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Study on the Berth Throughput Volume of Shanghai Shengdong International Container Terminal

By

Mingkong Chen

Acknowledgements

The study experience in MEL is so colorful that I will remember the amazing year in Rotterdam forever. The professors in MEL are quite different form the Chinese teachers. Everyone in the international class blends in the global environment, which leaves me a nice memory. By the multinational group work policy MEL really creates a very positive atmosphere for the students to learn from each other. Through the group study, I got the chance to co-operate with people who have different culture background and working experience. All of these could not be achieved if I did not study in MEL.

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Abstract

Shanghai port faces an increasing shipping market. Through a series of development and construction works, Shanghai has 8 container ports that handle container vessels from all over the world. However, the continuously increasing throughput volume put a lot of pressures over the terminal operators. To study the relation between the throughput and the berth handling volume, the paper focuses on the biggest container terminal, SSICT and adopts a quantitative analysis to the research topic. The paper consists of 2 parts, which are the throughput forecast and the berth handling volume calculation. In the throughput forecast, the paper compares estimations of exponential smoothing model with GM (1, 1) model, then, the paper detects that GM (1, 1) produces a more accurate forecast result. Hence, the GM (1, 1) model is used by the author to forecast the throughput volume of SSICT and Shanghai Port.

After the forecast, the study pays attention to the berth handling volume of SSICT. A basic introduction about the berth side operation process is given and the practical data are used in the berth handing volume. Comparing with the throughput forecast, the research concludes that SSICT needs to improve the berth productivity in the future. Finally, the paper makes sensitive analyses of the impacts which have influence on the berth handling volume. Basing on the sensitivity analysis, the author proposes some solutions to increase the berth productivity of SSICT.

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List of abbreviation

AGO	Accumulated Generating Operation
HIT	Hongkong International Terminals
IAGO	Inverse Accumulating Generation Operator
LOA	Length of All
PICT	Pudong International Container Terminal
QQCT	Qingdao Qianwan Container Terminal
RF	Refrigerated
SECT	Shanghai East International Container Terminal
SGICT	Shanghai Guandong International Container Terminal
SMCT	Shanghai Mingdong International Container Terminal
SSICT	Shanghai Shengdong International Container Terminal
TEU	Twenty-foot equivalent unit
ZCT	Zhendong International Container Terminal

Chapter 1 Introduction

1.1 General Background

Since the 21st century, Chinese ports have gone through a paradigm shifting development. With the continuously increasing in the throughput, a lot of construction works were taken by the coastal cities to add berths at the quay side or build new ports. However, both the constructions of new ports and the expansion of existing ports are huge projects, which take a few years from the preparation to the completion. On the one hand, the construction works take a rather long time, but the skyrocketing throughput does not wait for the slow construction. On the other hand, the increasing vessel size also puts pressure on berth efficiency. In theory, a big vessel needs more time to be handled, however, in the practical situation, the shipping lines hope the terminal operators to maintain the same service time of a big vessel or even decrease service time further. If the ports cannot handle the vessels in a very efficient way, the shipping line companies will change their ports of call without any hesitation. Hence, the inefficient ports will lose their competitive advantages over the container operation business. In the past 10 years, the port operators were engaged in adding port throughput capacity. However, the added throughput capacity could not satisfy the increasing demand of throughput volume. The following table demonstrates the gap between the throughput and the design throughput capacity in the biggest 5 ports in China.

Table1-1 Throughput and the Design Throughput Capacity of the Biggest 5 Ports in China

Port	**Throughput capacity in 2009 (in 10,000TEU)**	**Throughput in 2009 (in 10,000TEU)**	**Terminal utilization rate (in percentage)**
Shanghai Port	1845	2472.7	134.02%
Ningbo-Zhoushan Port	1310	1010.4	77.13%
Guangzhou Port	625	749.9	119.98%
Qindao Port	790	1010.7	127.94%
Dalian Port	515	439.9	85.42%

Source: *China Ports*, 2009

The statistics show that Shanghai Port has suffered the overcapacity most severely among all the Chinese ports. Regarding to the quay length, Shanghai Port has a 12,938-meter-long quay, and the average productivity of per 100m quay length is 213,100 TEU (Du and Meng, 2010). The figure is astonishingly high, because Shanghai does not want to leave behind in the container shipping market.

To handle continuously increasing container throughout in Shanghai Port, 2 new deep sea ports were built on the Yangshan Island, namely Shanghai Shengdong International Container Terminal and the Shanghai Guandong International Container Terminal. However, the throughput of the 2 terminals keeps increasing in recent years. The following table describes tendency of the market demand of the Shanghai Shengdong International Container Terminal.

