Revisiting Port Capacity: A practical method for Investment and Policy decisions

Ioannis N. Lagoudis
Head of R&D, XRTC Ltd, Business Consultants
95 Akti Miaouli Str., 18538, Piraeus, Greece
&
Adjunct Faculty, University of the Aegean – Department of Shipping trade and Transport
2A Korai Str., 82100, Chios, Greece

and

James B. Rice, Jr.
Deputy Director, MIT – Center for Transportation and Logistics
1 Amherst Street, Second Floor, Cambridge, MA 02142

Abstract

The paper revisits port capacity providing a more holistic approach via including immediate port connections from the seaside and the hinterland. The methodology provided adopts a systemic approach encapsulating the different port terminals along with the seaside and hinterland connections providing a holistic estimation of port capacity. Capacity is defined with the use of two dimensions; static and dynamic. Static capacity relates to land availability or in other words the available space for use. Dynamic capacity is determined by the available technology of equipment in combination to the skill of available labor. With the presentation of a case study from a container terminal the practical use of this methodology is illustrated. Based on the data provided by the terminal operator the results showed that there is still available space to be utilised at a static level and also room more improvement at a dynamic level. The benefits stemming from the above methodology are multidimensional with the key ones being the flexible framework adjusted to the needs of each port system for measuring capacity, the productivity estimation of the different business processes involved in the movement of goods and people and the evaluation of the financial performance of the different business units and the port as a whole.

Introduction

The role of ports in modern supply chains is impetuously increasing. Supply chain engineering takes into serious consideration among other factors the selection of nodes involved during the physical movement of finished goods and commodities. Port selection is a crucial factor for shippers as the seamless flow of shipments is essential to their global operations.

A number of studies are present in the literature examining the factors shippers and shipping management companies take into account when it comes to port selection especially in areas where significant competition exists (Murphy and Daley, 1994). Among the factors considered by users are accessibility, levels of service, infrastructure, value adding activities etc. Of course cargo characteristics determine to a significant extent supply chain design and thus mode and node selection (Lagoudis et al, 2001)

From their part port authorities and operators around the globe driven by a trend of increasing demand for port services have invested and are still investing significant amounts of financial resources in increasing capacity. This need for investment stems from additional factors apart from demand, which are mainly attributed to a number of events such as strikes, low productivity of equipment, unskilled labor, geopolitical changes, new technologies and more.

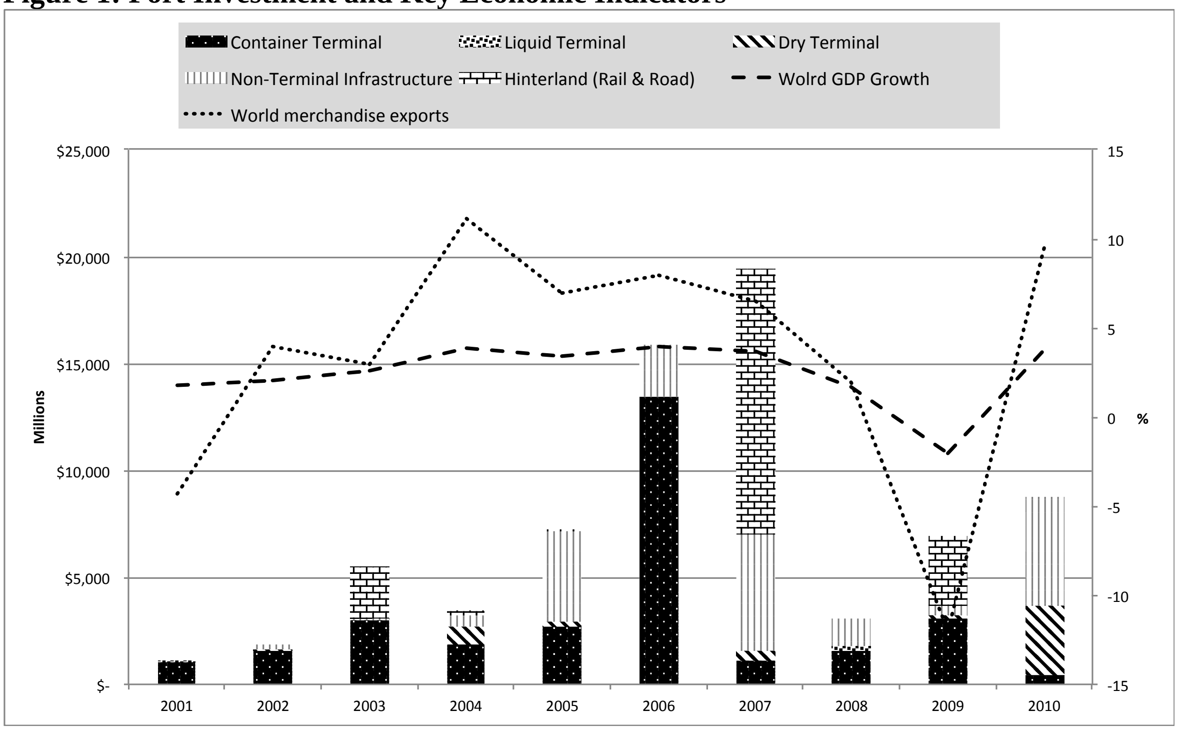
Characteristic is the case of the lockout which took place in 2002 in all 29 West coast U.S. ports where significant disruptions were reported during the 11 day duration of the strike. Shippers calling at the West Coast had limited options in switching to alternative ports (i.e. in Canada or Mexico), since there were significant capacity constraints in other ports of the region resulting in major economic and social implications. The case of Alaska is probably the most representative one since 70% of consumer goods were shipped via the port of Tahoma (reference). The creation of Port of Prince Rupert in Canada has been the recent development in tackling future problems of similar type as it can act as a significant competitor with the West Coast U.S. ports due to its easiness in connectivity via rail with the U.S. mainland markets in the Northern States of the U.S. (Reference).

