

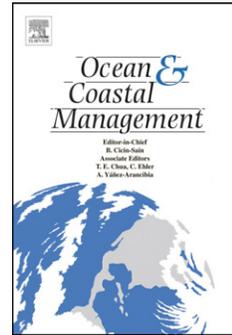
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80 Million-Twenty-Foot-Equivalent-Unit Container Port? Sustainability Issues in Port and Coastal Development

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80 Million-TEU Container Port? Sustainability Issues in Port and Coastal Development

Highlight

- Container throughput of Shanghai, Singapore and Shenzhen is projected to increase by several times within the next 15 years.
- Need for a balanced approach in sustainability for port and coastal development.
- Innovative solutions and flexibility in capacity expansion are required.

80 Million-Twenty-Foot-Equivalent-Unit Container Port? Sustainability Issues in Port and Coastal Development

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Abstract

The container port industry has experienced phenomenal growth over the past decades since the era of containerisation. The continuous population growth, urbanisation and industrialisation will continue to propel seaborne commodity trades which are largely handled via ports. Given that the four busiest container ports of Shanghai, Singapore, Hong Kong and Shenzhen handle significantly high throughputs, this research aims to examine their likely growth paths, sustainability issues in port and coastal development and related policy implications. The paper uses a longitudinal approach to analyse growth patterns that are exhibited by the selected ports in 1990-2010. The results of which will be used to derive scenarios for throughput growth and additional quay length required up to 2025. Container ports could expect to face immense pressure for their traffic-handling systems given that container throughput is projected to increase by several times within the next 15 years. The research contributes to both policy and research by addressing the need for a balanced approach in sustainability for port and coastal development. Increasing capacity does not mean that ports must resort to new terminal/berth construction extensively. If the decision is made to accommodate this growth in throughput, innovative solutions and flexibility in capacity expansion will also be required to accommodate the addition to traffic given the scale involved so as to alleviate pressures on spatial demand and the environment.

Keywords: Container Port, Sustainability, Port Development, Coastal Development

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80 Million-Twenty-Foot-Equivalent-Unit Container Port? Sustainability Issues in Port and Coastal Development

Abstract

The container port industry has experienced phenomenal growth over the past decades since the era of containerisation. The continuous population growth, urbanisation and industrialisation will continue to propel seaborne commodity trades which are largely handled via ports. Given that the four busiest container ports of Shanghai, Singapore, Hong Kong and Shenzhen handle significantly high throughputs, this research aims to examine their likely growth paths, sustainability issues in port and coastal development and related policy implications. The paper uses a longitudinal approach to analyse growth patterns that are exhibited by the selected ports in 1990-2010. The results of which will be used to derive scenarios for throughput growth and additional quay length required up to 2025. Container ports could expect to face immense pressure for their traffic-handling systems given that container throughput is projected to increase by several times within the next 15 years. The research contributes to both policy and research by addressing the need for a balanced approach in sustainability for port and coastal development. Increasing capacity does not mean that ports must resort to new terminal/berth construction extensively. If the decision is made to accommodate this growth in throughput, innovative solutions and flexibility in capacity expansion will also be required to accommodate the addition to traffic given the scale involved so as to alleviate pressures on spatial demand and the environment.

Keywords: Container Port, Sustainability, Port Development, Coastal Development, Terminal Construction

1. Introduction

The container port industry has experienced phenomenal growth over the past decades since the era of containerisation. To appreciate the scale of growth in container throughput handled, consider the developments seen for Singapore and Hong Kong. Both ports were consistently ranked in the first and second positions for almost two decades up to 2006. In 1990, each handled about 5 million TEUs of cargoes. By 2000, throughput for each port had grown by more than three times to 18 million TEUs. By 2010, container throughput handled by Singapore was 5.4 times of that handled in 1990 at 28.4 million TEUs whereas the comparative figure for Hong Kong was 4.6 times at 23.5 million TEUs.

The pace of growth witnessed by the world's busiest container port of Shanghai was even faster within the twenty year period. While Shanghai handled only 460,000 TEUs in 1990, the figure had grown by 12 times to 5.6 million TEUs in 2000. By 2010, container volumes grew by another 5.2 times to 29.1 million TEUs. Altogether, this was 64 times of the throughput handled in 1990. If we consider the situation in Shenzhen, the pace of demand expansion was even more spectacular. In 1990, the port handled a mere 18,000 TEUs. By 2000, the figure had grown by 223 times to reach 4.0 million TEUs. In 2010, container throughput handled by the port grew by a further 5.6 times to 22.5 million TEUs, a clear lead by 8.4 million TEUs from the next busiest port which is Busan (Informa UK Ltd, 2011). Altogether, the four busiest container ports all located in Asia each registers container throughput in excess of 20 million TEUs in 2011.

Considering ports as strategic assets, countries and port operators must take a long term view in port development. The world population is projected to grow by 57 million a year (or 0.33%) on average between 2000 and 2050, representing a 47% increase over 50 years. Asia's share of world population is on average 60% (UN, 2012). Its urban population growth is one of the highest in the world, and is projected to grow from 37% in 2000 to 66% in 2050 (UN, 2007). The tremendous population growth, urbanisation and associated industrialisation will continue to propel seaborne commodity trades which are largely handled via ports. Hence, it is hypothesised

that the growth in Asia's container port industry would be substantial considering the medium to long term trend, albeit facing some short term fluctuations.

With regards to capacity utilisation and container terminal development, the unprecedented expansion in volumes handled threw up many challenges for container ports. Given that the four busiest container ports of Shanghai, Singapore, Hong Kong and Shenzhen handle significantly high throughputs, this research aims to examine their likely growth paths and sustainability issues in port and coastal development and related policy issues. Importantly, the hub statuses enjoyed by these ports in the Yangtze River Delta, Pearl River Delta (both located in China) and South East Asia mean that success or failure in their ability to capitalise on opportunities afforded by this expansion from the demand perspective could have ramifications and far-reaching consequences on the competitive potential of these important economic regions. However, these are also highly populated regions with long coast lines which mean that externalities brought by port and shipping activities would impose substantial social and environmental consequences on the coastal communities and systems. What would the implications be for policy makers, port developers and port operators for the next 15 to 20 years and beyond?

To answer these research questions, the organisation of the paper is as follow. The next section will elaborate on the issue of capacity expansion from the spatial perspective whereas a review of literature will also be provided. Section three will cover the methodology aspect. Analysis and results of our investigation will be presented in sections four and five respectively. Section six is to discuss the resulting implications and recommendations, while conclusions and suggestions for future research are provided in the last section.

2. Port capacity expansion process from the spatial perspective

Avenues pursued by container ports to achieve higher productivity and output generally involved (i) restructuring of existing spaces; (ii) expanding into adjacent spaces; and (iii) developing capacity in new locations. In the case for restructuring, this strategy involves maximising use of

existing spaces by reconfiguring terminal design and modernising facilities to increase handling capacity and provide capability to receive the next generation of container vessels expected to enter service. The rationale for pursuing this strategy can be attributed to the lack of suitable and sufficient land and sea space for adjacent expansion which means that container terminals have to deliver higher output from the existing space. Considering the past two decades, examples of container ports which pursued this strategy include Hamburg (Hamburg Port Authority, 2011) and Long Beach (The Port of Long Beach, 2010).

Container terminals in these ports are located close to the city centre when they were first developed in the 1960s to 1980s. However, gradual enlargement of the city centre meant that container ports have to compete increasingly with activities which possessed higher bid-rent functions such as commercial and high-end residential real estate developments (O'Sullivan, 1996; Rondinelli, 2001; Rodrigue, 2004; Grossmann, 2008). Furthermore, larger economies of scale required while catering to higher levels of container throughput may require the entire system of container-handling facilities to be redeveloped with the latest terminal design and technologies aimed to achieve higher levels of productivity and address concerns of an increasingly demanding stakeholder community with respect to the spatial and environmental quality of the vicinity (Hoyle, 1996; Pellegram, 2001; and De Langen, 2007).

Where there is space available for development in adjacent areas fronting the coast and/or river, container terminal could be expanded to capitalise on economies presented by larger-scale production through higher traffic volumes generated from a bigger contiguous land area. Many container ports in the world utilised this strategy to stay ahead of competition. In the case of Singapore, container berths at Pasir Panjang Terminal Phase One, which began operations in March 1999, were designed with 360 metres per berth (PSA Corporation Ltd, 2011). The terminal was equipped with automated overhead bridge cranes and berths that could handle the largest container vessel then on the orderbook (i.e. *OOCL Shenzhen* with a length of 323 metres). When the adjacent development of Phase Two began operations in June 2005, the longest berth had a length of 418 metres which could handle the vessel *Emma Maersk* (PSA International, 2011). The new terminal project is part of a master plan to relocate the existing port to a site where it is of lesser commercial value and closer to the industries it supports in longer term (Lui

and Tan, 2001). In addition to Singapore, the list of ports which saw this strategy being adopted includes Shanghai at Waigaoqiao (SIPG, 2011), Hong Kong at Kwai Tsing (HKCTOA, 2011), Shenzhen at Yantian (HPH, 2011) and Port Klang at Westport (Westport Malaysia Sdn Bhd, 2011).