Table1-2 Throughput and the Increase Rate of SSICT

Year	Throughput (in TEU)	Increase Rate (in percentage)
2006	3,236,000	
2007	6,007,697	0.86
2008	5,636,998	-0.06
2009	4,638,234	-0.18
2010	5,750,330	0.24
2011	7,133,342	0.24
2012	7,550,082	0.06

Source: Compiled by author based on the *Year Book of Chinese Port*

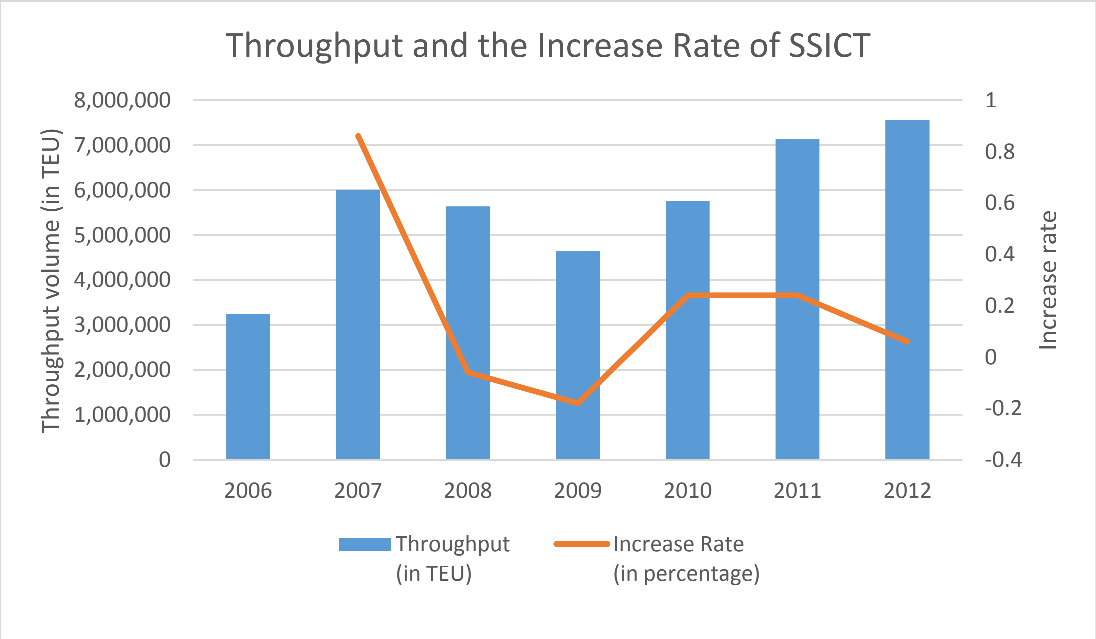


Figure 1-1 Throughput and the Increase Rate of SSICT
Source: compiled by the author based on the official data from SSICT

From the figure above, we can feel that the pressure over throughput capacity comes from the continuous increasing throughout. Since 2007, the construction of Yangshan Deep Sea Port has fully completed, which means that the berth quay length is fixed. It is impossible for the terminal operator to increase the berth handling capacity by adding berths. The limited number of berth and the increasing container through demand make the port more and more congested.

This paper aims to take Shanghai Shengdong International Container Terminal as an object of study and work out the relation between the throughput demand on the terminal and the real berth handling capacity. The throughput demand study is based on forecasting methodology. The paper makes estimations of the throughput of both the Shanghai Shengdong International Container Terminal port and Shanghai Port in the following years. Regarding the berth handling capacity, the paper proposes a quantitative analysis to analyze the berth throughput volume based on the practical situation. After the sensitive analysis, the paper gives some suggestions on how to increase the berth throughput volume by optimizing the port operation process.

1.2 Objectives of the Study

Container terminals act as an important node in the global transportation business. The construction of a container terminal not only takes a long time but also needs a vast investment. To satisfy the increasing market demand, Shanghai Shengdong International Container Terminal was built on Yangshan Island. After the construction, the terminal capacity is facing the challenge from the continuously increasing throughput volume all the time. According to the design report the port authority expected Shanghai Shengdong International Container Terminal to handle 4,400,000 TEU annually. However, the throughput volume of the terminal outnumbers the expected handling volume in a large scale. Although the throughput of the terminal hit the bottom in year 2009, the throughput was 4,638,234 TEU, which was still higher than the expected capacity. When the market was booming in year 2007 or in year 2011, the throughput volume of the terminal went far beyond the expected handling volume. Now days, the terminal still faces an increasing market demand, so it is necessary to re-calculate the terminal throughput volume. The figure from the port authority is too much conservative, which cannot measure the handling capacity of the terminal precisely. Because the terminal makes strategies on the basis of the terminal capacity, the underestimated handling volume contributes a conservative terminal strategy. In this study, the paper proposes a scientific way to calculate the real terminal handling volume on the berth operation perspective.

The paper hopes to give an objective understanding of Shanghai container market on the throughput view, and analyze berth handling volume of Shanghai Shengdong International Container Terminal in a scientific way. By the correction of the berth handling volume, the paper hopes to bring some re-thinkings and changes to the terminal operator when it is making the operation strategy.

1.3 Methodology

In Chapter 2, a literature review is taken to conclude the outcome from the existing research papers. By the literature review, the research objective of this paper will be specified in a detailed way. Besides, the exponential smoothing forecast model and the grey model are introduced in the forecast process. Through comparing the estimations of these 2 forecast models with the raw data, the author uses the more accurate one to make the forecast of the throughput of Shanghai Shengdong International Container Terminal in the following 3 years.

The second part is a quantitative analysis about the berth handling volume of Shanghai Shengdong International Container Terminal. In the quantitative analysis, the paper aims to use the data from the practical operation to calculate how many TEUs pass through the berth in a year. Then a comparison between the throughput forecast and the theoretical throughput handling volume is given. The paper studies the parameters of SSICT and other world class ports, then, analyzes the potential of increasing the berth productivity. Besides the comparison, the paper also makes a sensitive analysis on the factors which have impacts on the berth throughput volume. In the end, the paper proposes some suggestions or innovative thoughts to improve the berth productivity of Shanghai Shengdong International Container Terminal.