An example of geopolitical change is also the case of the Panama Canal expansion (reference). This enormous investment which is mainly driven by the increasing growth of container traffic and improvements in ship technology, which has enabled the operation of 10,000+ TEU capacity vessels, will provide the enabling of possible re-engineering of supply chains for finished goods and products. The doubling in TEU vessel capacity crossing the canal in 2014 as planned, means that East Coast U.S. ports will have the chance to compete with West Coast U.S. ports. Due to that reason ports in the U.S. have begun capacity preparation projects in order to be ready when demand arrives. Such projects include the installation of larger cranes, the dredging of channels (reference) or even bridge elevations as is the case of the Port of New York and New Jersey (reference) in order to increase the clearance under the bridge.

Investments in port infrastructure do not take place in the U.S. alone. There are numerous projects taking place around the world from Europe and Asia to Africa and Australia despite the recent economic downturn, which has led to the postponement or cancellation of some of them. A very good outlook of these investments can be found in the latest annual Review of Maritime Transport (UNCTAD, 2010), where the portfolio of the different strategic decisions is seen. Based on this and previous annual reports published by UNCTAD it can be clearly seen that the majority of the reported investments are focused on the operations of container terminals, which need to cope with the increasing growth of container trade and the increasing size of container vessels (reference). Characteristic is the case of Port Klang in Malaysia, which achieved a world record of 83 container moves per hour per crane in March 2010 (reference) leading not only to higher productivity levels but to increased capacity challenges as well. The developments in the dry bulk terminals should not be ignored since significant achievements are found as well with Cochin Port in India managed to unload 10,024 tons of industrial salt in 24 hours in October 2009 (reference).

Figure 1 illustrates the investment decisions as reported by state agencies, port authorities and port operators between 2001 and 2010. It must be mentioned here that the information is not complete as the main investment decisions have been adopted as reported in the Annual Reviews of Maritime Transport published by UNCTAD. In addition the cancellations or postponement of any of these investments are not included as it is very difficult to trace any single development at a global level. Nevertheless having these limitations in mind a very good presentation on the prevailing trends can be observed especially when compared with the global Gross Domestic Product (GDP) and Merchandise Exports.

Figure 1: Port Investment and Key Economic Indicators



Source: Authors based on UNCTAD, WTO & World Bank

A number of additional observations need to be made at this point based on the presented data regarding the level and type of port investments announced:

- The majority of the investments are related to container terminals.
- Liquid and Dry cargo terminals have the least reported investments.
- Non-Terminal infrastructures refer to investments that have not been reported for specific terminals and may include dredging, waterfront improvements, acquisition of extra land for future terminal development etc.
- Hinterland investments are related to road and rail infrastructure for the improvement of intermodal improvements.
- Port investments follow the trend of the global economy especially when hinterland investments are excluded.

The present paper aims at revising the port capacity issue providing a more holistic approach via including immediate port connections from the seaside and the hinterland. The methodology provided adopts a systemic approach encapsulating the different port terminals along with the seaside and hinterland connections providing a holistic estimation of port capacity. The specific methodology enables not only the measurement of the port capacity itself by the identification of possible bottlenecks present in the handling process of goods, commodities and people but also provides a framework enabling the state, port authorities and port operators to make strategic decisions regarding investment priorities in the modern global turbulent business environment.

The distinction between these three decision making levels (state, port authorities and port operators) is made since the decision making process may differ as the center of interest shifts from societal to business. The authors believe that the present methodology provides a base on which all stakeholders involved in the port industry will share a common understanding of capacity and at the same time provide an aligned framework when it comes to investment and not only decisions.

Literature Review

There has been a lot of interest in ports leading to extensive international research examining different aspects of the port industry related to strategy, policy, operations and other issues using different techniques ranging from quantitate to qualitative analysis. There is a significant bias in the focus of port research in the area of container terminals, which can be explained by a number of reasons among which are the impetus growth of container traffic since the 1960s when containerization begun (reference) and the need for better coordination between the different players involved in the modern intermodal supply chains (reference).

