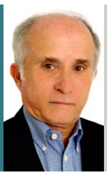
Evolution of container sea transport

The transport of goods by sea, using containers, took a long time to develop into the enormous global industry that it has become. This article discusses how this mode of transport, particularly for break bulk cargoes, has affected shipping, quay equipment and the operation of a new type of terminal, the container terminal.



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BRIEF HISTORY OF CONTAINERISATION

There are two main types of dry cargo – bulk cargo and break bulk cargo. Bulk cargoes, like grain, coal and minerals, are transported unpackaged in the hull of the ship, generally in large volumes. Break bulk cargoes, on the other hand, are transported in packages and generally are manufactured goods. Before the advent of containerisation in the 1950s, break bulk items were loaded, lashed, unlashed and unloaded from the ship one piece at a time.

However, by grouping cargo in containers, about 1 000 (28.3 m³) to 3 000 (84.9 m³) cubic feet of cargo, or up to 64 000 (29.05 metric tons) pounds are moved at once, and each container is secured to the ship once in a standardised way. Containerisation has increased the efficiency of moving traditional break bulk cargoes significantly faster, reducing shipping time by about 84%. In 2001 more than 90% of world trade in non-bulk goods was transported in ISO (International Organization for Standardization) containers. In 2009 almost one quarter of the world's dry cargo was shipped by containers, an estimated 125 million TEU (twenty foot equivalent units) or 1.19 billion metric tons worth of cargo (average 9.52 metric tons per container).

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Modern container ships can carry up to 19 224 TEU. As a class, container ships now rival crude oil tankers and bulk carriers as the largest commercial vessels in the ocean.

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By the 1830s railroads on several continents were carrying containers that could be transferred to other modes of transport. The Liverpool and Manchester Railway in the United Kingdom was one of these. "Simple rectangular boxes", four to a wagon, were used to carry coal from the Lancashire collieries to Liverpool where they were transferred to horse-drawn carts by crane. Originally used for moving coal on and off barges, "loose boxes" were used to containerise coal from the late 1780s at places like the Bridgewater Canal. By the 1840s iron and wooden boxes were used. The early 1900s saw the adoption of closed container boxes designed for movement between road and rail.

On 17 May 1917 Benjamin Franklin Fitch inaugurated exploitation of the experimental installation for transfer of containers, called "demountable bodies" based on his own design in Cincinnati, Ohio, in the United States. Later in 1919 his system was extended to over 200 containers serving 21 railway stations with 14 freight trucks.

Prior to the Second World War (WWII) many European countries, independently, developed container systems.

In 1919 Stanislaw Rodowicz, an engineer, developed the first draft for the container system in Poland. In 1920 he built a prototype of the biaxial truck, but the Polish-Bolshevik War stopped the development of the container system in Poland.

In 1926 a regular connection of the luxury passenger train from London to Paris, the *Golden Arrow/Fléche d'Or*, was started by the Southern Railway and French Northern Railway. To transport the passengers' baggage, four containers per truck were used. These containers were loaded in London or Paris and carried to the Ports of Dover or Calais, on flatcars in the UK, and the Golden Arrow Fourgon of CIWL in France.

At the Second World Motor Transport Congress in Rome in September 1928, Italian Senator Silvio Crepi proposed the use of containers for road and railway transport systems, using collaboration rather than competition. This would be done under the auspices of an international organ similar to the Sleeping Car Company which provided international carriage of passengers in sleeping wagons. In 1928, Pennsylvania Railroad started regular container services in the Northeast United States. After the Wall Street crash of 1929 in New York and the subsequent Great Depression, many countries were without any means of transport for cargo. The railroads were sought as a possibility of transporting cargo, which opened up an opportunity to bring containers into broader use. Under the auspices of the International Chamber of Commerce of Paris, in Venice on 30 September 1931, on one of the platforms of the Maritime Station (Mole di Ponente), practical tests were done to determine the best construction method for European containers as part of an intermodal competition.

In the same year (1931) in the USA, Benjamin Fitch designed the two largest and heaviest containers in existence anywhere at the time. One measured 17'6" (5.33 m) by 8'0" (2.43 m) by 8'0" (2.43 m), with a capacity of 30 000 pounds (13.63 metric tons) in 890 cubic feet. The second one measured 20'0" (6.01 m) by 8'0" (2.43 m) by 8'0" (2.43 m), with a capacity of 50 000 pounds (22.7 metric tons) in 1 000 cubic feet.