1.4 Outline of the Paper

The paper consists of 7 chapters which are organized as follows.

Chapter 1 gives a description of the background of the paper. In this chapter, the author explains the reason why he chooses the topic. Additionally, Chapter 1 briefly shows the structure and the methodology of the paper, which is quite helpful for readers to understand the contents of the paper.

Chapter 2 is about the literatures regarding the research topic of the paper. The author studies the methodologies applied in throughput forecasting and berth handling volumes calculation. In this chapter, the paper not only includes the methodology from the related literatures, but also makes comments on these methodologies.

Chapter 3 consists of the models the paper uses. The paper introduces both the Holt's exponential smoothing forecast model and GM (1, 1) model in this chapter. The measurements of the forecast accuracy are also discussed in this chapter.

Additionally, the paper also explains the factors that determine the berth throughput volume. How to calculate the berth handling volume is the problem that the paper will discuss in this part. Several berth throughput volume formulas are chose and compared. Through the analysis of these formulas, the paper gives the throughput volume formula for Shanghai Shengdong International Container Terminal.

Chapter 4 focuses on the empirical findings regarding throughput volumes and berth capacity. Then, the paper gives a detailed introduction of SSICT. The empirical findings include the berth operation, the handling technologies and the yard operation strategies. Basing on the practical data of Shanghai Port, the author analyzes how the factors affect the berth productivity.

Chapter 5 presents the analysis of the throughput volume in Shanghai Port in a macroscopic view. After the qualitative analysis, the paper uses exponential model and GM (1, 1) model to analyze the throughput volume quantitatively. Both models are used to calculate the estimations of the throughput of SSICT, and then, the paper assesses the estimation accuracy of the 2 forecast models by SSE and MAD. After the comparison, the more accurate forecast model will be taken to make the throughput forecast for the next 3 years. Because the market share is one of the drivers of throughput demand, the paper also focuses on the market factor and discusses the development tendency of the market share of Shanghai Shengdong International Container Terminal. Through the analysis of the market influence, we can get a thorough conclusion about the tendency of the throughput volume of Shanghai Shengdong International Container Terminal.

Chapter 6 analyzes the factors which affect the berth handling volume, and calculates the berth handling volume of Shanghai Shengdong International Container Terminal. Then, some analyses are given regarding the results of the berth throughput volume. In this chapter, the paper introspects the problems existing in the operation and gives suggestions to optimize the port operation process. Some efficient terminals are taken as examples. The paper compares Shanghai Shengdong Container Terminal with these efficient terminals and then, some re-thinking and suggestions will be given. Because sensitivity analyses can help us find the most effective way to improve the berth throughput volume, the paper includes a sensitivity analysis which displays the extent of the impacts of different factors in a quantitative way.

Chapter 7 draws the conclusion of the study. Some defects of the research are also included in this part.

Chapter 2 Literature Review

2.1 Introduction

In this part, the some relative literatures are discussed. After analyzing the result of previous studies, we can achieve a better academic understanding about the logic behind the existing problems.

The figure 2-1 below is a visualized demonstration of the logic which is involved in this study. With the booming in the sea born trade of China, there is a continuous increasing in throughput. As a newly built deep sea port, Shanghai Shengdong International Container Terminal has faced a rising market demand since the project completed. From the throughput prospective, the terminal is the biggest container terminal in Shanghai. In 2012, the terminal handled 7,550,082 TEU containers, which consists 1/4 market share of Shanghai Port.

Because the terminal services a large hinterland in the Yangtze Delta, the hub status of the port attracts many ocean liners to call at the terminal. Many containers are needed to be transshipped at the terminal. Facing the increasing throughput volume, the operator should have some ideas of the bottle neck in the berth operation and then, make the corresponding strategies to solve the problems.

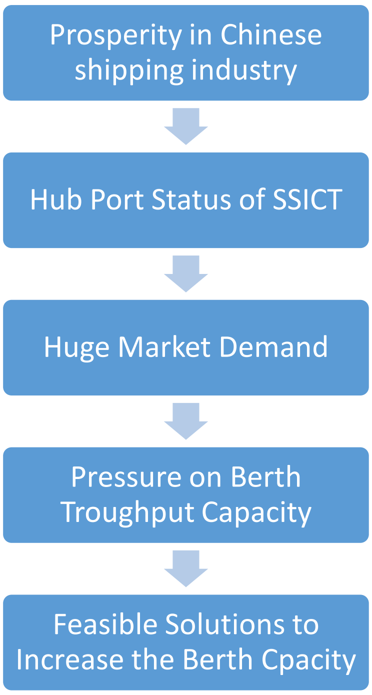


Figure 2-1 Logic behind the Paper
Source: Compiled by Author

Under the guide of the logic above, the structure of the literature review part is established as follows. In section 2.2, the paper studies the factors which have influence on throughput. The paper analyzes the relative literatures and concludes the main factors which affect the throughput of a terminal. Section 2.3 is regarding the forecasting approaches which are taken to estimate the throughput capacity. The paper compares the quantitative approaches and qualitative approaches and then, concludes the advantages and disadvantages of these approaches. Section 2.4 includes several literatures which focus on how to calculate the berth throughput volume. Because different calculation methods take different factors into consideration, we discuss the preconditions of the application of these different calculation methods in this section.