However, in some cases, policy makers deliberately choose to site new container terminals on greenfield locations away from the city centre as depicted by Bird (1971) and Notteboom and Rodrigue (2005). This development is usually attributed to the need for increase in capacity which is driven by scale considerations and contemplation for sustainable land use for long-term port development. In some cases, the new location of the container port may be beyond the statutory confines of the city as witnessed by the example of Shanghai where the new development at Yangshan Island was formerly located within the jurisdiction of Zhejiang Province instead of Shanghai Municipality. The list of ports which had used this strategy to cater to future throughput growth includes Shanghai at Yangshan (SIPG, 2011), Busan at Busan New Port (Busan Port Authority, 2011), Dubai at Jebel Ali (DP World, 2011) and Guangzhou at Nansha (People's Daily Online, 2011).

Taken together, the busiest container ports usually see all three forms of capacity expansion undertaken to stay ahead of competition and maintain their hub status in their respective port ranges. In the event where capacity is found to fall significantly short of demand, severe congestion could arise leading to gridlock for supply chains. Negative direct costs and externalities generated would be compounded if the situation occurs at a major container hub port where supply chain networks congregate (Lam, 2011). Specifically, this development would translate into higher penalties exerted on port users and thereby significantly lower their ability to compete with other supply chain systems (Lam and Yap, 2011). Conversely, where capacity is found to exceed actual throughput by substantial margins could imply the situation of over-investment and wastage of precious resources that could otherwise be better employed.

The challenge of providing sufficient capacity is often exacerbated by significant volatility in actualised container throughput attributed to variations in global trade from the demand perspective (Fung, 2001), lower loyalty of shipping companies in a particular port (Perez-

Labajos and Blanco, 2004), and involvement by a bigger community of stakeholders which include environmentalists (Martin and Thomas, 2001) among other issues.

As we can see, there are only scant literatures which relate port development to the environmental aspect which mainly focus on land use issues. There could be more in-depth exploration on the long term consequences considering economic, social and environmental perspectives together. To the authors' knowledge, there is no prior study which assesses sustainability in port spatial expansion and coastal development for future projection in an explicit and systematic manner. Also, there is a serious lack of study addressing the social and environmental impacts of Asia's tremendous port growth. This paper attempts to fill the void by offering a balanced approach in sustainable port and coastal development.

3. Research methodology

A variety of methods have been used to forecast container throughput. These approaches include those using error correction model (Fung, 2001; Hui, et al., 2010), spatial-economic simulation model (Luo and Grigalunas, 2003), ordinary least square regression (Seabrooke et al., 2003) and genetic programming (Chen and Chen, 2010). Among the merits of these approaches is that they were able to take into consideration factors that could affect throughput performance such as GDP, trade value, port competition and terminal handling cost. Nonetheless, a major shortcoming of these approaches is that they are dependent on the accuracy and relevance of the associated indicators used. The results will also vary in accordance to the time period considered and factors taken into account. If spurious results are generated from forecasting models and are used for policy making in practice, there would be expensive and long-term consequences for both investors and stakeholders. While forecasting by mathematical and statistical means would still be useful, an alternative method focusing on investment, institution and other factors that are harder to be quantified is a valuable reference and will present an original contribution to research and policy.

In view of this, the paper proposes a longitudinal approach to analyse growth patterns that are exhibited by the selected ports in the past two decades, i.e. 1990-2010. This method derives from the observation that there are specific events which significantly altered growth paths for container throughput. Specifically, growth trends experienced by a container port in the 1990s would be different from those of the 2000s as the macro and micro environment that they operated in could have changed considerably. Hence, the challenge is to identify the relevant growth trend and its implication for container-handling capacity that will need to be developed to accommodate further expansion in demand. The results of which will be used to derive scenarios for throughput growth for the next 15 years to 2025. There will be three growth scenarios developed for each port which are namely (a) the base scenario which provides the expected rate of growth and associated throughput volume based on current volume growth; (b) scenario where growth is lower than the base scenario to account for unfavourable factors including maritime and port policy changes, terminal capacity constraint, excessive competition with neighbouring ports, global and regional economic performance, and political disturbances; and (c) scenario where growth is higher than expected to account for those factors with favourable developments. As supported by Meristo (1989), multiple scenario analysis is information-rich and would be superior to forecasting in coping with uncertainties.

4. Analysis of port development paths and growth scenarios

With reference to figure 1, the case of *Shanghai* shows that changes in container throughput handled can be categorised broadly into two periods within the time frame specified. The first period covering the years from 1990 to 2000 was characterised by high growth averaging 29% on an annual basis. This was propelled by Yangtze River Delta's remarkable speed of development (Wang and Slack, 2004). Shanghai is at the estuary of Yangtze River which is the longest river in China. It is also in the middle of China's coastline possessing great geographical advantages to economic development with the added edge of preferential policy of Chinese central government (Frankel, 1998). This period was marked by the first container terminals on the Yangtze River coming on stream beginning with the facility at Baoshan and initial phases of Waigaoqiao. Although the port started from a low base in 1990, Shanghai was able to achieve

annual throughput growth in the range of 1.0-1.4 million TEUs towards the end of this period. The period ended with a sharp slowdown of growth in 2001 to 13.0% (or 700,000 TEUs) in view of a global economic slowdown.

Insert figure 1

The second period saw subsequent phases of Waigaoqiao enter into operations as well as commissioning of Yangshan Deepwater Port. Nonetheless, this period experienced growth slowing gradually from 35.8% in 2002 to 16.5% by 2010 which could be attributed to a higher cargo base as container throughput exceeded the 10 million-TEU mark in 2003. With more phases of Waigaoqiao and Yangshan port entering into operation, Shanghai was able to secure annual throughput increases in the range of 3.0-4.0 million TEUs. As such, the three growth scenarios proposed for Shanghai are as follow:

- (a) Base scenario: continuation of the growth trend at 3.0-4.0 million TEUs per year to 2025;
- (b) Low growth: slowing down of growth to 2.0-3.0 million TEUs per year by 2025; and
- (c) High growth: continuation of growth at 10-15% before slowing down to 3.0-4.0 million TEUs per year by 2025.

In the case of *Singapore*, figure 2 shows that container throughput performance can be distinguished by three periods for the time frame specified. The first period saw growth averaging 20% as Singapore was the premier hub port for the region (Gordon et al, 2005). However, the second period saw growth slowing from 15.0% in 1994 to 7.2% by 2000 with Port Klang and Tanjung Pelepas having emerged as key competitors to Singapore to vie for cargo from the transshipment business as well as Malaysia and Indonesia. This period also saw annual throughput growth slowing from 1.3-1.5 million TEUs to approximately 1.0 million TEUs. The third period saw growth ranging mostly from 7-9% as the main terminal operator PSA fought back by offering discounts on handling charges as well as making the unprecedented move of entering into terminal agreements joint venture with shipping lines COSCO, MSC and subsequently PIL (Cullinane et al., 2007). As a result, instead of slowing down, this period saw

annual throughput increasing approximately at a pace of 2.0-2.5 million TEUs per annum. Hence, the three scenarios proposed for Singapore are:

- (a) Base scenario: continuation of the growth trend at 2.0-2.5 million TEUs per year to 2025;
- (b) Low growth: slowing down of growth to 1.0-2.0 million TEUs per year by 2025; and
- (c) High growth: continuation of growth at 7-9% before slowing down to 2.0-2.5 million TEUs per year by 2025.

Insert figure 2

As with Singapore, container performance for the case of **Hong Kong** can also be categorised into three distinct periods. With reference to figure 3, the first period saw strong growth averaging 20% benefited from an export-oriented economy. However, throughput growth slowed considerably in the second period ranging between 6-8%. Annual throughput growth also slowed from almost 2.0 million TEUs in 1994 to less than 1.5 million TEUs by 2004. This could be attributed to two developments. Firstly, a series of investments by Hong Kong-based professional container terminal operators, which took place between 1994 and 1999, lent credence to Shenzhen as a viable alternative to Hong Kong (Cullinane et al., 2004). Secondly, a lack of investment in new container-handling facilities after completion of Container Terminal 8 in 1994 until Container Terminal 9 in 2003 resulted in Hong Kong's container terminals becoming increasingly congested and expensive (Drewry Shipping Consultants Ltd, 2003; and Ocean Shipping Consultants Ltd, 2003).

Insert figure 3

Faced with fiercer competition from its counterparts in Mainland China, the third period from 2005 saw Hong Kong's growth slowing even further to the low single digits of 2-4%, averaging about 600,000 TEUs per annum. By contrast, neighbouring ports of Shenzhen and Guangzhou were garnering port expansion and strong double-digit performance. Although container throughput rebounded by 11.8% in 2010, it is considered unusual for the port due to the recovery

after the negative growth caused by the severe global financial crisis in 2009. Overall throughput remained lower than the figure achieved in 2008, prior to the global financial crisis. In view of the analysis, the three scenarios proposed for Hong Kong are:

- (a) Base scenario: continuation of the growth trend at 0.5-1.0 million TEUs per year to 2025;
- (b) Low growth: slowing down of growth to 300,000 TEUs per year by 2025; and
- (c) High growth: continuation of growth at 3-5% before slowing down to 0.5 million TEUs per year by 2025.