Table 1 presents an indicative list works that are present in the port industry examining different aspects of a port system. The categorisation made here is intentionally structured in a way to show the fragmentation that a exists in most of the studies where there is hardly any work that examines the port system as a whole or even measuring port capacity at a terminal level let alone within a supply chain concept.

Table 1: Indicative studies on Ports

	Authors
Anchorage	Zrnić D.N. Dragović B.M. & Radmilović Z.R. (1999), Berg-Andreassen & Prokopowicz A.K. (1992), Huang S.Y., Hsu W.J. & He Y. (2011)
Waterway	Seidenfus H.S. (1994), Dai M.D.M. & Schonfeld P. (1998), Veldman S.J. et al. (2005), Blonk W.A.G. (1994), Collins J.W.F. (1984), Ulusçu Ö.S & Altiok T. (2009), Burn S.A. (1984), Khisty C.J. (1996), Cook M & Wells R.J.G. (1985)
Terminal	
Container	Petering M.E.H. (2011), Bassan S. (2007), Chu C.Y. & Huang W.C. (2005), Lagoudis I.N & Platis A.N. (2009), Mennis et al. (2008), Dragović B.M. et al. (2006), Imai et al. (2002), Imai et al. (2007), Nishimura et al. (2005), Kim K.H & Park Y.M. (2004), Park Y.M. & Kim K.H (2003), Günther H.O. & Kim K.H. (2006)
General cargo	-
Liquid	-
Car	-
Ferry & Cruise	Vaggelas G.K. & Pallis A.A. (2010)

Source: Authors

As seen most of the studies focus on berth allocation and yard operations optimization of container terminals followed by general cargo terminals. In the case of liquid, car, ferry and cruise terminals studies are significantly limited as is the case for waterways and anchorage. The list of studies mentioned here is not extensive as, this is not the aim of this work, but it provides a fairly good picture of the present status of where it stands at the moment.

There are a few recent good studies aiming at examining the impact of ports on supply chain integration and performance (references), which is a step forward to better understanding the importance of ports within the supply chain context, but are rather limited in reference to empirical data and are more conceptually oriented.

The present paper makes an effort to address the importance of ports as an essential value adding component of the supply chain via revisiting the capacity definition. The authors perception in estimating port capacity encapsulates the following:

1. port capacity should not be limited at the terminal level but sea and land links should be included
2. capacity should have a common measure throughout all processes involved within the port system

The methodology presented next takes into account the above two dimensions and aims at addressing the capacity issue via (i) documenting and understanding the individual components of a port system and (ii) calculating a realistic measure, which will assist in providing a final numerical figure. This final figure will enable the identification of possible constrains and bottlenecks in the transportation process of goods, commodities and passengers.

Methodology

The present effort aims at furthering existing work on defining and measuring port capacity moving forward and expanding the concept within a supply chain framework. The authors strongly favour the view that a more holistic approach to the prevailing one in the international literature and industry is needed to be adopted for achieving strategic competitive advantage by companies operating global supply chains.

The analysis begins by defining port capacity, followed by the detailed presentation of the key parameters needed to measure capacity based on the given definition and finally with the use of a case study an example on the applicability of this method is illustrated. Before proceeding with the definition of port capacity it is worth reminding at this point that the capacity of the hinterland links are also included (i.e. road and rail), which are within or adjacent to the port area, as the identification of possible bottlenecks in the physical flow of the goods and people throughout the entire supply chain process is intended.

Port Capacity Definition

A very good description of port capacity is given by Frankel (1987, p. 170) according to whom "*... A port' s capacity is normally defined as the cargo volume that the port is capable of handling within 1 year and is often expressed as a throughput in tons per unit length of a wharf per year (MT/m/yr or LT/ft/yr), multiplied by the available berth length, for each type of berth separately.*"

Frankel' s definition focuses significantly on the berth side of operations as it describes the prevailing philosophy of the 1980s when ports were not evolved to the state they are today where significant value adding activities take place. Regardless of the terminal type (whether this is cargo or passenger) today different value adding activities take place within or adjacent a port area. Indicative examples of such activities are those of consolidation/de-consolidation of shipments and the keeping of strategic stock of empty boxes for liner companies in container terminals, the mear storage of vehicles at car terminals and even the final assembly of cars adjacent to the port premises before being exported (such an example is VW factory close to Emden Port in Germany), the refinery products produced on site and exported with tanker vessels etc. In other words, today ports are not just an interface between the sea and the land but play an increasingly significant role to modern supply chains via the investment in additional services and infrastructure.

Having in mind the new role of ports authors define port capacity as the volumes handled in terms of cargo and passengers from the different terminals operated. There is a significant distinction that needs to be made here and refers to the two dimensions of capacity; static and dynamic (Figure 2). The former indicates the capacity in terms of volume a port can handle at a given point in time and related to space availability. It is reminded that a port encapsulates all terminals, waterways and links with the hinterland. Dynamic capacity indicates the capacity in terms of volume a port can handle during a period of time (usually a year) and encapsulates two key components; labour and technology of equipment.