2.2 The Inference on the Throughput

It is obvious that many elements affect the throughput of a port. In the paper written by Liu and Park (2011), the authors listed a series of variables which had impacts on port throughput, such as hinterland's GDP, direct call liners, transshipment, investment of government etc. The paper introduced a regression model to determine the weight of these variables in both China ports and Korean ports. In the case of China ports, the strongest factors were hinterland's import-export volume and investment of the government. The 2 authors argued that Chinese economy development and the support of government policy created a big hinterland's import-export volume. As a result, Chinese throughput volume kept increasing in a high speed when China achieved a big economic development.

Yeo et al. (2011) analyzed the terminal throughput in a logistician perspective. Because the international shipping acts an important node in the global logistics, the level of related logistic service has an influence on the terminal throughput. Yeo scored 6 ports (including Shanghai Port) in all 7 categories, namely port service, hinterland condition, availability, convenience, logistics cost, regional cost, connectivity. The author applied the fuzzy model into the measurement of port competitiveness. Some experts' judgments were included in port competitiveness measurements. Shanghai ranked 1st in hinterland condition, which was identical to the result of Liu and Park (2011). Yeo et al. believed that Shanghai had a huge advantage in the logistic cost, because the labor cost was cheap in the main land of China. Additionally, the geographic advantage also ensured hub port status of Shanghai Port in the far-east area. Basing on the above factors, the authors concluded that the attractiveness in the logistic field would bring more containers to Shanghai port in the future.

Yap and Lam (2013) made a clear conclusion that the magnitude of increase in Shanghai port could be several times of its current increase. The methodology involved in the paper was a longitudinal approach. The author identified the correlation between the growth tendencies in recent years. After that, a certain growth path was given and throughput in the next 15 years was estimated on the basis of the growth path. The paper forecasted how many berths need to be constructed and how long the new quay should be built in the future. Although there was a fierce competition between the ports in the East Asia, Shanghai, as the hub port in the Far East, had an unparalleled competitive advantage. Finally, the paper drew the conclusion that the container throughput of the major container ports was expected to grow (Yap and Lam, 2013).

Yap et al. (2007) predicted that Shanghai would become a hub port on the Europe-Far East route, in the near future. Because of the continuous efforts in the construction of intermodal infrastructure, the intermodal transport was getting more mature and efficient in recent years. With the expansion in the hinterland and the high speed growth of Chinese economy, the throughput volume would increase in some Chinese sea terminals. Shanghai port might grow into one of the hub port in Far East in the development process.

2.3 Forecast Approaches

It is doubtless that the throughput of Shanghai port will increase after the emergence of the Shanghai–Yangshan gateway hub. Therefore, how to forecast the increase is the question faced by the terminal operators in Shanghai port. Generally speaking, the forecast approaches can be divided into 3 categories, namely time series approach, cause-and-effect approach, and judgmental approach (Gosasang et al., 2011).

2.3.1 Time Series Approaches

Time series forecasting makes forecast based on the historical data. Because time series forecast is a very basic forecast approach, this method has been wildly used in the forecast of economic development, product sales, inventory management and port throughput. When using the time series approach to forecast the throughput volume, we identify the inherent relation between the throughput volume and the time. There are a lot of methodologies can be used in the establishment of time series model, such as the moving average, simple exponential smoothing, Grey Model, auto-regression, trend estimation, etc.

- Grey Model

Chi et al. (2013) made a forecast of throughput on the basis of GM (1, 1) model. They took the GM (1, 1) model as a main forecast model and use a logistic growth curve model to improve the forecast accuracy. Xu and Chen (2005) proposed a forecast of the throughput in Lianyun Port by a GM (1, 1). In the research, the mean relative error of the GM (1, 1) model was 0.7%, which indicated that the GM (1, 1) model had a satisfying accuracy in the forecasting process. The authors pointed out that the GM (1, 1) fitted the observation well in the condition that the original data had an exponential smoothing accumulative generating operator.

- Exponential Smoothing

Exponential smoothing forecast is another time series forecast method, which makes forecast through a serial smoothed data. Chen et al. (2005) adopted the exponential smoothing method when they were making throughput forecast of a certain port in China. In the research, the authors used a second exponential smoothing method to correct the impact of the trend in the throughput. The mean relative error for the exponential smoothing model was 1.7%, which showed an acceptable accuracy of the exponential smoothing model. The authors concluded that the exponential smoothing forecast had a good forecast performance when the throughput shows an increasing tendency.

Although exponential smoothing model is simple and understandable, the selection of the smoothing constant is very critical. Jiang (2012) remarked a way to optimize the smoothing constant by Excel. In the research, the author used the built-in “table” function of Excel to give a trial calculation of several smoothing constants. After the trial calculation, the paper compared the forecast accuracy of these different smoothing constants. In the research, the author tested the MAD and SEE of different smoothing constants, and then, he took the constant which produced the smallest MAD and SEE as the optimal smoothing constant for the exponential smoothing forecast.

- Moving Average

Moving average is very direct way to make the data smooth. Maloni and Jackson (2005) forecasted the throughput in United States and Canada indirectly by moving average. The forecast was indirectly because they used the moving average method to forecast the growth rate of the throughput instead of the throughput volume. After forecasting the growth rate, they multiplied the throughput volume by the growth rate, and then they got the throughput volume for the next 12 years. The pro of this method is that the calculation of moving average is very simple. However, the con of the method is that the forecast model does not include many factors which can probably trigger a fluctuation in throughput. In the research paper, Maloni and Jackson assumed that the growth rate maintained the same in the next 12 years. In fact, 12 years is a long period, and the growth rate cannot maintain stable in such a long time.