Lastly, we turn our attention to the case of *Shenzhen*. The port's growth was driven by the strong manufacturing base in Pearl River Delta. Shenzhen can also be analysed in light of Hong Kong's development, especially a series of investments by Hong Kong-based professional container terminal operators as discussed above. Figure 4 shows that throughput performance for the port can be categorised broadly into three periods as well. Period 1 was characterised by an extremely low volume base and thereby saw throughput doubling every three years. By 1997, Shenzhen's annual container throughput had crossed the 1 million-TEU mark. In the second period, Shenzhen continued to see strong double-digit growth with annual increments rising from 800,000 TEUs in 1998 to reach 3.0 million TEUs by 2004, translating into growth rates averaging 43.2%. By the period's end in 2004, container throughput had grown by twelve times to reach 13.7 million TEUs. In the third period, Shenzhen continued to witness strong performance although the pace of expansion slowed from 28.3% in 2004 to 14.2% in 2007. While performance was affected by the global financial crisis which saw throughput contract by 14.8%, a strong recovery by 23.3% in 2010 saw the port attain a new record throughput of 22.5 million TEUs, almost on par with Hong Kong. The port also maintained volume growth for container throughput at 2.5-3.0 million TEUs per annum in this period. With continuous trend in the rise of shipping capacity connected Shenzhen, its throughput growth would be more favourable versus Hong Kong's (Yap and Notteboom, 2011). As such, the growth scenarios proposed for Shenzhen are:

- (a) Base scenario: continuation of the growth trend at 2.0-3.0 million TEUs per year to 2025;
- (b) Low growth: slowing down of growth to 1.0-2.0 million TEUs per year by 2025; and

- (c) High growth: continuation of growth at 10-14% before slowing down to 2.0-3.0 million TEUs per year by 2025.

As a whole, the respective growth scenarios for the selected ports can be summarised in table 1. While the port development path is unique for each of the ports, a similar feature among them is that the rate of growth in throughput handled has slowed down when compared to 1990s. It shows that the ports have reached a more mature stage. But for such mega ports, even a single-digit growth per annum over the next 15 years means a huge volume increase in absolute terms. Furthermore, since the ports have been expanded substantially over the past decades as shown above, further expansion would be a greater strain on coastal land, sea space and marine ecosystem when compared to greenfield ports.

Insert table 1

5. Results of growth projections

Based on the growth scenarios, the projection results in terms of container throughput and number of berths needs to be constructed are presented in this section.

With reference to figure 5 for the base case of *Shanghai*, the port could expect to handle more than 68 million TEUs in 2020 and almost 85 million TEUs by 2025 in the base scenario. This is based on the assumption that the port handles 3 to 4 million in additional TEUs on a yearly basis as mentioned above in table 1. With annual terminal productivity at an estimated 580,000 TEUs per berth (Cargonews Asia, 2008), the increase in demand by an additional 55.8 million TEUs will require 96 berths to be constructed in the next 15 years. However, if productivity can be raised to match the levels designed for Kwai Tsing container terminals in Hong Kong at 960,000 TEUs per berth (Hong Kong Container Terminal Operators Association, 2011), this demand would translate into a lower requirement of 58 berths.

Insert figure 5

For the other scenarios that are presented, table 2 shows that the high growth scenario could see Shanghai's container throughput quadruple to 123 million TEUs by 2025 at a compound annual growth rate (CAGR) of 10.1%. This would add further pressure on space requirements with another 98-162 new berths required. In the low growth scenario, throughput is projected to reach a still considerable 70.5 million TEUs or 2.4 times of that achieved in 2010 which will require 43-71 new berths.

Insert table 2

With reference to figure 6 for the case of *Singapore*, the base scenario shows that the port could expect to handle 52 million TEUs in 2020 and 64 million TEUs by 2025 with the assumption of an annual throughput growth of 2 to 2.5 million TEUs. Container throughput is expected to grow more than double by an addition of 35 million TEUs in the next 15 years. This will require another 40 berths assuming annual terminal productivity is maintained at the design capacity for the latest phases at Pasir Panjang Terminal of 875,000 TEUs per berth (Singapore Straits Times, 2007). Raising productivity to match the annual design capacity of Kwai Tsing container terminals in Hong Kong would still require another 37 berths.

Insert figure 6

In the event that the high growth scenario materialise, container throughput could quadruple to 75.5 million TEUs with CAGR at 6.7% (see table 3), translating into a requirement for 49-54 new berths to be constructed. Nonetheless, a low growth scenario could see the port handling 46 million TEUs which will require 18-20 berths to be added in the next fifteen years.

Insert table 3

The case of *Hong Kong* presents a contrasting picture as compared to the other selected ports. The scenarios depicted in figure 7 show throughput growth to be considerably slower, ranging in the low single digits. As mentioned in table 1, this is due to the assumption that the container

port experiences a throughput growth of only 0.5 to 1 million TEUs on an annual basis for the base scenario. Nonetheless, the scenario projected container throughput to grow by 12 million TEUs or 1.5 times to reach 36 million TEUs by 2025. This development would still require 13 new berths assuming for the current design capacity at Kwai Tsing container terminals with annual terminal productivity at 960,000 TEUs per berth.

Insert figure 7

Should the trend for high growth scenario take place, table 4 shows that throughput would reach 38.5 million TEUs with overall CAGR for the 15 years at 2.8%. This would translate into 16-17 new berths required for the port. Conversely, the low growth scenario could see throughput just reaching 30 million TEUs in 2025. This development would require 7-8 new berths. If annual terminal productivity can be increased to 1.3 million TEUs per berth, existing facilities should be able to accommodate the additional demand and construction of new berths would not be required.

Insert table 4

Turning to the case for *Shenzhen*, the base scenario shown in figure 8 projects container throughput to reach almost 60 million TEUs in 2025 on a CAGR of 6.7%. This is based on the assumption for an annual increment of 2 to 3 million TEUs for the base scenario which is shown in table 1. Using the design capacity for container terminals at Yantian in 2010 which is 630,000 TEUs per berth (Singapore Straits Times, 2008), the additional 36.8 million TEUs of containers will require 58 new berths. If annual terminal productivity could be raised to match those levels achieved in the neighbouring port of Hong Kong, the number of new berths required could be reduced to 38.

Insert figure 8

In the event where the port experiences a high growth scenario with CAGR for the 15-year period at 8.0%, projected throughput would reach 71 million TEUs (please see table 5). This development would see 49 million TEUs generated requiring 51-78 new berths. Even if the low growth scenario materialises, Shenzhen would still expect to handle 50 million TEUs by 2025 which will require 28-43 new berths to be constructed to accommodate this traffic.

Insert table 5

Altogether, the results show that Shanghai is projected to see the strongest growth with the port expected to handle 85 million TEUs by 2025 in the base scenario. Similarly, Singapore and Shenzhen are also expected to see strong growth for the next 15 years thereby enabling their container throughput to reach 64 and 59 million TEUs respectively. In the case of Hong Kong, slower growth could see throughput expanding at CAGR 1.7% to reach 36 million TEUs within the same time period.

In retrospect, the 1980s saw container throughput handled by major container ports reach the 5 million-TEU mark on an annual basis whereas the 10 million-TEUs mark was subsequently breached in the 1990s. In the 2000s, the world witnessed crossing of the 20 million-TEU mark and the end of the decade saw the busiest container ports closing in on 30 million TEUs. Expansion of global trade, population growth and increasing levels of urbanisation and industrialisation would continue to fuel container trade with corresponding increases for port-handling. Our projections show that the 2010s could see the busiest ports handle 50 million TEUs (i.e. Shanghai and Singapore) whereas by 2025, together with Shenzhen, container throughput handled would have doubled or tripled. The low growth scenario could still see the ports handling at least 45 million TEUs each.

6. Sustainability issues in port and coastal development and recommendations

Our research findings suggest that the next 15 years could see container ports handling throughput which are several times of their current volumes. With sufficient capacity to cater to

higher demand being seen as an important element towards sustaining port competitiveness, port planners and developers are working to ensure that this requirement is met. However, while it is paramount to note the economic aspect, environmental and social issues cannot be ignored for the port, coastal system and local community to be truly sustainable. The resolution of this issue is made more complex in view of several developments that are simultaneously taking place. This section discusses the three aspects of sustainability in the context of port and coastal development based on the port growth projection results.

The first development relates to the phenomenon of an increasing price tag for investment in container terminals. Consider the situation in East and South East Asia, comparison between expenditure involved in various types of container terminal development shows the huge amount of investment required for such projects. This development is further compounded by the relentless rise in construction cost experienced for such projects. Consider the case of Shanghai. Table 6 shows the cost of developing a 350-metre berth for Yangshan Phase 1 was US\$179 million. However, the cost of developing the same berth length for Yangshan Phase 3B rose by 1.7 times to reach US\$307 million. Table 6 further shows container terminal developments in Singapore to cost even more at about US\$400 million for a 350m berth. Hence, such projects will have important financial bearing on the investors against this situation of burgeoning costs. This will have consequences on the cost competitiveness of downstream activities as the operators attempt to generate financially-acceptable returns to shareholders.

Insert table 6

Secondly, the scarcity of coastal land translates into the need for optimising land use in view of increasing competition for coastal land from other sectors in the economy such as tourism, marine parks and residential use. Considering economic benefits at large, port developers should demonstrate the value to be added by port investment projects when compared to other sectors and urban planners should evaluate and compare the various sectors' contribution carefully. In particular, on top of direct economic benefits, indirect multiplier effects should be assessed. In terms of social aspect, the impact on the residents' employment and quality of life should be taken into account. This is especially important for ports located in a highly populated area like

the four ports under study. Also, environmental benefits as well as externalities such as pollution during terminal construction and after the terminals are operational are all key considerations. Not only inside the seaport boundary, policy makers also have to take note of the ripple effects on the local vicinity including pollution generated by inland transport distribution connecting to the port.