Figure 2: Capacity Dimensions

Dynamic	Static: Low	Static: High
High	✓ Labor and technology operate at satisfactory levels ✓ Static capacity utilization can be increased	Use of full resources
Low	✓ Labor and technology can be improved ✓ Static capacity can be increased	✓ Labor and technology can be improved ✓ Static capacity cannot be increased

Source: Authors

The categorisation between low and high static capacity is made in order to determine the maximum and lower levels of capacity at this level. High capacity indicates the aper available level of capacity for a specific port or terminal. The maximum level is determined by land availability. This is the case of ports where they are adjacent to big cities and there may be limited or no land for expansion. In the case where there is no more space it means that from a static point of view the port cannot expand.

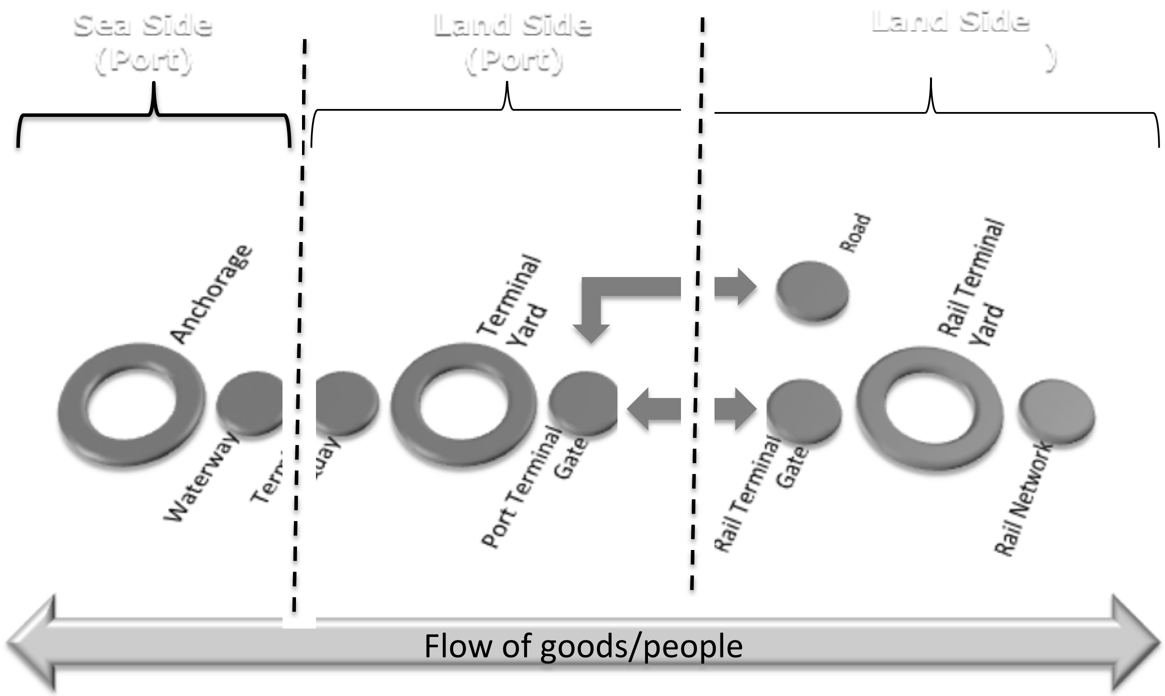
Dynamic capacity is determined by the available technology of equipment in combination to the skill of available labor. The maximum level of dynamic capacity is achieved when the full capabilities of technology and labor are exploited. In the case for instance a container terminal operates cranes which are designed to make 35 moves per hour it means that any performance under that level is below tha maximum capacity that can be offered.

As illustrated in Figure 2 there are for strategic outcomes each one describing the present status of a port or terminal and at the same time indicating the possible actions which could be taken to increase its capacity. The decision on which way to go is dependent on a number of factors already mentioned in the previous section of this paper such as demand, competition, economic environment etc.

Measuring Port Capacity

Since capacity has been defined as the volume a port and handle and has been categorised under static and dynamic the next step is to identify those parameters which will allow its measurement. It is reminded at this point that the aim of the present methodology is to take a more holistic approach thus the different components of a port system are taken into consideration as presented in Figure 3.

Figure 3: Port System



Source: Authors

The aim for taking such an approach stems from the effort to identify the possible bottlenecks throughout the transportation and any other process that takes place within the port premises. It must be made clear that in this effort both goods and people are taken into consideration thus the sum on the different types of terminals and operations are taken into consideration when measuring capacity. As seen in Figure 3 the main stages involved in port operations are pictured. To our understanding, to obtain a complete overview of port capacity all the above echelons must be measured based on their unique characteristics at both static and dynamic level. Table 2 presents in detail the parameters taken into account at the static and dynamic level for each of the port system components.