2.3.2 Cause-and-effect Approaches

Cause-and-effect approach assumes that the variable to be forecasted is the result of a series variables. The forecast model should include these variables which have influence on the forecast result. The classic cause-and-effect approach is regression analysis.

- Regression Analysis Prediction Method

Regression analysis prediction assumes that there is a relation between observations and the variables. Regression analysis is a process to establish a regression model which demonstrates the relation. Chou et al. (2008) used a modified regression model to forecast the throughput in Taiwan. They calculated the correlation between the different economic variables and then integrated some of these economic variables into the regression process. By the correlation calculation, Chou et al. excluded the variables which have a high correlation to each other. Hence, the forecast model performed a good forecast accuracy. Seabrooke et al. (2003) also applied the ordinary least squares regression analysis on the forecast of the Hongkong Port.

- Neutral network model

Neutral network model is more complicated than the regression model. Gosasang et al. (2011) used the basic multilayer perceptron network model to forecast the throughput. In the research, the authors compared the forecast results from the regression models and the results from the multilayer perceptron network model. The conclusion indicated that although the parameter setting for multilayer perceptron model was complex than a linear regression model, the multilayer perceptron had a high correlation coefficient, and a lower MAD than linear regression. Hence, Gosasang et al concluded that neutral network model had a bright application prospect.

2.3.3 Judgmental Approaches

Gosasang et al. (2011) defined the judgmental approach as a model which did not require data in the same manner as quantitative forecasting methods. A very common judgmental approach is the Delphi method, which makes the final decision through a couple of rounds of expert questionnaires. In a Delphi method, the research result relies heavily on the experts' judgments. Because the result of the questionnaire is a rating scale, instead of on hard data, the quality of the research is depend on the interviewee. The selection of the expert team is critical to the research quality. If the team makes full use of their expertise, the research result will be quite helpful. However, if the team is influenced by some disturbance, it is very difficult for the researchers to detect the disturbance factors and remove such negative impacts from the final result.

2.3.4 Conclusions

Because time series approach is more direct and simple than cause-and-effect approach in throughput forecasting process, it is wildly applied in many ports of different countries and regions. The time series assumes that the observation of the historical throughput data contains the result of different variables impact. If we can identify the tendency of the throughput, we can forecast the throughput as well. Hence, this approach requires a lot of the data analyses. The quality of the data affects the accuracy in a large scale. Besides, the time series has a better forecast performance in a short time period than in a long time period. Because the forecast is based on the time series, the recent data represent the trend of the throughput more precisely in a short time period than in a long time period. As a result, time series approach is applicable in a short term throughput forecast. In the long term forecast, the decisive factors of the throughput may change, so time series approach is not applicable any more.

Although judgmental approach contains a lot of objective elements, it is still a helpful approach in the decision making, market analysis, and in some other areas. Although some methods are taken to increase the accuracy, such as the anonymity of the questionnaires and regular feedbacks in the Delphi process, the result is still related to the personal judgment of the expert. The result of the judgmental approach is quite objective, so the persons involved in the research have significant influence on the accuracy of the forecast result.

2.4 Berth Capacity Analysis

- Questionnaire and Interview

Questionnaire and interview is a very basic research methodology, so many people choose this method when they produce a qualitative analysis. Maloni and Jackson (2005) adopted this method to the North American container port capacity research. In the study, they selected 33 container ports as sample ports. The authors spent 5 months on the questionnaire process. All the interviewees were senior managers, CEOs, port directors, presidents or the authorities of ports. Although delivery questionnaire and making interview was a very simple way to approach the data required, it was difficult to assess the accuracy and the authenticity of the data. In the research, the questionnaire consisted of 75 questions or statements, so the responders might be impatient after answering a few questions. Moreover, the questionnaire was based on the regular mail and the Internet instrument, so the author could not supervise the responding process at all. All of these drawbacks probably had negative impacts on the accuracy of the data and the final conclusion.

- Queuing Model

Some researchers use queuing model to analyze the berth capacity from the terminal operators' prospective. Because the ship arrival pattern changes from port to port, different terminals are subjected to the different queuing models. Shabayek and Yeung (2000) assumed that the shipping arrival interval had a negative exponential distribution, the service time followed general distribution, and there were 18 servers. Under such an assumption, the author chose the M/G/18 model to analyze the port capacity. Edmond and Maggs (1978) calculated the corresponding berth performance and the cost of vessels under a different queuing model. In the research, the author compared the cost of 3 queuing patterns, namely the M/M/n pattern, the D/M/n pattern, and the $D/E_2/1$ pattern.

Although the queuing models help a lot in the port operation and investment decisions, the queuing theory still has some shortages in assessing the port capacity. For example, container ships usually try to avoid waiting in the roadstead by slow steaming policy. Once the vessel detects that it could wait at the roadstead, the vessel reduces the speed instead of waiting at the roadstead. Additionally, most container vessels have a fixes schedule, so M/M/1 model does not fit the real shipping arrival interval distribution in a good manner. Because the ship arrival interval and the service rate do not fit the standard queuing model perfectly in the real operation process, there are some endogenous defects in the queuing approach.