Related to the above point, the third development is extension of quay length which will directly alter the existing coastal environment. Our estimation can quantify the extent of coastal zone disruption by berth construction in terms of additional quay length. Tables 7 to 10 show that additional quay length required could range from as low as 2.4 kilometres in the low growth scenario in Hong Kong to 40.9 kilometres for the high growth scenario in Shanghai. Overall, these are considerable berth extensions at the expense of natural coastal zone. However, the magnitude of encroachment upon coastal space in terms of the actual amount of coastal area taken up by container handling activities depends on the design configuration and layout of the new facilities. Some ports may choose to perform reclamation works into deeper waters in order to accommodate larger vessels while others may choose a design that hugs the coastline instead of going ahead with costly reclamation works. The associated environmental impacts will be further elaborated below.

Insert tables 7 to 10

The fourth development involves shipping traffic that accompanies container throughput handled. Specifically, container ports have to supply essential anchorage space, navigation channels and container-handling facilities in order to accommodate the associated shipping capacity deployed in liner services. Based on the latest available data compiled as shown in figure 9, these are substantially higher than those of container throughput and the port's container-handling capacity. For example, the case of Singapore saw the container port handling 24.8 million TEUs in actual number of containers handled (the first bar in figure 9). However, the capacity available for handling containers at the port was 1.5 times higher (the second bar), and the accompanying shipping capacity calling at the port totalled 79 million TEUs which was 3.2 times as much (the

third bar). The amount of shipping traffic can be as high as 4 times like in the case of Hong Kong and Shenzhen. Even in Shanghai, an actual container throughput of 21.7 million TEUs translates into 56 million TEUs of accompanying shipping traffic.

Insert figure 9

In many cases, higher traffic volumes have immediate repercussions on the container port sector where significant increases in vessel traffic led to delays in berthing, departure, loading and discharge of cargoes and other forms of unexpected waiting time being incurred as a result of congestion experienced in accessing the port from both the seaward and landside aspects. Notteboom (2006) found that 86.1% of schedule unreliability experienced on the East Asia-Europe trade route in the fourth quarter of 2004 was attributed to such events. Hence, container ports could expect to face immense pressure for their traffic-handling systems given that container throughput is projected to increase substantially. If severe enough, delays experienced in one container port can reverberate throughout the entire shipping network and affect networks operated by other shipping lines and supply chain systems (Lam and Yap, 2011). The effect will be compounded if these services congregate at a major container hub port that is unable to cope with the influx. Furthermore, the negative direct costs and externalities generated by congestion will permeate throughout the entire network thereby affecting the whole spectrum of players.

Increasing shipping traffic at ports also generates a chain of environmental impacts, which specifically create a strain on the marine ecosystem and the community resided on coastal land. Negative environmental impacts can be broadly classified into water pollution and greenhouse gas emissions. Water pollution comes from ballast water, fuel oil residue and waste disposal from ship operations as well as cargo residue (Ng and Song, 2010). There would be even more severe adversity and immediate impact if there is accident causing oil spill. These marine pollutants are harmful to natural habitats located around port waters which would upset marine and coastal ecology, as well as lead to the damage and loss of coastal and fishery resources. On the other hand, dominate emissions generated by ships are CO₂, SO₂, NO_x, PM₁₀, PM_{2.5}, HC, CO and VOC. Taking Kaohsiung Port in Taiwan as an example, container ships are found to be the second largest group of ships emitting such pollutants (Berechman and Tseng, 2012). The health

effects to residents of the local community include asthma, other respiratory diseases, cardiovascular disease, lung cancer and premature mortality (Bailey and Solomon, 2004). Hence, negative environmental impacts create social problems and these effects would not be paid off by economic prosperity.

In relation to the fourth development about increasing shipping traffic, the fifth issue arises from the upgrading and maintenance of navigation channels at port waters. A phenomenon in the shipping industry is deployment of larger vessels. Accommodating ultra large container vessels requires substantial investment in the infrastructure of maritime access in terms of dredging and channel widening works. Port developers must solicit necessary financial and technical means for such investment. As for the environmental perspective, there could be contaminated sludge from dredging. For the port of Hong Kong, there were significant reductions to the abundance and richness of gastropod species which could be attributed to sedimentation impacts close the dredging sites. The scale of reduction was approximately two thirds which represented a major impact on such marine habitats (Morton, 1996). Reference can also be taken from other parts of the world. In the Ems estuary in the Netherlands, the effects of dredging due to extensive dredging works could result in increased turbidity which in turn, led to the decline in food for the total ecosystem with wider debilitating consequences on the sustainability of the entire region's marine ecology including fishery stocks (De Jonge, 1983). Newell et al. (1998) also revealed dredging to be associated with a 30-70% decline in species diversity, 40-90% decline in population density and a similar decline in the biomass of benthic fauna within the limits of dredged areas. At Marina di Carrara Harbor in Italy, Cappucci et al. (2011) found that the cumulative effect of the dredging activities included sediment deficit due to the disposal of sediment out of the sand-sharing system leading to coastal erosion and contamination of sediments mainly due to the presence of Hg, Pb and DDT in the top most 100 cm within the harbor basin and inlet. There may also be a need to alter the sea floor and natural geographical feature due to dredging and civil works (Peris-Mora et al., 2005). Again, these effects bring negative externalities to the marine habitats and disrupt natural reserves such as estuaries and lagoons.

To address the complexities presented by these challenges, an integrated approach to coastal management should be adopted, with reference to cases from various regions in the world. These include the works of De Ruig (1998) for the Netherlands, De Jonge (2000) for the Ems Estuary (the Netherlands), Shi et al. (2001) for Shanghai (China), Anfuso and Martínez del Pozzo (2005) for Ragusa (Italy) and Cappucci et al. (2011) for Marina di Carrara Harbour (Italy). In the case of Shanghai, the issue of balancing between competing requirements of socio-economic development and environmental sustainability proved ever more urgent with increasing amount of port and shipping traffic that uses the Yangtze estuary (Shi et al., 2001). The area will face greater ecological pressures as the rate of growth and development accelerates, causing further contamination and environmental degradation, thereby threatening the ecosystem and aquatic resources in the estuary. Similarly, it is paramount for Singapore, Hong Kong and Shenzhen to address the pressing concern on sustainable development. To tackle these challenges, an integrated approach is proposed which incorporates various aspects including cross-sectoral management, strategic environmental assessment, systematic scientific research and public involvement. Nonetheless, previous studies stated above also acknowledged that the approach represents more of an ideal and could take years to implement. A major challenge is in navigating through an apparatus of decision makers at the local, state and national levels.

As with the studies mentioned above, our major recommendation is still to take a holistic view to understand and plan port/ terminal development by balancing economic, social and environmental sustainability in spite of bureaucratic governmental mechanisms or potentially contentious public opinion involved. This aspect is particular crucial for the operational lifespan of a container terminal typically spans several decades. Therefore, the development will have serious implications for generations of human beings as well as well-being of the ecosystem many years down the road. It is important to note that the facilities once developed, will drastically alter the levels of socio-economic activity which could in turn create new dynamics for the coastal environment. As such, human oversight to the longer term consequences could cause irreversible damages to the environment and lead to the further weakening of the region's eco-sustainability.

A survey of the world's busiest container ports will see terminals that were developed from the 1980s still in use. In fact, the situation in Singapore and Hong Kong saw terminals that were developed in the 1970s still in operation forty years on where these facilities were constructed at a time when containerisation was first introduced to both ports. Hence, the location of a new container terminal will have long term consequences on the spatial well as competitive potential of the port and not to mention, economic, social and environmental implications for the local community and coastal system. Specifically, market conditions and technology status encountered by these terminals would have changed from their initial period of operations. With a high likelihood of better technology and productivity as the port industry progresses towards the long term future, it would be possible to reduce the extent of terminal expansion as port developers originally plan for at the current technology status. To consider from another angle, port developers and operators should try their best to optimise port space and to improve productivity in order to avoid unnecessary terminal/berth expansion. Such measures can include cargo stacking, deploying newer equipment, upgrading information system, rationalising resources and terminal design and optimisation approaches alike. As demonstrated in the last section, the ports of Shanghai, Singapore and Shenzhen can reduce the number of berths to be constructed if berth productivity can be enhanced to reach or exceed Hong Kong's standard. While port's social-economic contributions are recognised, it has been discussed that there are financial strain and negative social and ecological effects brought by port activities and shipping traffic. Also in view of market volatility, mindful and gradual terminal expansion would be a sustainable strategy in port and coastal development. In other words, given the very long-term nature of container terminal investments, prudence should be exercised when decisions are undertaken to expand capacity.

To measure port development's economic, social and environmental impacts, thorough cost and benefit analysis consisting of all three aspects should be performed at the coastal system level, not only at the port level. It would be myopic to focus on commercial and trade benefits alone since social and environmental problems eventually translate into economic losses such as compensation and penalty expenses. The reputation of a port or port city at large with regards to green image and corporate social responsibility (CSR) is also an invaluable marketing tool leading to commercial benefits. Additionally, more financial institutions state that CSR is now a

key criterion when assessing funding applications (IHS Fairplay, 2012). Hence, the concern on financing increasingly expensive port projects as discussed earlier can be alleviated by enhancing bankability. It means that port developers can enjoy economic benefits as they adopt a more balanced approach addressing social and ecological concerns. They should appreciate the strategic implication of such an approach and be more proactive in contributing to the sustainable development of the port and coastal systems, rather than merely being compelled by regulations.