Table 2: Measuring Capacity at Static and Dynamic Level

	Static	Dynamic
Anchorage	Area determined by longitude and latitude in the ocean.	It depends on the average time a vessel waits before it is actually served.
Waterway	It is determined by the length, breadth and depth of the channel. Regulation in terms of safety is a non-physical factor that affects capacity.	Mostly determined by the frequency of the vessels and their characteristics in terms of size and type.
Terminal Quay/Berth	The length of the quay and the available depth determine the size of the vessels that can call and the number that can be served at the same time	The available equipment in combination with labor determine the vessels' turnaround
Terminal Yard/Area		
Container	The layout is composed of three main areas: stacking area, consolidation/de-consolidation area and traffic space. The number of ground slots provide the basis for the static capacity. Depending on the product mix (import, export, empty, refer, dangerous) and the stacking policy the total static capacity is derived.	The available equipment (cranes etc) in combination with labor and the demand mix characteristics (import, export, empty, refer, dangerous) determine the containers' turnaround and thus the overall capacity volume wise.
General cargo	The terminal layout is composed of three main areas: stacking area, consolidation/de-consolidation area and traffic space. The stacking capacity is derived by the length, breadth and highth of the products. Depending on the product mix (commodities, finished goods etc) and the stacking policy the total volume that can be handled can be derived.	The available equipment (cranes etc) in combination with labor and the demand mix characteristics (commodities, finished goods etc) determine the merchandises turnaround and thus the overall capacity volume wise.
Liquid	The terminal layout is composed of three main areas: tanks where oil products are stored, refining area and traffic space. Tank capacity is dependent on the density of the products stored.	The available equipment (pumping specification of pipes) in combination with labor and the demand mix characteristics (oil, ethanol, gas etc) determine the overall capacity volume wise.
Car	The layout is composed of two main areas: stacking area and traffic space. The number of ground slots provide the basis for the static capacity. Depending on the vehicle mix (cars, trucks etc) the total static capacity is derived.	The available equipment (security check pints etc) in combination with labor and the demand mix characteristics determine the vehicles' turnaround and thus the overall capacity volume wise.
Ferry	The terminal layout includes infrastructure for passenger waiting area, space for vehicle waiting area and free space for traffic. Here capacity is measured in terms of passengers and vehicles. Capacity is dependent on the allocated area in both cases.	The available equipment (security check pints etc) in combination with labor and the demand mix characteristics determine the passenger and vehicles turnaround and thus the overall capacity volume wise.
Cruise	The terminal layout includes infrastructure for passenger waiting area, and free space for traffic. Here capacity is measured in terms of passengers thus is dependent on the allocated area.	The available equipment (security check pints etc) in combination with labor determine the passenger turnaround and thus the overall capacity volume wise.
Port Terminal Gate	The number of servers at the gates is determined by the terminal layout which determines the length of the gate	The available equipment in combination to labor determine the truck/cars/rail cars/people turnaround
Rail Terminal Gate	The number of servers at the gates is determined by the terminal layout which determines the length of the gate	The available equipment in combination to labor determine the rail cars turnaround
Rail Terminal Yard	The layout is composed of three main areas: stacking area for boxes, stacking area for commodities and traffic space. The number of ground slots provide the basis for the static capacity. Depending on the product mix (import, export, empty, refer, dangerous) and the stacking policy the total static capacity is derived.	The available equipment (cranes etc) in combination with labor and the demand mix characteristics (import, export, empty, refer, dangerous, commodities etc) determine the containers' turnaround and thus the overall capacity volume wise.
Rail Network	It is defined by the number of trucks connecting the terminal with the rail network	It is determined by the available equipment (rail cars and locomotives), labor and regulatory environment related to safety
Road Network	It is defined by the number of lanes connecting the terminal with the road network	It is determined by the mix of vehicles (cars/trucks/bikes/buses) and regulatory environment related to safety