- Simulation Approach

Dragovic et al. (2005) used the simulation method to conclude that the simulation modelling was a very effective method to examine the impacts of operation priority for a certain class of ships. The paper focused on the PECT terminal, which introduces a priority in berth schedule. Dragovic et al. simulated the berth operation and assessed the ship-berth performance at PECT.

Arena simulation was used by Kozan (2006) to calculate the optimal capacity for Intermodal Container Terminals. In the paper, the simulation model was very powerful and gave a detailed quantitative analysis on the cost of different configuration of yard facilities. The feature of the simulation approach is that it can cover the shortage of the queuing models.

- Economic Approach

All the methodologies mentioned above analyze the port capacity in an engineering approach. A lot of engineering approaches purely focus on the number of containers a terminal can handle in a certain period. However, Chang et al. (2012) calculated the port capacity in a different way. In the research, the author introduced an economic approach to assess the berth performance. He calculated the long run total cost and the long run average cost when a new berth was built in the port.

- Formula Approach

Liu (2009) compared the throughput capacity formula used in China, Korea and Hong Kong. In the research, the author pointed out that the berth throughput formula used by Korean is given by

$$P_t = n * p_1 * 8760 * K_1 * K_2 * K_3$$

Where:

P_t= the port throughput capacity

p_1= the productivity of a quay crane

n= the number of quay crane

K_1= the TEU factor

K_2= the rate of the operation time of a quay crane in a year

K_3= the reshuffling rate

Hong Kong also uses a similar berth throughput formula, which is given by

$$P_t = n * P_1 * 8760 * K_1 * \rho$$

Where:

P_t= the port throughput capacity

p_1= the productivity of a quay crane

n= the number of quay crane

K_1= the TEU factor

ρ= the rate of the operation time of a quay crane in a year

The author marked that both these 2 formulas calculated the throughput capacity on the basis of quay performance, so many factors were neglected by the formulas, such as the operation days, the berth utilization rate etc.

2.5 Conclusions

Through the literature review, the paper gives the potential explanation to the increase in throughput of Shanghai Port, and then, makes comparison between different forecast approaches. Because the time series approach is objective and quantitative, the paper chooses the exponential smoothing method and GM (1, 1) method to study the throughput capacity. Regarding to the berth throughput volume calculation, the paper studies several ways to quantify the berth capacity. In these researches, the critical factors relating to the berth capacity are the call size, berth utilization rate, the quay crane productivity, number of available quay cranes, so all of these factors should be considered in the berth throughput volume calculation. Because of the characteristic of the line shipping, the author decides to use a formula approach to calculate the berth capacity.

Chapter 3 Research Design and Methodology

3.1 Introduction

The purpose of this paper is to make a forecast of the throughput of Shanghai Shengdong International Container Terminal and to analyze the berth throughput volume of this terminal. In the research design and methodology chapter, the paper explains the methodologies involved in the throughput forecasting and berth throughput volume calculation.

3.2 Research Design

This paper focuses on a 2-part question: a) the forecast of the throughput and b) the analyses of the berth throughput volume. The paper chooses Shanghai Shengdong International Container Terminal as an example to study on. To solve the 2-part question, the paper is structured as follows.

a) The author studies more than 30 relevant literatures and then, gets a thorough understanding of the research question. The topic of the literatures includes the forecast methods of throughput, berth capacity, queuing model, the development of Chinese container terminal, etc. Literatures include books, journal articles, conference theses and papers.

b) Smoothing exponential forecast and grey model forecast are the 2 forecast approaches chosen to estimate the throughput of Shanghai Shengdong International Container Terminal. After the estimation calculation, a comparison will be made between these 2 forecast methods, and then, the more accurate forecast result will be taken.

c) Next, the paper focuses on the quantitative analyses of the berth throughput volume. The methodology applied in this part is formula approach. After the calculation of the berth throughput volume, the paper compares the forecast value of the throughput with the current berth throughput. Then, corresponding conclusion will be given.

d) According to the result of the comparison, the paper proposes a sensitive analysis to the factors which have influence on the berth throughput volume. Through the sensitive analysis, the paper concludes the impacts of these factors on the berth throughput volume.

e) The paper compares berth productivities of Shanghai Shengdong International Terminal and other world class terminals. Basing on the result of the comparison, the paper gives some potential solutions to increase the berth throughput volume.

f) The paper makes the final conclusion of the research. All the defects are summed up. Some advices are given to guide future studies.

3.3 Forecast Models

3.3.1 Introduction of Exponential Smoothing

Since the establishment of research operation, people have introduced rational methods in the decision making process. Brown et al. (1956) initiated the exponential smoothing theory and used this forecast method to make a demand forecast. Exponential smoothing forecast applies the least squares techniques to create a curve which fits the history data. In the smoothing process, a constant parameter called smoothing constant α ($0<\alpha<1$) is introduced to determine the weight of the old data. Generally speaking, a small α ($0<\alpha<0.2$) is applicable to the relatively smoothing observations. However, if the observations oscillate in a large scale and there is a significant increasing trend, a large α ($0.6<\alpha<1$) can perform a better smoothing effect. No matter what value α takes, the recent observations weighted higher than the older observations. Because the selection of α is very important to the forecast accuracy, the paper uses Excel to process a trial arithmetic and then, we choose the α which produces the best estimation as the optimal smoothing constant.

After the smoothing process, we can make forecasts on the basis of the smoothing data. The exponential smoothing forecast assumes that the forecast objective in the future is related to the existing trends. In another word, the development of the forecast objective has a consistence and regularity. Hence, we can make a forecast relying on the history observations. Brown et al. (1956) indicated that the historical demand for an item was a time series in which it was convenient to distinguish several types of components.