In November 1920, in Enola, USA, the first container terminal in the world was opened by the Pennsylvania Rail Road Company. The Fitch hooking system was used for the reloading of containers.

From 1926 to 1947 in the United States, the Chicago North Shore and Milwaukee Railway carried motor carrier vehicles and shipper's vehicles, loaded in flatcars between Milwaukee and Chicago, Illinois. Beginning in 1929, Seatrain Lines carried railroad box cars on its sea vessels to transport goods between New York and Cuba.

In the mid-1930s the Chicago Great Western Railway, and then the New Haven Railroad, began a "piggyback" service (transporting highway freight trailers on flatcars) limited to their own railroads. The Chicago Great Western Railway filed a US patent in 1938 in their method of securing each trailer to a flatcar, using chains and turnbuckles. Other components included wheel chocks and ramps for loading and unloading the trailers from the flatcars. By 1953 the Chicago and Eastern Illinois, and the Southern Pacific railroads had joined in the innovation. Most of the rail cars used were surplus flatcars equipped with new decks. By 1955 an additional 25 railroads had begun some form of "piggyback" trailer service.

During WWII the Australian Army used containers to help with gauge breaks in railroads. These non-stackable containers were about the size of the later 20-foot ISO containers.

During the same time, the United States Army started to combine items of uniform sizes, lashing them onto a pallet, unitising cargo to speed up the loading and unloading of transport ships. In 1947 the Transport Corps developed the "Transporter", a rigid corrugated steel container with a 9 000 lb (4.12 metric tons) carrying capacity for shipping household goods of officers in the field. During the Korean War the "Transporter" was evaluated for handling sensitive military equipment and, proving effective, was approved for broader use. Theft of material and damage to wooden crates convinced the Army that steel containers were needed.

In 1952 the US Army developed the "Transporter" into the "Container Express" or "Conex" box system. The size and capacity of the "Conex" were about the same as the "Transporter", but the system was made modular by addition of a smaller half-size unit of 6'3" (1.9 m) long, 4'3" (1.29 m) wide and 6'10" (2.08 m) high. "Conex" containers could be stacked three high and protected their contents from the elements.

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The first major shipment of "Conexes" containing engineering supplies and spare parts was made by rail from the Columbus General Depot in Georgia to the Port of San Francisco, then by ship to Yokohama, Japan, and then to Korea in late 1952. Shipment times were almost halved. By the time of the Vietnam War, the majority of supplies and materials were shipped by "Conexes". By 1965 the US military used some 100 000 "Conex" boxes and more than 200 000 by 1967, making this the first worldwide application of intermodal containers. After the US Department of Defense standardised an 8 foot (2.43 m) by 8 foot (2.43 m) cross-section container in multiples of 10 foot (3.05 m) lengths for military use, it was rapidly adopted for shipping purposes.

In April 1951, at the Zurich Tiefenbrunner Station, the Swiss Museum of Transport and the Bureau International des Containers held demonstrations of container systems with the aim of selecting the best solution for Western Europe. Present were representatives from France, Belgium, the Netherlands, Britain and the United States. The system chosen for Western Europe was based on the Netherlands system for consumer goods and waste transportation called "Laadkisten" (literally "loading bins"). This system used roller containers that were moved by rail, truck and ship in various configurations up to a capacity of 5 500 kg and up to 3.1x2.3x2 m in size, and became the first post-WWII European railway standard UIC 590, known as "pa-Behalter". It was implemented in the Netherlands, Belgium, Luxembourg, West Germany, Switzerland, Sweden and Denmark. With the popularisation of larger ISO containers, support for the "pa" containers was phased out by the railways. In the 1970s they began to be used widely for transporting waste.

In 1955 former trucking company owner, Malcolm McLean, worked with engineer Keith Tantlinger to develop the modern intermodal container. The challenge was to design a shipping container that could efficiently be loaded on ships and would hold securely on long sea voyages. The result was an 8 foot (2.4 m) tall by 8 foot (2.4 m) wide, 10 foot (3.0 m) long unit constructed from 0.098" (2.5 mm) thick corrugated steel. The design incorporated a twist-lock mechanism atop each of the four corners, allowing the containers to be easily secured and lifted using cranes. After helping McLean to create the successful design, Tantlinger convinced him to give the patented design to industry, and this began the international standardisation of shipping containers.