As a whole, our research has shown that projections for container volumes to be handled by major container ports are expected to grow. In view of the aforementioned developments, conscious decisions should be taken by policy makers to ensure that sufficient capacity will be made available. Failing this, negative consequences stemming from congestion and diseconomies in operation could have detrimental effects on the long-term competitiveness of the port community and economy. Nonetheless, increasing capacity does not mean that ports must resort to new terminal/berth construction extensively. If the decision is made to accommodate this growth in throughput, innovative solutions and flexibility in capacity expansion will also be required to accommodate the addition to traffic given the scale involved so as to alleviate pressures on spatial demand and the environment, failing which, the same negative consequences would also apply.

7. Conclusions and suggestions for future research

The study has derived scenarios for throughput growth for the world's four busiest container ports up to 2025. In the case for Shanghai, Singapore and Shenzhen, the magnitude of increase could be several times of their current throughput. The number of berths need to be constructed and additional quay length required were estimated accordingly. Research findings draw important insight that this trend of trade growth would see developing and re-developing container terminals in order to provide adequate capacity to cater for future growth in cargo volumes as a key challenge for these ports. Strategic issues include having to accommodate higher volumes of cargo and shipping traffic without upsetting schedule reliability of liner services and normal functioning of other port activities as well as optimising coastal land use in

view of competition for land and sea space from other sectors in the economy. There are also negative externalities leading to environmental and social problems. While on-going advances in cargo-handling systems, terminal design and pollution abatement technologies could help to alleviate the pressures on land use and the environment, the fact remains that container ports will face greater complexities involved in arriving at optimal solutions for an ever-larger throughput. Furthermore, the location once actualised, will have long term consequences for the commercial, social and environmental viability of the local coastal system and community where the operator and port authority are members of.

The research contributes to both policy and research by addressing the need for a balanced approach in sustainability for port and coastal development. It fills the literature gap of studying terminal physical expansion and its implications on coastal systems. While prior studies and the port industry started in recent years to take note of green port practice when the port is already in operations, it is even more important to address ecological issues at the planning stage and before terminal construction for any future port development projects. This is due to the substantial terminal expansion that is projected, and also the philosophy that adopting preventive measures are more effective than reactive actions alone.

We focused on the quantitative dimension in the form of throughput projections on the basis of changes to growth trends observed from past performances of the major container ports. As such, a limitation would exist in the form of structural changes and unanticipated developments that could trigger growth paths to take on new trends. However, such limitation is also applicable to any projection studies and this research had tried to mitigate this deficiency by presenting alternative scenarios for the upper and lower bound performances and restricting the projections to a reasonable period of 15 years. The paper also explained that multiple scenario analysis is a quality tool to encounter uncertainties in the future. Importantly, the sustainability issues discussed are still applicable even if the actual terminal expansion is lower than projected, and would intensify in earlier future if the actual rate of growth exceeds projection.

The research findings focused on the major container ports. As such, it would be useful to investigate the implications and consequences for other ports which could exhibit higher growth

potential and therefore exert great pressure on their respective local environments. Furthermore, since different stakeholders in the coastal system have different perception and priorities regarding port development, the participation of various stakeholder groups in decision-making might also influence the objectives chosen and eventually the outcome of the port development policy. Empirical analysis can be conducted in future in this regard.

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Table 1: Growth Scenarios (per annum) to 2025 for Container Throughput in the Selected Ports

	Shanghai	Singapore	Hong Kong	Shenzhen
2010 Throughput	29.1 M TEUs	28.4 M TEUs	23.5 M TEUs	22.5 M TEUs
Base Scenario	3.0-4.0 M TEUs	2.0-2.5 M TEUs	0.5-1.0 M TEUs	2.0-3.0 M TEUs
Low Growth	2.0-3.0 M TEUs	1.0-2.0 M TEUs	0.3 M TEUs	1.0-2.0 M TEUs
High Growth	10-15%, slowing to 3.0-4.0 M TEUs	7-9%, slowing to 2.0-2.5 M TEUs	3-5%, slowing to 0.5 M TEUs	10-14%, slowing to 3.0 M TEUs

Source: authors' computation.

Table 2: Projected Additional Demand and Compound Annual Growth Rate for Shanghai

Time Period	Base Scenario		Low Growth Scenario		High Growth Scenario	
	Additional TEUs (M)	CAGR (%)	Additional TEUs (M)	CAGR (%)	Additional TEUs (M)	CAGR (%)
2010-2015	20.7	11.4	14.9	8.6	29.1	14.9
2015-2020	18.6	6.5	14.8	6.0	36.3	10.2
2020-2025	16.5	4.4	11.7	3.7	28.9	5.5
Overall	55.8	7.4	41.4	6.1	94.2	10.1

Source: authors' computation.

Table 3: Projected Additional Demand and Compound Annual Growth Rate for Singapore

Time Period	Base Scenario		Low Growth Scenario		High Growth Scenario	
	Additional TEUs (M)	CAGR (%)	Additional TEUs (M)	CAGR (%)	Additional TEUs (M)	CAGR (%)
2010-2015	10.9	6.7	6.5	4.2	13.7	8.2
2015-2020	12.5	5.7	5.8	3.1	16.8	7.0
2020-2025	11.8	4.2	5.1	2.4	16.5	5.1
Overall	35.3	5.5	17.4	3.2	47.0	6.7

Source: authors' computation.

Table 4: Projected Additional Demand and Compound Annual Growth Rate for Hong Kong

Time Period	Base Scenario		Low Growth Scenario		High Growth Scenario	
	Additional TEUs (M)	CAGR (%)	Additional TEUs (M)	CAGR (%)	Additional TEUs (M)	CAGR (%)
2010-2015	5.5	4.3	3.0	2.4	5.9	4.5
2015-2020	4.1	2.7	2.1	1.6	5.2	3.3
2020-2025	2.6	1.5	1.5	1.0	3.9	2.2
Overall	12.3	2.8	6.6	1.7	15.0	3.3

Source: authors' computation.

Table 5: Projected Additional Demand and Compound Annual Growth Rate for Shenzhen

Time Period	Base Scenario		Low Growth Scenario		High Growth Scenario	
	Additional TEUs (M)	CAGR (%)	Additional TEUs (M)	CAGR (%)	Additional TEUs (M)	CAGR (%)
2010-2015	13.5	9.8	12.5	9.2	16.8	11.8
2015-2020	12.2	6.0	8.3	4.3	16.4	7.2
2020-2025	11.1	4.2	6.4	2.8	15.7	5.1
Overall	36.8	6.7	27.2	5.4	48.8	8.0

Source: authors' computation.

Table 6: Capital Expenditure for Terminal Development in East and South East Asia

Container Port	Annual Capacity (mln TEUs)	Quay Length (metres)	Operational in	Cost (mln US\$)	Cost Per 350 metres (mln US\$)
Hong Kong Container Terminal 9	2.6	1910	2005	1300	238
Shanghai Yangshan Phase 1	2.2	1600	2005	820	179
Shanghai Yangshan Phase 2	2.1	1400	2006	870	218
Shanghai Yangshan Phase 3A	2.8	1350	2007	1153	299
Shanghai Yangshan Phase 3B	2.2	1250	2008	1095	307
Shenzhen Dachan Bay Phase 2	3.2	1695	2009	909	188
Singapore Pasir Panjang Terminal Phases 1 and 2	12.0	4500	2004	5000	389
Singapore Pasir Panjang Terminal Phases 3 and 4	14.0	6000	2013	<i>7000</i>	<i>408</i>

Sources: authors including authors' estimation (*in italics*), based on data from Informa UK Ltd (2011) and various terminal operators' and port authorities' websites.

Table 7: Estimated additional quay length required at Shanghai for new berth construction based on projected container throughput in 2025

<i>Existing</i>	Container Throughput (million TEUs)	Number of Berths	Productivity (TEUs per berth)	Quay Length (kilometres)
2010	29.1	42	693,000	12.9
<i>Projection</i>	Container Throughput (million TEUs)	Additional Number of Berths	Assumed Productivity (TEUs per berth)	Additional Quay Length (kilometres)
Base Scenario	55.8	58	960,000	24.2
Low Growth	41.4	43	960,000	18.0
High Growth	94.2	98	960,000	40.9

Sources: Authors' estimation based on data from Chinaports (2008) and HPH (2008).

Assumption: Based on container throughput productivity at levels seen in Kwai Tsing in Hong Kong of 960,000 TEUs per berth coupled with the latest container terminal facility at Yangshan phase 3B with a design capacity of three berths at 417 metres per berth on a total length of 1,250 metres.

Table 8: Estimated additional quay length required at Singapore for new berth construction based on projected container throughput in 2025

<i>Existing</i>	Container Throughput (million TEUs)	Number of Berths	Productivity (TEUs per berth)	Quay Length (kilometres)
2010	28.4	52	546,000	15.5
<i>Projection</i>	Container Throughput (million TEUs)	Additional Number of Berths	Assumed Productivity (TEUs per berth)	Additional Quay Length (kilometres)
Base Scenario	35.3	37	960,000	13.9
Low Growth	17.4	18	960,000	6.8
High Growth	47.0	49	960,000	18.4

Sources: Authors' estimation based on data from Singapore Straits Times (2007), MPA (2011) and PSA (2011).