3.3.2 The Exponential Smoothing Forecast Model

Exponential smoothing forecast is a type of forecast method, which bases on a series of data smooth. The most common exponential smoothing methods are simple exponential smoothing and second exponential smoothing. Because the seasonality reduces the smooth of the raw data, the simple exponential smoothing does not perform well when the raw data shows strong trend or seasonality. Hence, Holt’s model is introduced in the exponential smoothing forecast to handle the trend effect.

A simple exponentially smoothed time series is one that is given by

$$\begin{cases} S_t^1 = y_1 \\ S_t^1 = \alpha * y_t + (1-\alpha) * S_{t-1}^1 \quad (for\ t \geq 2) \end{cases}$$

Where:

S_t^1 = Exponentially smoothed time series at time t

y_t = Time series at time period t

S_{t-1}^1= Exponentially smoothed time series at time t-1

α = Smoothing constant, where $0 \leq \alpha \leq 1$

In general:

$$\begin{cases} S_t^1 = y_1 \\ S_t^1 = \alpha * y_t + \alpha * (1-\alpha) * y_{t-1} + \cdots + \alpha(1-\alpha)^{t-1} * y_1 (for\ t \geq 2) \end{cases}$$

However, the simple exponential smoothening does not take the secular into consideration. To correct the trend effect in an increasing throughput situation, the paper introduces the Holt's Model to solve the trend effect in the exponential smoothing forecast.

The basic thought behinds the Holt's model is the assumption that observation data have a level and a trend. The trend and level are both determined by a regression model. The initial level (S_0) is equal to the intercept coefficient of the regression line and the initial trend (T_0) is equal to the slope of the regression line, which indicates the rate of change in a period unit.

The smoothing formula is given by:

$$\begin{cases} S_{t+1} = \alpha * y_{t+1} + (1-\alpha)(S_t + T_t) \\ T_{t+1} = \beta * (S_{t+1} - S_t) + (1-\beta) T_{t+1} \end{cases}$$

Where:

S_t= the estimated level for time period t

y_t= time series at time period t, t$\geqslant$0

T_t= the estimated trend for time period t

α= smoothing constant for the level, $0 < \alpha < 1$

β= smoothing constant for the trend, $0 < \beta < 1$

We use the following formula to forecast the throughput in period t.

$$F_{t+n} = S_t + nT_t$$

Where:

F_{t+n} = the forecast value for the period (t + n)

S_t = the estimated level for time period t

T_t = the estimated trend for time period t

n = forecast period

In the forecast process, the selection of α and β has an impact on the forecast accuracy. The traditional selection is empirical, which is not scientific enough. Hence, the paper introduces the build-in *Table* function of Excel in the selection process of parameter α and β. With the help of *Table* function, we can work out and compare the accuracy of different smoothing constants.

Table function is very helpful when you want to compare the results from a formula which has 1 or 2 variables. In this case, the 2 variables are the level smoothing constant α and the trend smoothing constant β. Because the values of α and β range from 0 to 1, the paper considers these two variables as 2 independent variables, the step size between 2 consecutive values is 0.01. Hence, α and β are assigned to the value from 0.01 to 0.99 with a step size of 0.01. After the value assignment, there are 100 α and β with different values respectively, we can get 10,000 forecasting results with the different combinations of parameter α and β. To compare the forecast accuracy, SSE is introduced. The formula of SSE is given by

$$\text{SSE} = \sum_{1}^{n} (y_n - F_n)^2$$

Where:

y_n = actual value of time series at time n

F_n = forecasted value at time n

n = number of time periods

SSE measures the square of the difference between the sample and the estimation. Because of the square calculation, SSE magnifies the deviations in a large scale (Keller, 2012). Hence, we choose SSE as the bench mark of the selection of variables α and β. The SSE of all the 10,000 forecasts is computed and then, the forecast model with the smallest SSE will be chosen as the best forecast model.

3.3.3 Introduction of Grey Model

Grey Model was introduced by Julong Deng of Huazhong University of Science in 1982, which is a theory basing on building model, controlling model, forecasting, making policy, optimization of grey system etc. After the 30 years' development, the grey model is quite mature so the model has been applied in many scopes successfully. According to the extent people know about the information system, we divide the information into three categories: white system, gray system and black system. If an information system is fully unknown, it is called black system. On the contrary, if a system is completely known, it is called white system. When a system is known between white and black systems, it is called gray system. Grey system theory thinks that the forecast is based on the grey procession that varies within certain positions. Though the phenomena indicate that the process is random and disorderly, the whole process is sequent and bounded. Therefore, such a data set has potential regularity. To deal the randomness of the time series data, Grey Model introduces the accumulated generating operation (AGO) to reduce the randomness in the raw data. (Deng, 1985). Grey forecast makes forecast by using the inherent regularities in the data set.

3.3.4 GM (1, 1) Model

In terms of container throughput, a few of time related factors have impacts on it, for example, the global economic cycles, the fluctuation of fuel price, and the hinterland economic development, etc. The paper focuses on the forecast of throughput by time series forecast. The author chooses the most wildly used GM (1, 1) model to establish the forecast of the throughput. The notation GM (1, 1) stands for one variable and first differential of a time series data. The precondition of the application of GM (1, 1) is that all the observations are positive (Deng, 1985). It is obvious that the throughput volume satisfies the precondition, so the model is applicable to the throughput forecast.