PURPOSE-BUILT SHIPS

The first purpose-built vessels to carry containers had begun operation in 1926 for the regular connection of the luxury passenger trains between London and Paris, the *Golden Arrow/Fléche d'Or Service*. As mentioned earlier, four containers per truck were used for the conveyance of passengers' luggage. These containers were loaded in London or Paris and carried to the ports of Dover or Calais. The next step was in Europe after the WWII. Vessels purpose-built to carry containers were used between the UK and the Netherlands and Denmark. In the United States ships began carrying containers in 1951 between Seattle, Washington and Alaska. However, none of these services was particularly successful. Firstly, the containers were rather small, with 52% of them having a volume of less than 106 cubic feet (3 m^3). Almost all European containers were made of wood and used canvas lids, and they required additional loading into rail truck bodies.

The world's first purpose-built container vessel was the *Clifford J Rodgers*. This ship was built in Montreal in 1955 by the White Pass and Yukon Route Hangen group of companies. Its first trip carried 600 containers between North Vancouver, British Columbia and Skagway in Alaska, on 26 November 1955. In Skagway the containers were unloaded to purpose-built railroad cars for transport north to the Yukon, in the first intermodal service using trucks, ships and railroad cars. Southbound containers were loaded by shippers in the Yukon and moved by rail, ship and truck to their consignees, without opening. This first intermodal system operated from November 1955 until 1982.

The first truly successful container shipping company dates to 26 April 1956, when American trucking entrepreneur McLean put 58 trailer vans, later called containers, aboard a refitted tanker ship, the SS IdealX, and sailed them from Newark, New Jersey, to Houston in Texas. Independently of the events in Canada, McLean had the idea of using large containers that never opened in transit and that were transferable on an intermodal basis among trucks, ship and railroad cars. McLean had initially favoured the construction of "trailer ships" taking trailers from large trucks and stowing them in a ship's cargo hold. This method of storage referred to as roll-on/roll-off was not adopted because of the large waste in potential cargo space on board the vessel, known as broken storage. Instead McLean modified his original concept into loading just the containers, not the chassis, onto to the ship, hence the designation of "container ship" or "box ship".

TOWARDS STANDARDS

In 1933 in Europe, under the auspices of the International Chamber of Commerce, the International Container Bureau (B.I.C.) was established. In June 1933 the B.I.C. decided on obligatory parameters for container use in international traffic. Containers handled by means of lifting gear (group I containers), constructed after 1 July 1933, were subject to the following obligatory regulations:

- Clause 1: Containers are, respectively referring to their form and capacity, either of the closed or open type, and either of the heavy or light type.
- Clause 2: The loading capacity of containers must be such that their total weight (load plus tare) is 5.0 metric tons for the heavy type and 2.5 metric tons for the light type; a tolerance of 5% excess on the total weight is allowable under the same conditions as for wagon loads.

During the first 20 years of containerisation, many different container sizes and corner fittings were used, resulting in dozens of incompatible container systems in the US alone. For example, big operators like the Matson Navigation Company had a fleet of 21-foot containers, while Sealand Service Inc operated a fleet of 24-foot containers. The standard sizes and fittings and reinforcement norms that now exist evolved out of a series of compromises among international shipping companies, European railroads, US railroads and US trucking companies. Four important ISO recommendations standardised containerisation globally:

- January 1968: ISO 668 defined the terminology and ratings.
- July 1968: R-790 defined the identification markings.
- January 1970: R-1161 made recommendations about corner fittings.
- October 1970: R-1897 set out the maximum internal dimensions of general purpose freight containers.

Based on these standards, the first TEU container ship was the Japanese *Hahore Maru*, from ship owner NYC, which started sailing in 1968 and could carry 752 TEU containers.

In the US, containerisation and other advances in shipping were impeded by the Interstate Commerce Commission (ICC) which had been created in 1887 to keep railroads from using monopolistic pricing. By 1960 ICC approval was required before any skipper could carry different items in the same vehicle, or change rates. The fully integrated system in the US today became possible only after the ICC regulatory oversight was abolished, trucking and rail were deregulated (in the 1970s) and maritime rates were deregulated (in 1984).

Double-stacked rail transport was introduced in the US to a concept that was developed by Sealand and the Southern Pacific railroads. The freight standardisation of the double-stacked container car (or single-unit 40 foot COFC well car) was delivered in July 1977. The five-unit well car, the industry standard, appeared for the first time in 1981. Initially these double-stack railway cars were deployed in regular train services. Ever since American President Lines initiated a dedicated double-stack container service between Los Angeles and Chicago in 1984, transport services increased rapidly.