Assumption: Based on container throughput productivity at levels seen in Kwai Tsing in Hong Kong of 960,000 TEUs per berth coupled with the latest container terminal facility at Pasir Panjang phases 3 and 4 with a design capacity of sixteen berths at 375 metres per berth on a total length of 6,000 metres.

Table 9: Estimated additional quay length required at Hong Kong for new berth construction based on projected container throughput in 2025

<i>Existing</i>	Container Throughput (million TEUs)	Number of Berths	Productivity (TEUs per berth)	Quay Length (kilometres)
2010	23.5	33*	712,000	10.7
<i>Projection</i>	Container Throughput (million TEUs)	Additional Number of Berths	Assumed Productivity (TEUs per berth)	Additional Quay Length (kilometres)
Base Scenario	12.3	13	960,000	4.5
Low Growth	6.6	7	960,000	2.4
High Growth	15.0	16	960,000	5.5

Sources: Authors' estimation based on data from HKPDC (2011), HPH (2011) and HKCTOA (2011).

* Assuming 3,000 metres of barge berths translates into 9 container berths at 333 metres each.

Assumption: Based on container throughput productivity at levels seen in Kwai Tsing of 960,000 TEUs per berth coupled with one of Hong Kong's latest container terminal facility at CT9 North with a design capacity of two berths at 350 metres per berth on a total length of 700 metres.

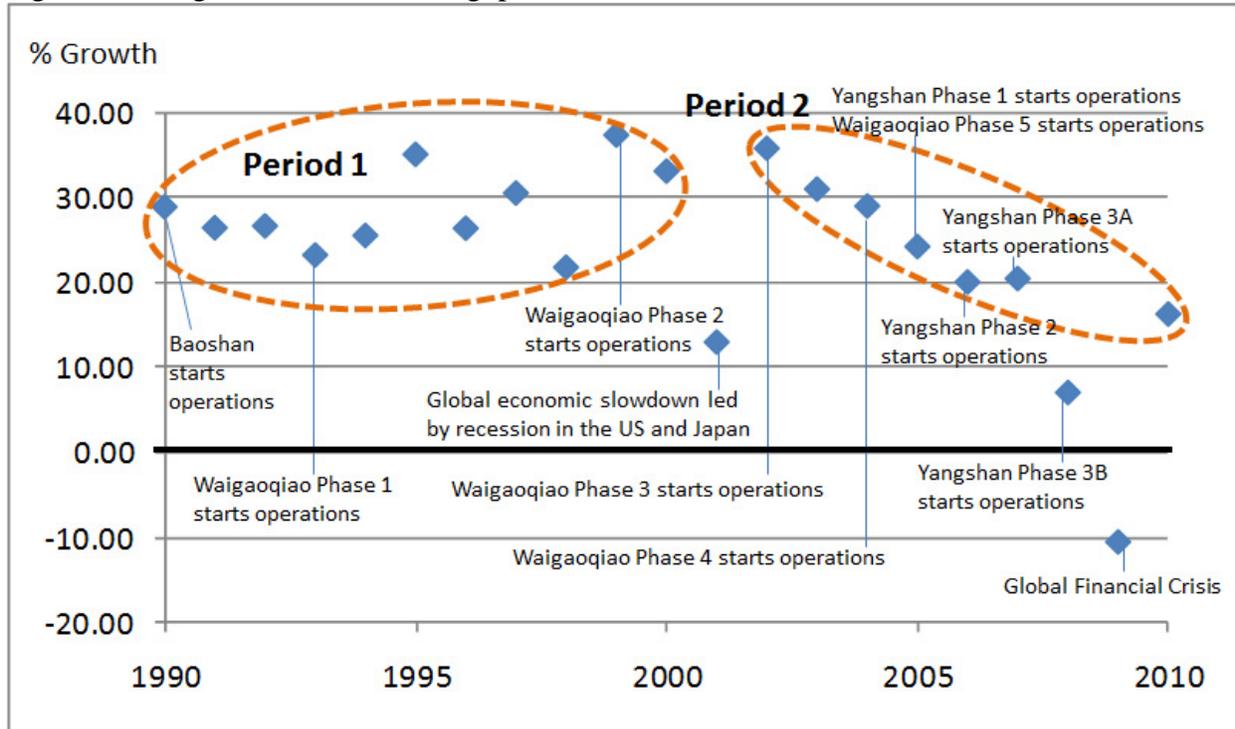
Table 10: Estimated additional quay length required at Shenzhen for new berth construction based on projected container throughput in 2025

<i>Existing</i>	Container Throughput (million TEUs)	Number of Berths	Productivity (TEUs per berth)	Quay Length (kilometres)
2010	22.5	44	511,000	17.8
<i>Projection</i>	Container Throughput (million TEUs)	Additional Number of Berths	Assumed Productivity (TEUs per berth)	Additional Quay Length (kilometres)
Base Scenario	36.8	38	960,000	17.9
Low Growth	27.2	28	960,000	13.2
High Growth	48.8	51	960,000	23.7

Sources: Authors' estimation based on data from Da Chan Bay Terminal One (2011), HPH (2011), Chiwan Container Terminal (2011) and Shekou Container Terminals (2011).

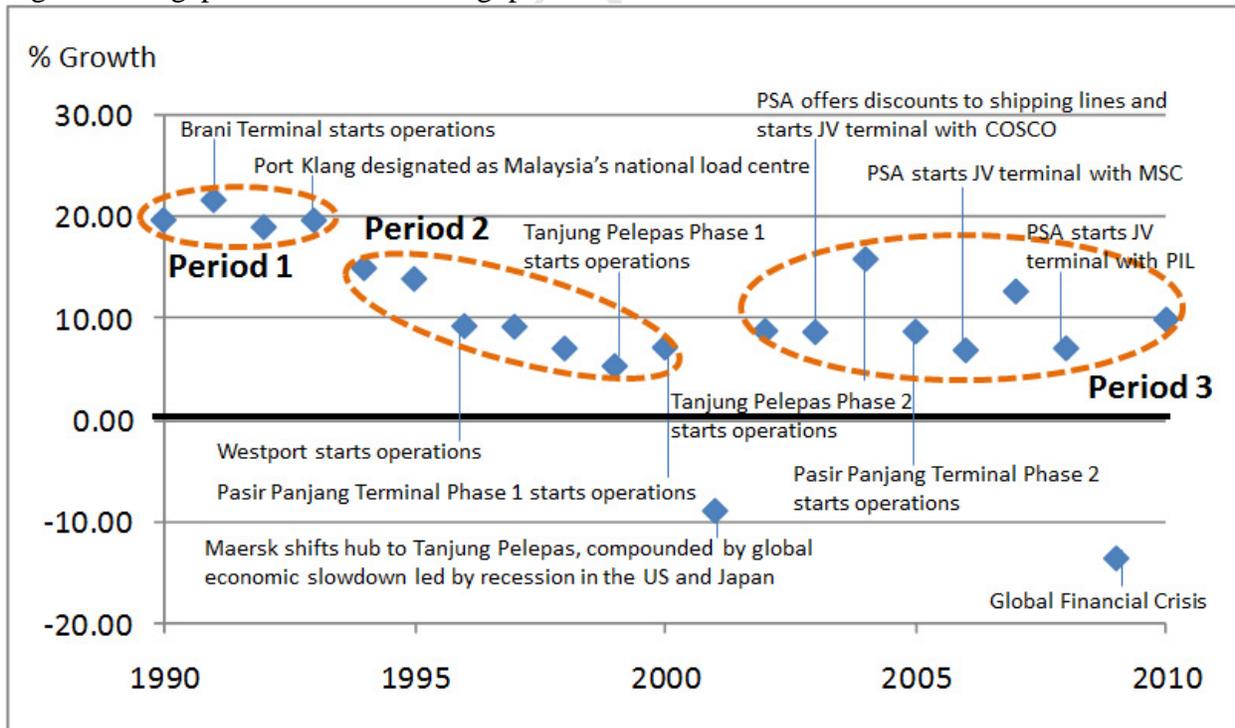
Assumption: Based on container throughput productivity at levels seen in Kwai Tsing of 960,000 TEUs per berth coupled with the facilities at Yantian International Container Terminals with a design capacity of nineteen berths at 466 metres per berth on a total length of 8,862 metres.

