness.

Even larger stacking heights of automated systems do not always result in less space consumption due to required wider lanes on the seaward and landward side of the stacking area. On the contrary, the resulting cost effectiveness of automation may be much more effective, especially in countries with high labor costs.

In container terminal planning it is always reasonable to investigate different terminal systems already in the preliminary design stage. Dependant on terminal parameters, like ground plot, transshipment ratio, storage periods, required productivity, climate and labor costs, the best fitting handling and storage system has to be selected.

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