EFFECTS

Containerisation greatly reduced the expense of international trade and increased its speed. It also dramatically changed the character of port cities worldwide. Prior to mechanised container transport, crews of 20–22 longshoremen would, for example, pack individual cargoes into the hold of a ship, but after the onset of containerisation these crews of longshoremen were no longer necessary.

Ports needed to adapt to the changes brought about by containerisation, with activities declining in some ports and expanding in others. At the Port of San Francisco the former piers used for loading and unloading were no longer required for container transport, and as a result the port virtually ceased to function as a major commercial port, while the neighbouring port of Oakland

VI INSTRUMENTS

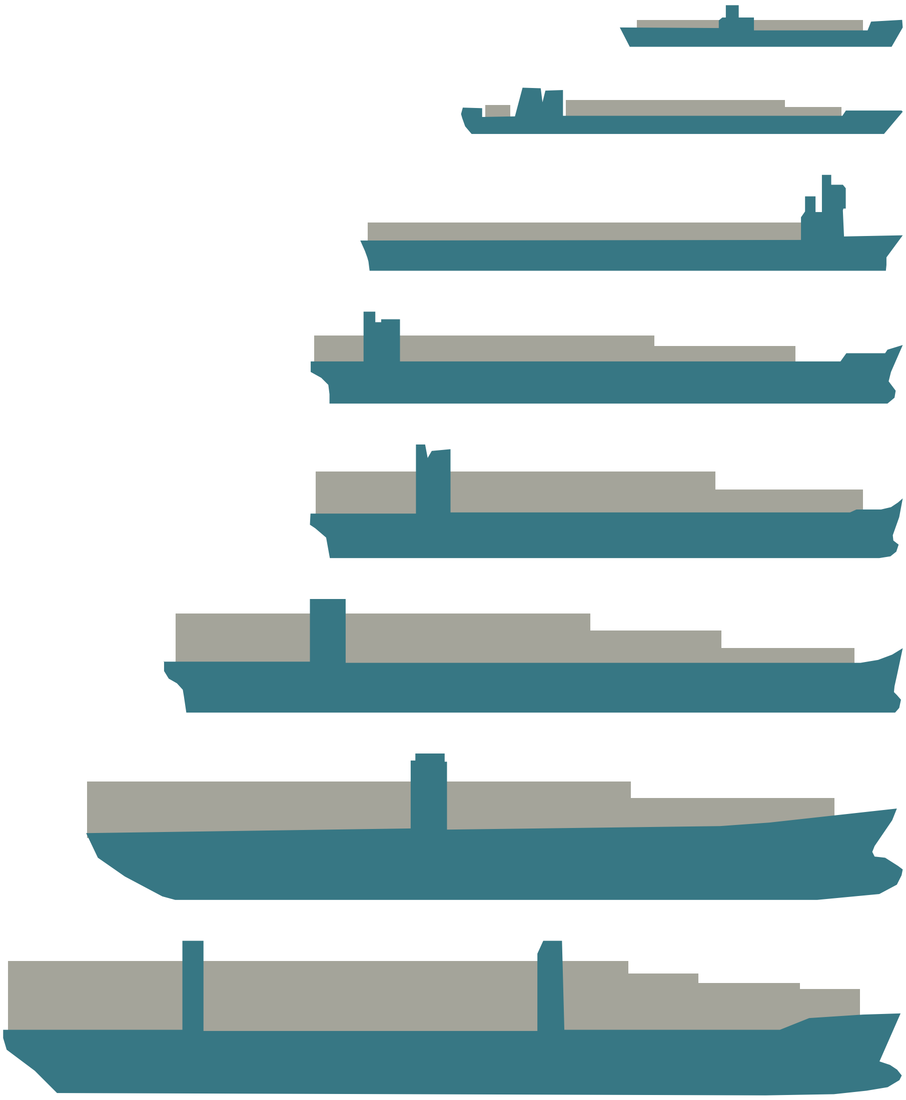

Figure 1: Evolution of container ship dimensions – the numbers after the TEU value, e.g. 400 x 59 x 15.5 m, refer to length x width (beam) x draught (Santos 2016, reproduced with author's permission)

emerged as the second largest on the US west coast. A similar situation developed between the ports of Manhattan and New Jersey. In the United Kingdom the Port of London and the Port of Liverpool declined in importance, while Britain's Port of Felixstowe and the Netherlands' Port of Rotterdam emerged as major ports. In general, inland ports on waterways incapable of deep-draught ship traffic declined as a result of containerisation in favour of sea ports. With intermodal containers the job of sorting and packing containers could be performed far from the point of embarking.