Figure 1: Shanghai Container Throughput Performance



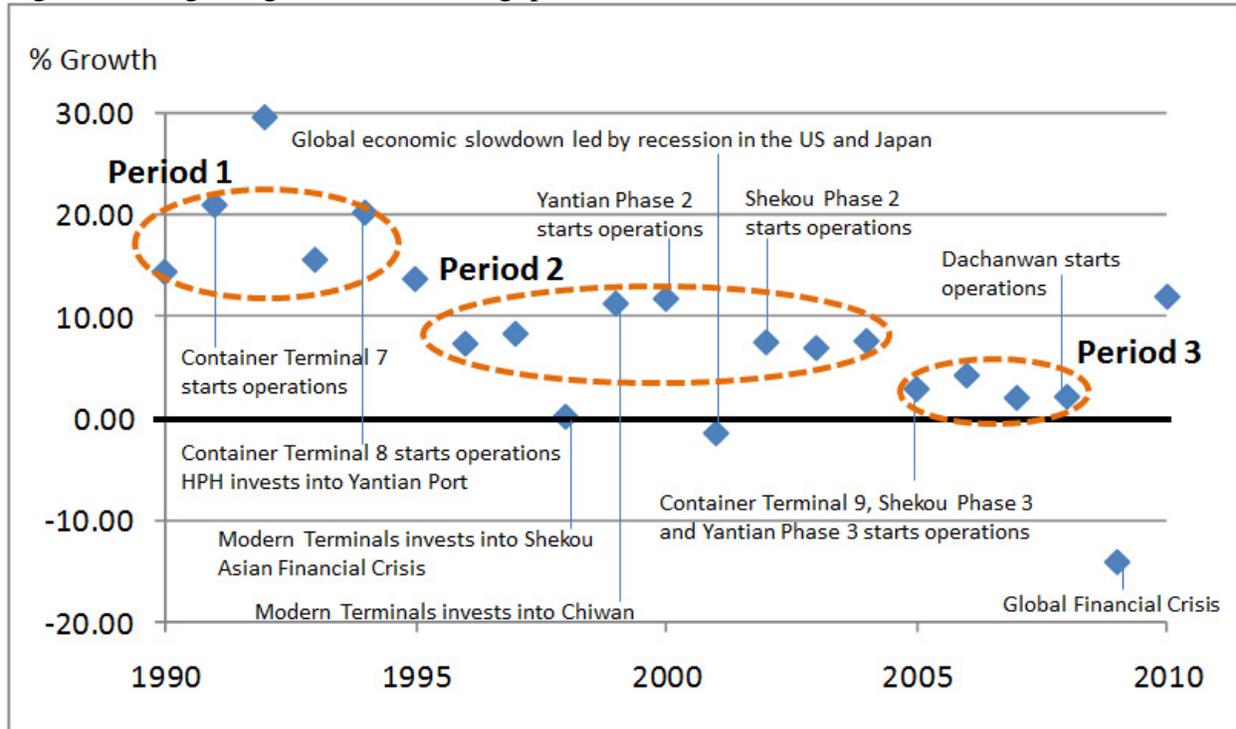
Source: drawn by authors with data gathered from Informa UK Ltd (2011) and terminal operators' websites.

Figure 2: Singapore Container Throughput Performance



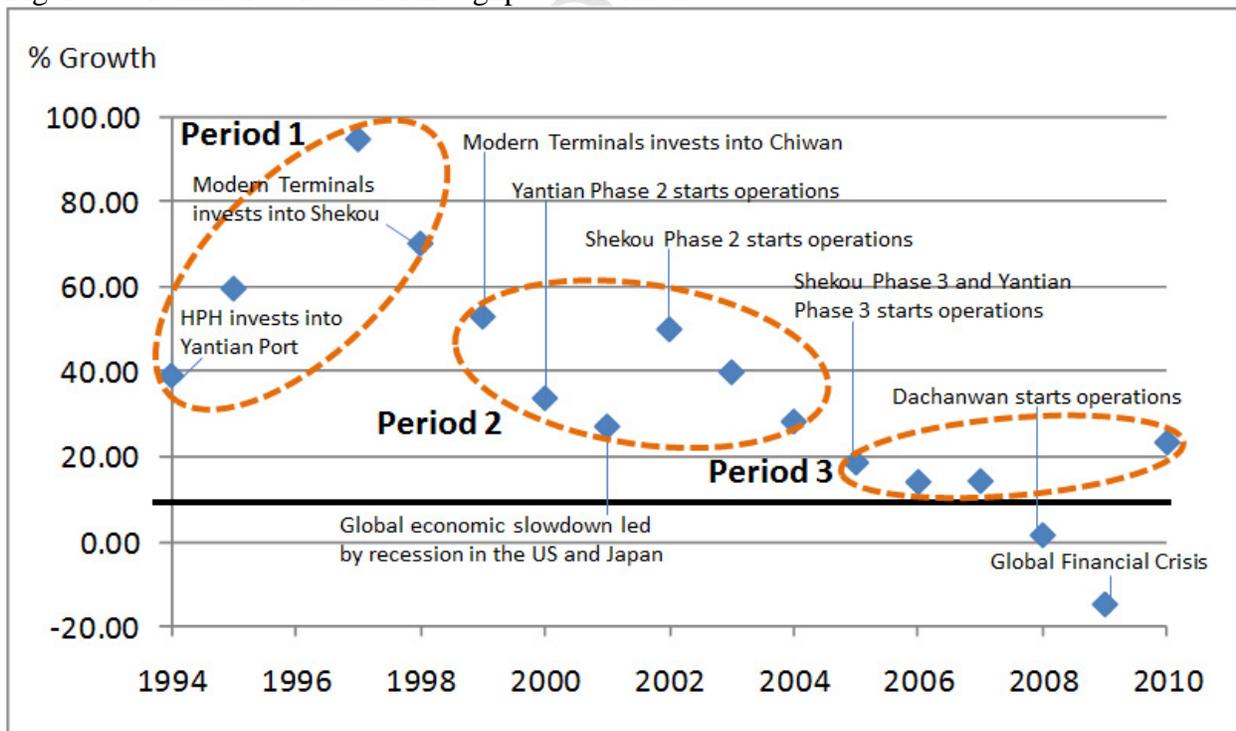
Source: drawn by authors with data gathered from Informa UK Ltd (2011) and terminal operators' websites.

Figure 3: Hong Kong Container Throughput Performance



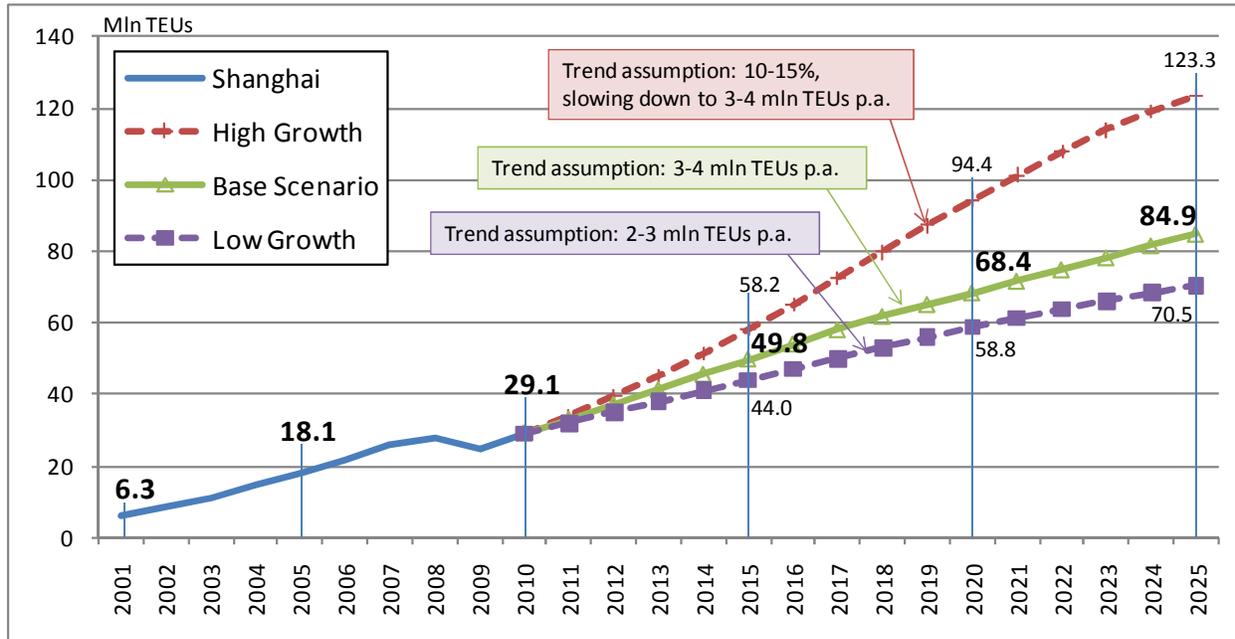
Source: drawn by authors with data gathered from Informa UK Ltd (2011) and terminal operators' websites.

Figure 4: Shenzhen Container Throughput Performance



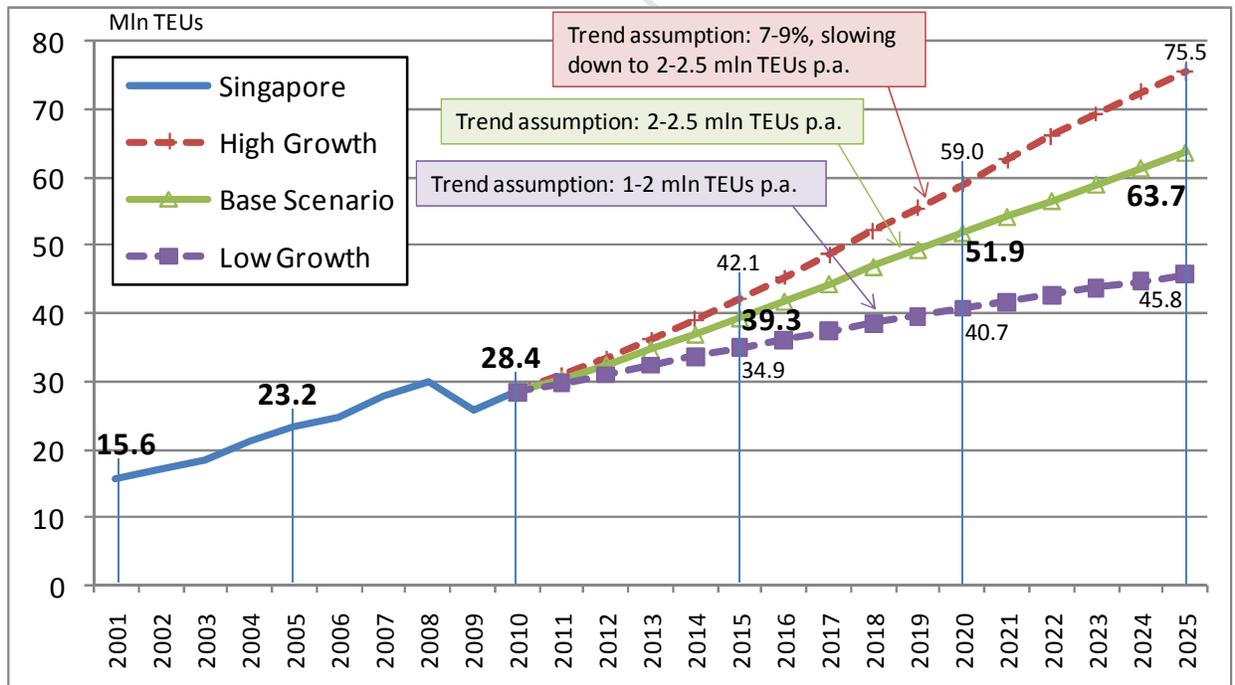
Source: drawn by authors with data gathered from Informa UK Ltd (2011) and terminal operators' websites.