Source: Authors

Table 3: Capacity Calculation

	Static	Dynamic
Anchorage	Anchorage Capacity = Designated Area / Area needed by average ship size	Anchorage Capacity = Designated Area / (Area needed by average ship size * Average Waiting time)
Waterway	Waterway Capacity = (Length * Number of lanes) / Average ship size	Waterway Capacity = (Length * Number of lanes) / (Average ship size * Average Cruising Time)
Terminal Quay/Berth	Quay Capacity = Length of Quay / Average vessel size	Quay Capacity = Length of Quay / (Average vessel size * Turnaround time)
Terminal Yard/Area		
Container	Container Terminal Yard Capacity = Designated area / TEU size = Number of ground slots * TEU stacking policy Container Terminal Warehouse Capacity = Designated area / TEU size = Number of ground slots	Container Terminal Yard Capacity = (Number of ground slots * TEU stacking policy) / TEU average idle time Container Terminal Warehouse Capacity = Number of ground slots / TEU average marshaling time
General cargo	Yard Capacity = Designated area / Commodity size Warehouse Capacity = Designated area / Commodity size	Yard Capacity = Designated area / (Commodity size * Commodity average idle time) Warehouse Capacity = Designated area / Commodity average marshaling time
Liquid	Liquid Capacity = Designated area / (No of Tanks * Average Tank Capacity)	Liquid Capacity = Designated area / (No of Tanks * Average Tank Capacity * Average pumping time)
Car	Car Capacity = Designated area / Average vehicle size = Number of slots	Car Capacity = Designated area / Average vehicle size = Number of slots / Vehicle average idle time
Ferry	Ferry Passenger Capacity = Designated area / Average space per passenger Ferry Vehicle Capacity = Designated area / Average vehicle size	Ferry Passenger Capacity = Designated area / (Average space per passenger * Average waiting time) Ferry Vehicle Capacity = Designated area / (Average vehicle size * Average idle time)
Cruise	Ferry Cruise Capacity = Designated area / Average space per passenger	Ferry Cruise Capacity = Designated area / (Average space per passenger * Average waiting time)
Port Terminal Gate	Port Terminal Gate Capacity = Gate Length / Gate size = Number of gates	Port Terminal Gate Capacity = Gate Length / Gate size = Number of gates / Average unit process time
Rail Terminal Gate	Rail Terminal Gate Capacity = Gate Length / Gate size = Number of gates	Rail Terminal Gate Capacity = Gate Length / Gate size = Number of gates / Average unit process time
Rail Terminal Yard	Rail Terminal Yard Capacity (Container) = Designated area / TEU size = Number of ground slots * TEU stacking policy Rail Terminal Yard Capacity (Bulk) = Designated area / Commodity size	Rail Terminal Yard Capacity (Container)= (Number of ground slots * TEU stacking policy) / TEU average idle time Rail Terminal Yard Capacity (Bulk) = Designated area / (Commodity size * Commodity average idle time)
Rail Network	Rail Network Capacity = (Truck length * Number of trucks) / Average car size	Rail Network Capacity = (Truck length * Number of trucks) / (Average car size * Average cruising speed)
Road Network	Road Network Capacity = (Lane length * Number of lanes) / Average vehicle size	Road Network Capacity = (Lane length * Number of lanes) / (Average vehicle size * Average cruising time)

Source: Authors

A case study

With the use of an example from a container terminal the practical aspect of the present methodology will be presented focusing on the numerical measurement of capacity. It is reminded here that the combination of these two dimensions will categorise the terminal' s status in one of the four areas presented in Figure 2. The static capacity will be measured first followed by the dynamic.

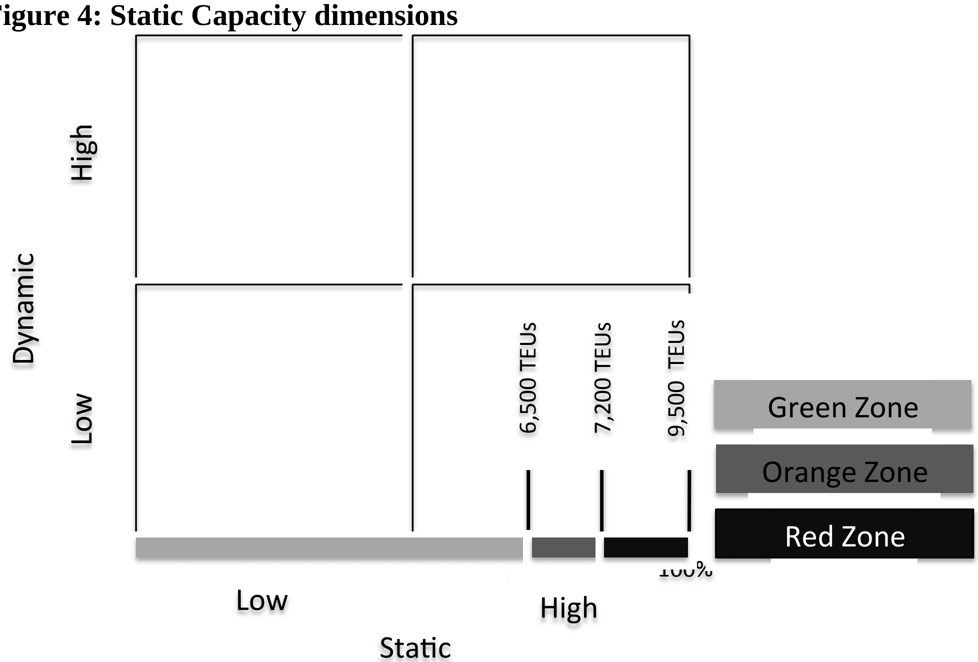
Static analysis

According to the terminal characteristics the total number of ground slots is 1,500 TEUs, which give a theoretical maximum of 9,000 TEUs capacity with six containers stacking policy. The 1,500 slots cover 70% of the total land the terminal occupies. Due to the location of the terminal this is the maximum land it can occupy and there is no scope for future expansion at least from the land side.