The effects of containerisation rapidly spread beyond the shipping industry. Containers were quickly adopted by trucking and rail transport industries for cargo transport not involving sea transport. Manufacturing also adapted to take advantage of containers. Companies that once sent small consignments began grouping them into containers. Many cargoes are now designed to fit precisely into containers. The reliability of containers also made just-in-time manufacturing possible, as component suppliers could deliver specific components on regular, fixed schedules.

As of 2009, approximately 90% of non-bulk cargo worldwide is moved by containers stacked on transport ships, and 26% of all container transshipment is carried out in China. For example, in 2009 there were 105 976 701 transshipments in China (both international and coastal, including Hong Kong) and only 21 040 096 in Hong Kong (which is listed separately) and 34 299572 in the United States. In 2005 some 18 million containers made over 200 million trips per year. Some ships can carry over 14 500 TEU units, such as the *Emma Maersk*, which is 396 m long and was launched in August 2006. It has been predicted that at some point container ships will be constrained in size only by the depth of the Strait of Malacca, one of the world's busiest shipping lanes, linking the Indian Ocean to the Pacific Ocean. The so-called "Malaccamax" size limits a ship to dimensions of 470 m in length and 60 m in width.

Few initially foresaw the extent of the influence of containerisation on the shipping industry. In the 1950s, Harvard University economist, Benjamin Chinitz, predicted that containerisation would benefit New York by allowing it to ship its industrial goods more cheaply to the Southern United States than other areas, but he did not anticipate that containerisation might make it cheaper to import such goods from abroad. Containerisation has indeed had a direct influence on the choices of producers and purchasers, and has remarkably increased the total volume of trade.

The widespread use of ISO standards has also driven modifications in other freight standards, gradually forcing removable truck bodies or swap bodies into standard sizes and shapes, and changing completely the worldwide use of freight pallets that fit into ISO containers or into commercial vehicles.

OPTIMAL LOCATION OF CONTAINER TERMINALS

The large dimensional variability of container ships has an enormous impact on the characteristics of a terminal (see Figure 1), and this should obviously be borne in mind when planning new container terminals. Factors that need to be considered include the typical profile of the ships that intend calling at the port, the maritime access characteristics of the port, and the quay equipment required. This would help to determine the extension, development and growth rhythm of the required infrastructure. Cost/benefit analyses would, for example, need to consider the integration of these terminals into the existing logistics chains, because a large portion of the costs occur in the land segments of this chain.

The next section of this article describes the prevailing tendencies in the development of container ships, and the impact thereof on the development of harbour terminals.

TENDENCIES IN THE DEVELOPMENT OF THE CONTAINER SHIP FLEETS

As mentioned above, the first container ships appeared only in the late 1950s, and the average dimensions of ships has increased significantly since then, as shown in Figure 1 (since 1988 beyond the dimensions allowed by the Panama Canal, i.e. width greater than 32.2 m and loading capacity greater than 4 000 TEU).

Some South Korean shipyards are building ships with capacities between 18 000 TEU and 19 000 TEU (class “triple E” from Maersk and “CSCL Globe” from China Shipping Container Lines), while Mitsui O.S.K. Lines (MOL) placed an order for 20 000 TEU container ships. Presently even bigger ships, with a capacity up to 22 000 TEU, are on the drawing board, which will bring them close to the maximum dimensions allowed by the Suez Canal.

The world fleet of container ships is also still growing. In 2014 there were 4 976 container ships in the world fleet compared with 2 776 in 2002.

The large dimensions of these ships impact on various aspects of the harbour terminal which they visit. The ship’s draught impacts on the depth of the harbour entrance, internal harbour channels, manoeuvring areas and quays. The larger ships have a design draught of 15.5 m and a template draught of 16.0 m, but they rarely use the design draught. The containers’ weight is very variable, usually assuming an average weight of 15 metric tons, which is much less than the ship’s indicated geometric capacity.