Figure 5: Projection of Container Throughput for Shanghai to 2025



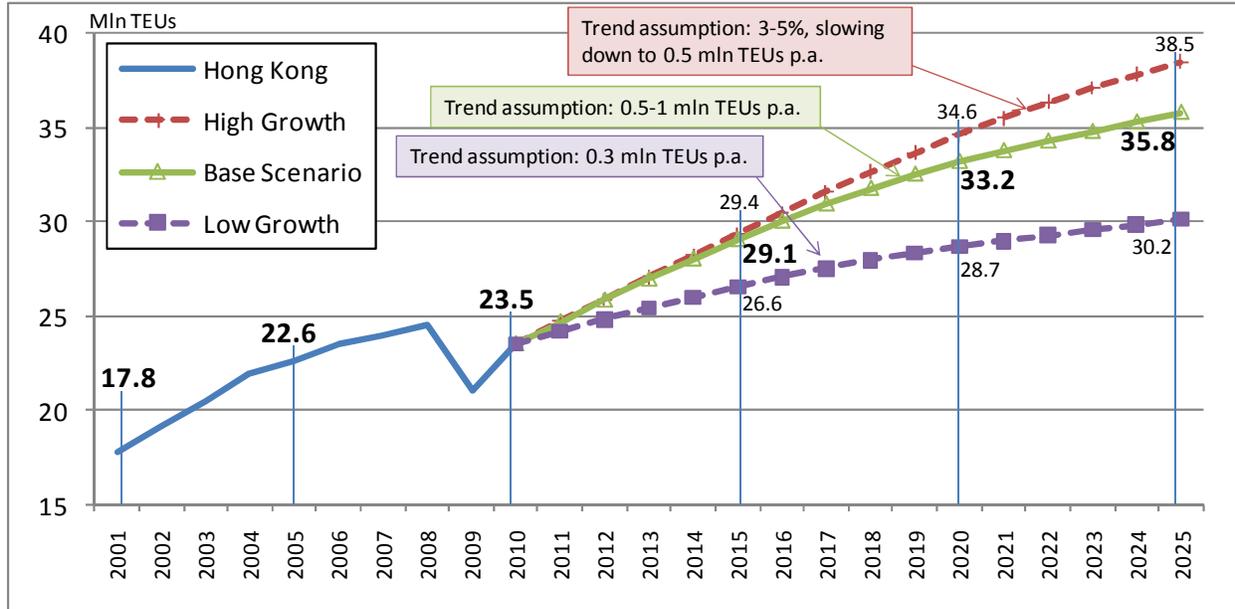
Source: authors' computation.

Figure 6: Projection of Container Throughput for Singapore to 2025



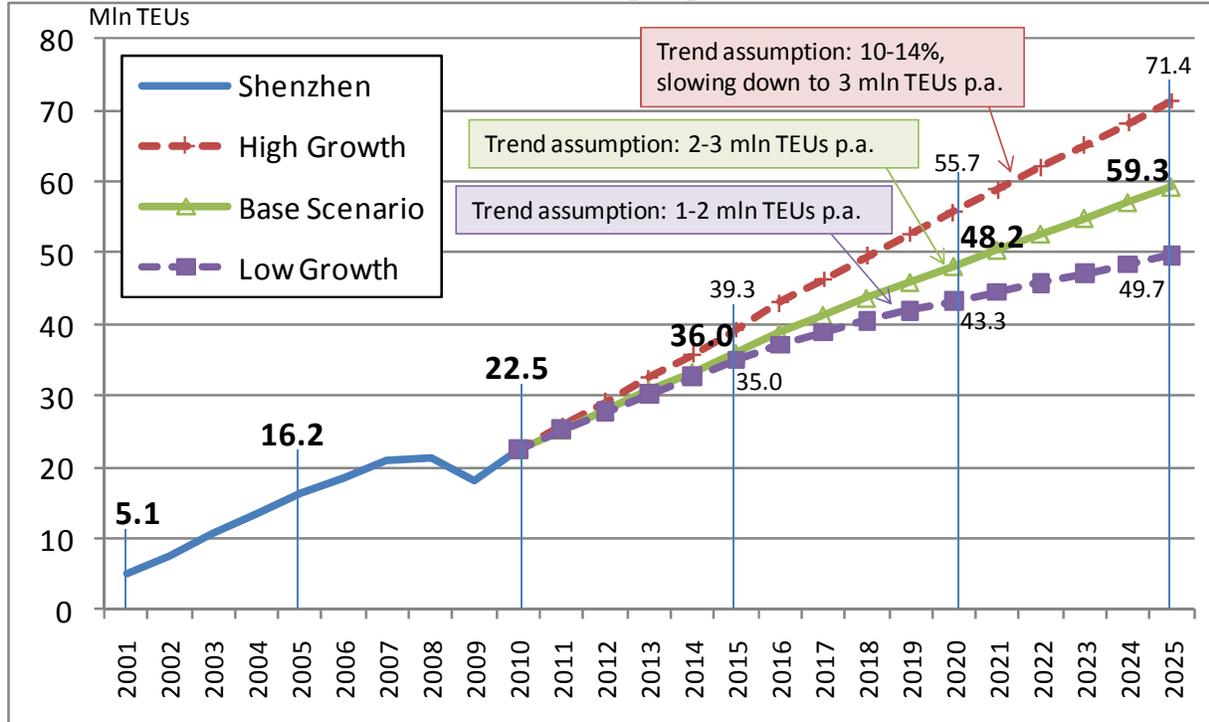
Source: authors' computation.

Figure 7: Projection of Container Throughput for Hong Kong to 2025



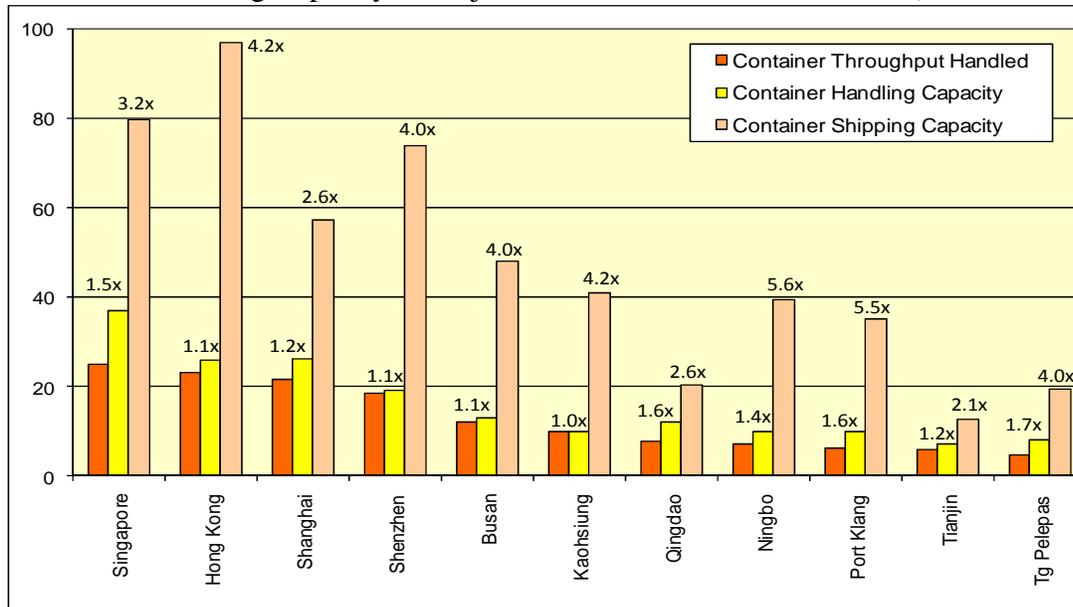
Source: authors' computation.

Figure 8: Projection of Container Throughput for Shenzhen to 2025



Source: authors' computation.

Figure 9: Comparison of Container Throughput, Container Shipping Capacity and Container Handling Capacity of Major Asian Container Ports in 2006 (million TEUs)



Source: Drawn by authors, based on data from Informa UK Ltd (2011) and various terminal operators' and port authorities' websites.