In order the terminal to operate at a satisfactory level without delays the total number of slots that can be used should not exceed 70%. In other words the terminal operates seamlessly when around 6,500 slots are occupied. As seen in Figure 4 the following observations can be made:

- there is a theoretical maximum of 9,000 slots which cannot be expanded since the total available land in the areas is used
- the terminal operates without significant delays up to when 6,500 slots are occupied (we will call this 'green zone')
- the terminal begins to be considered as congested when between 70% and 80% of the slots are occupied, which in terms of slots is translated between 6,500 and 7,200 (we call this 'orange zone')
- the terminal faces significant delays above 80% slot utilization (we call this 'red zone')

Figure 4: Static Capacity dimensions



Source: Authors

An additional issue that needs to be clarified here is that the above numbers need to be expressed at an annual base in order to have a filling of the annual container terminal capacity that the specific terminal can serve. This number is heavily dependent on the dwell time of containers. In other words the time that each container spends on the yard affects the total number of containers the terminal can serve. In the case of the specific case the average dwell time among all types of containers (import, export and transhipment) is four days, which means that the theoretical maximum is 821,250 TEUs (see equation 1) implying that at the 70% level the demand that can be served is 593,125 TEUs. In other words the specific terminal can accomodate 593,125 TEUs without facing congestion problems. It can be easily derived that if dwell time increases the total capacity decreases and vice-versa.

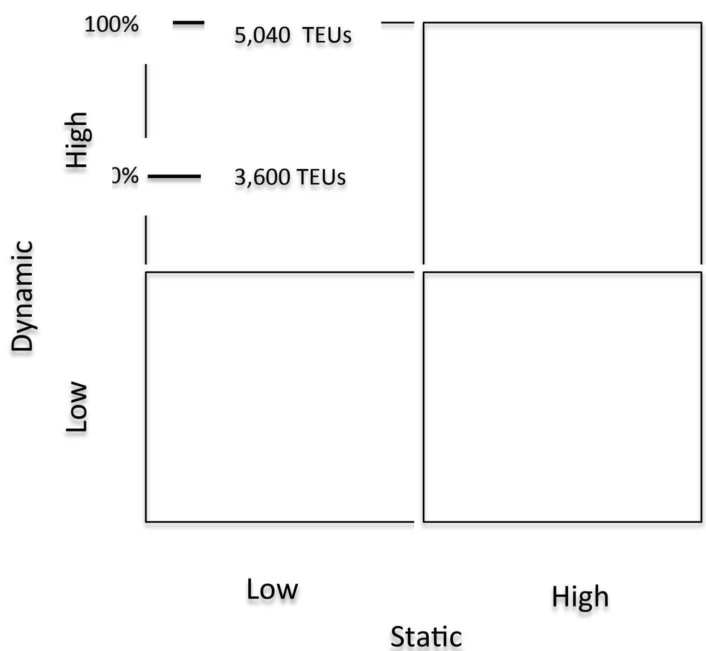
(Number of slots * annual operating days)/dwell time = (9,000 * 365)/4 = 821,250 (eq. 1)

Dynamic analysis

As mentioned, dynamic analysis is dependent on the technology of the available equipment and the skills of man power. The terminal operates eight gantry cranes and 10 straddle carriers. The former equipment serves the ship-to-shore operations and the latter assist in the movement of boxes in the yard. Stacking operations are taken care of by two RTGs, which can stack up to six high. According to the data provided by the terminal in a period of 18 hours, which is the full working day, the theoretical maximum the eight gantry cranes can achieve is 5,040 TEU moves provided they work at a rate of 35 moves per hour per crane (see equation 2). The fact that the terminal operates 10 straddle carriers decreases the feasible maximum to 25 moves per hour per crane. Based on these numbers the maximum feasible number of moves is 3,600 TEU moves as presented in Figure 5.

Number of cranes * moves per hour per crane * working hours per day = 8 * 35 * 18 = 5,040 TEU moves (eq. 2)