The maximum depth necessary for the new container quays must be 1.0 m deeper than the ship’s draught. Other important dimensions are the ship’s length and width (beam), which in harbours

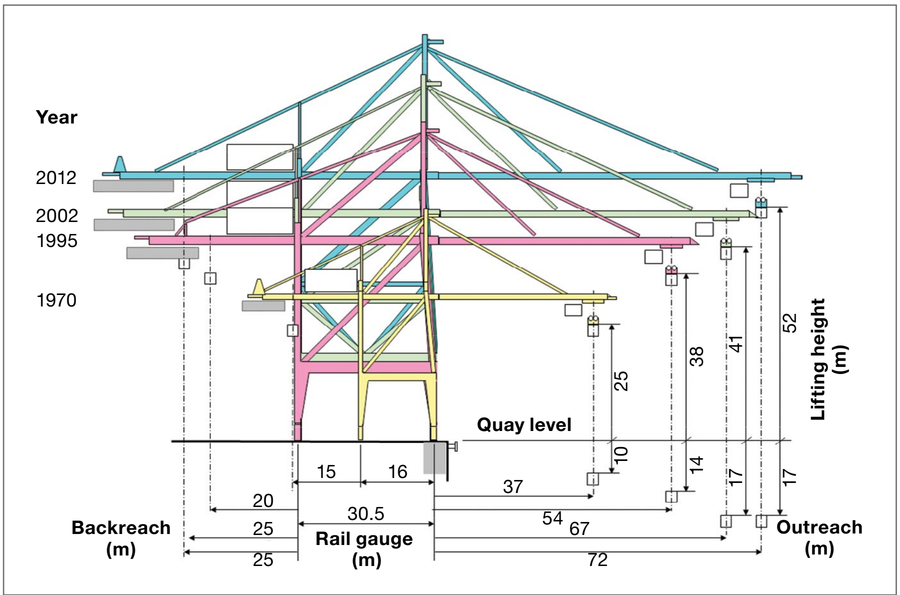

Figure 2: Evolution of container crane dimensions (Santos 2016, reproduced with author's permission)

of smaller dimensions are restrained by the navigation channels, manoeuvring areas and canal gates. Once at berth, the ships have a significant impact on the dimensions of the container cranes and the number of container rows that they can reach. Figure 2 shows the evolution of container crane dimensions.

As seen in Figure 1, ship dimensions have evolved in terms of transverse and longitudinal container rows. The number of transverse container rows define the ship width (beam) and the necessary container crane reach. A "Panamax" ship usually has 13 transverse rows, an 8 000 TEU ship has 18 rows, a "New Panamax" ship can reach 19 rows and the new "Triple E" container ship class has a capacity of 22 rows. The ship's length defines the number of container cranes required to assist a ship simultaneously (e.g. eight cranes would be able to assist a container ship with a capacity of 18 000 TEU).

Container ships are used in regular lines, and are operated by a relatively small number of shipping companies who control hundreds of ships operating many routes linking all continents. In 2012 the three largest container shipping companies controlled 29.5% of the total transport capacity of the world fleet of container ships. At the same time global companies specialising in the management of container terminals have also developed, to the extent that the four largest container terminal companies control 26.2% of the total movement of containers worldwide.

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IMPACT OF GROWING DIMENSIONS ON SOUTH AFRICAN PORTS

In 2014, 21% of the existing ships and 60% of the ordered ships had a capacity of more than 5 000 TEU, and the larger number of ships ordered in 2014 had capacities above 7 500 TEU.

A high number of ships carrying between 6 000 and 10 000 TEU have been placed on routes where ships with smaller capacities, between 4 000 and 6 000 TEU, have typically been used. This tendency has been noticed on both the east-west routes and the north-south routes.

On the route between Europe and the east coast of South America, for example, ships went from an average dimension of 4 420 TEU in 2010 to 6 400 TEU in 2013, with some ships of 8 700 TEU also being used. The 14.5 m draught of an 8 000 TEU ship requires a depth of 16.0 m. (The widening of the Panama Canal will allow 12 000 TEU ships on the routes between Europe and the west coasts of North and South America.)

Even the West African routes are served by 4 500 TEU container ships. These tendencies indicate that the ports of Richards Bay, Durban, Coega and Cape Town are capable to receive the largest container ships, provided they are fitted with the required quay equipment, parking areas and related equipment, as well as road and rail links to other areas of the country.

IN SUMMARY

- The average dimensions of container ships has increased considerably, as has orders for larger classes of ships.
- This growth has a cascading effect on the various routes, as smaller ships are replaced by larger ships on various shipping routes.
- Larger container ships require deeper harbour access channels, and adequate quays and manoeuvring space.
- Quay lifting equipment and land container handling equipment need to be increased, and larger areas of container parking developed.

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