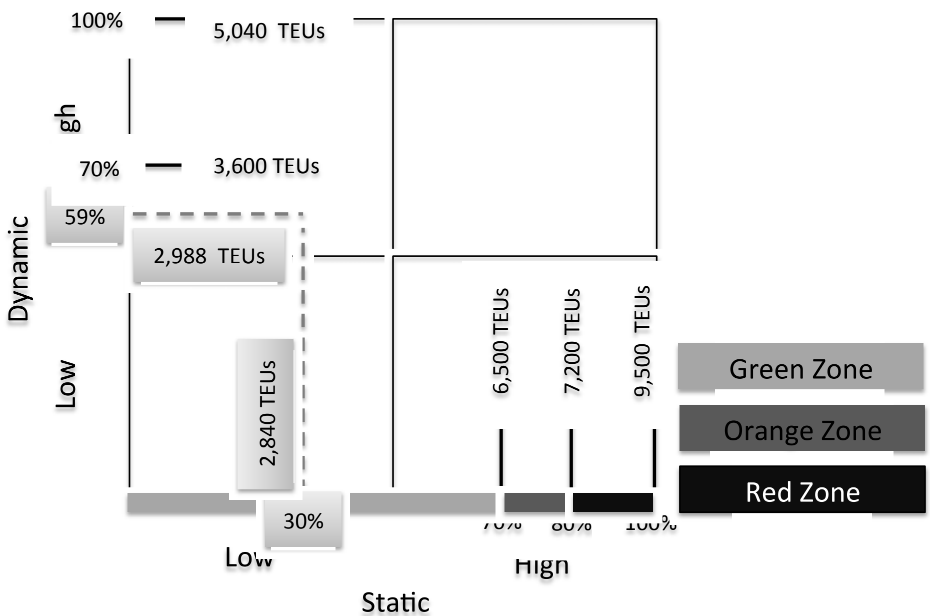
Figure 5: Dynamic Capacity dimensions



Source: Authors

In order to obtain the full picture Figure 6 is presented. As seen the specific terminal falls in the northwest corner of the matrix as the average occupied slots per day based on data of a six month period was 2,840 TEUs occupying 30% of the theoretically maximum available capacity and close to 50% compared to the Green Zone available capacity. In reference to the dynamic analysis based on the given observations the average number of moves per day has been 2,988, which is close to the 60% of the theoretically maximum and very close to the maximum feasible capacity, which is 3,600 moves per day.

Figure 6: Putting it all together



Source: Authors

Based on the results and according to the model the terminal' s both static and dynamic capacity have scope for improvement. In reference to the static capacity the terminal shows no signs of congestion and can aim for the attraction of more traffic in order to improve yard utilization. It is reminded here that there is no additional land available if the terminal needs to expand in the future thus other alternative solutions need to be examined such as the sharing of resources with adjacent terminals.

As far as the dynamic side there is room for productivity improvement as on average it operates at 60% capacity compared to the theoretical maximum (5,040 TEU moves per day). This though cannot be achieved with the present number of available straddle carriers. Thus additional investments in this type of equipment should be considered if the terminal wants to move towards this direction. Even in the case of the feasible optimum though there is room for improvement since on average the daily operations are short by 612 TEU moves. In this case solutions should be considered at operational level.

Conclusions

The paper revisits port capacity providing a more holistic approach via including immediate port connections from the seaside and the hinterland. The methodology adopts a systemic approach encapsulating the different port terminals along with the seaside and hinterland connections providing a holistic estimation of port capacity. The specific methodology enables not only the measurement of the port capacity itself by the identification of possible bottlenecks present in the handling process of goods and commodities but also provides a framework enabling the state, port authorities and port operators to make strategic decisions regarding investment priorities in the modern global turbulent business environment.

The methodology defines capacity with the use of two dimensions; Static and dynamic. Static capacity relates to land availability or in other words the available space for use. Dynamic capacity is determined by the available technology of equipment in combination to the skill of available labor. This categorisation enables the two-dimensional picturing of the situation in any of the different components of the port system as the different bottlenecks can be attributed either to space or equipment and labor issues or to the combination of both.

With the presentation of a case study from a container terminal the practical use of this methodology was illustrated. Based on the data provided by the terminal operator the results showed that there is still available space to be utilised at a static level and also room for more improvement at a dynamic level.

The benefits stemming from the above methodology are not restricted to productivity measures only. They are multidimensional with the key ones being the following:

- the provision of a flexible framework adjusted to the unique characteristics of each port system
- the measurement of the overall port production capacity
- the productivity estimation of the different business processes involved in the movement of goods and people
- the financial performance of the different business units and the port as a whole

In reference to future research there is scope for a range of ideas and applications. The authors believe that a detailed examination of an entire port system will provide significant insights in the testing not only of the methodology itself but in its practical use at the business level.

References

http://www.historylink.org/index.cfm?DisplayPage=pf_output.cfm&file_id=8692

http://www.cargosystems.net/freightpubs/cs/index/asian-and-us-ports-lag-behind-accelerating-growth/20017835612.htm?source=ezine&utm_source=Cargo+Systems+E-Bulletin&utm_campaign=8b183b0d06-CS_Bulletin_21st_Dec12_21_2010&utm_medium=email

http://www.cargosystems.net/freightpubs/cs/index/bayonne-bridge-set-to-be-raised/20017838227.htm?source=ezine&utm_source=Cargo+Systems+E-Bulletin&utm_campaign=2245b0c847-CS_bulletin_6_Jan_111_6_2011&utm_medium=email

http://www.cargosystems.net/freightpubs/cs/index/australia-plans-national-ports-strategy/20017838773.htm?source=ezine&utm_source=Cargo+Systems+E-Bulletin&utm_campaign=f1df8220a2-CS_bulletin_11_Jan_20111_11_2011&utm_medium=email