The basic calculation procedure is as follows. The model uses Accumulating Generation Operator (AGO in short) to decrease the randomness oscillation in the original data (Deng, 1985). A differential equation is used to obtain the n-step ahead predicted value of the system. Finally, an Inverse Accumulating Generation Operator (IAGO) is applied to calculate the forecast of original data (Erdal, 2010).

- AGO

A first Accumulating Generation Operator is subjected to the GM (1, 1) model, which is in the following from.

$$x^1(t) = \sum_{n=1}^{t} x^0(n) \qquad (t = 1,2,3,\ldots,n)$$

Where:

$x^0(n) =$ the n^th observation

$x^1(t) =$ the 1-AGO

- AGO Estimation Equation

The whitened linear differential equation for GM (1, 1) is given with 2 parameters: α and u (Vishnu and Syamala, 2012).

$$\frac{dx^1(t)}{dt} + ax^1(t) = u$$

Where:

t is the time index. $\mathrm{t} = 2,3, \dots, n$

$x^1(t) =$ the 1-AGO

$\frac{dx^1(t)}{dt}$ is the derivative of $x^1(t)$. $\frac{dx^1(t)}{dt} = x^1(t) - x^1(t-1) = x^0(t)$ $(\mathrm{t} = 2,3, \dots, n)$

α and u are 2 parameters to be determined later.

The estimated values for 1-AGO can be calculated by the solution to the whitened linear differential equation. The solution is given by (Vishnu and Syamala, 2012)

$$\hat{x}^1(t+1) = \left[x^1(1) - \frac{u}{a}\right] e^{-at} + \frac{u}{a}$$

- Parameters Determination

To determine the parameter a and parameter u, we substitute the differential $(\mathrm{dx}, \mathrm{dt})$ by difference $(\Delta \mathrm{x}, \Delta \mathrm{t})$. Because the time span between two observations is 1, difference (Δt) is given by:

$$\Delta \mathrm{t} = (\mathrm{t} + 1 - \mathrm{t}) = 1.$$

It is obvious that:

$$\frac{\Delta x^1(2)}{\Delta(t)} = \Delta x^1(2) = x^1(2) - x^1(1) = x^0(2).$$

$$\frac{\Delta x^1(3)}{\Delta(t)} = \Delta x^1(3) = x^1(3) - x^1(2) = x^0(3).$$

$$\cdots$$

$$\frac{\Delta x^1(t)}{\Delta(t)} = \Delta x^1(t) = x^1(t) - x^1(t-1) = x^0(t).$$

Then, the differential equation $\frac{dx^1}{dt} + ax^1 = u$ turns into the forms given by:

$$x^0(2) + ax^1(2) = u$$

$$x^0(3) + ax^1(3) = u$$

$$\cdots$$

$$x^0(n) + ax^1(n) = u$$

We write the solution in the forms of dot product, so the solutions are given by:

$$x^0(2) = [-x^1(2), 1]\begin{bmatrix} a \\ u \end{bmatrix}$$

$$x^0(3) = [-x^1(3), 1]\begin{bmatrix} a \\ u \end{bmatrix}$$

$$\cdots$$

$$x^0(n) = [-x^1(n), 1]\begin{bmatrix} a \\ u \end{bmatrix}$$

Because $\frac{\Delta x^1(t)}{\Delta(t)}$ is related to the time point t and (t-1), we substitute $\Delta x^1(t)$ by the mean of $x^1(t)$ and $x^1(t-1)$. Namely $\Delta x^1(t) = \frac{1}{2} * [x^1(t) + x^1(t-1)]$ (t ≥ 2).

Then solutions turn into the forms given by:

$$x^0(2) = [-\frac{1}{2} * (x^1(2) + x^1(1) - 1), 1]\begin{bmatrix} a \\ u \end{bmatrix}$$

$$x^0(3) = [-\frac{1}{2} * (x^1(3) + x^1(2) - 1), 1]\begin{bmatrix} a \\ u \end{bmatrix}$$

$$\cdots$$

$$x^0(t) = [-\frac{1}{2} * (x^1(t) + x^1(n-1), 1]\begin{bmatrix} a \\ u \end{bmatrix}$$

Let $y = (X^0(2), X^0(3), \ldots, X^0(\mathrm{t}))^T$, $B = \begin{bmatrix} -\frac{1}{2} * (x^1(2) + x^1(1) - 1) & 1 \\ -\frac{1}{2} * (x^1(3) + x^1(2) - 1) & 1 \\ \vdots & \vdots \\ -\frac{1}{2} * (x^1(n) + x^1(n) - 1) & 1 \end{bmatrix}$ and $U = \begin{bmatrix} a \\ u \end{bmatrix}$,

then , we can write the solutions in the matrix given by:

$$\mathrm{y = BU}$$

The least-square estimation of the matrix form which is given by:

$$\hat{U} = \begin{bmatrix} \hat{a} \\ u \end{bmatrix} = (B^T B)^{-1} B^T y$$

Put the least-square estimation value of the equation set $\hat{U} = \begin{bmatrix} \hat{a} \\ u \end{bmatrix}$ into the solution equation $\hat{x}^1(t+1) = \left[x^1(1) - \frac{u}{a}\right] e^{-at} + \frac{u}{a}$ and then, we can get the 1-AGO of $\hat{x}(\mathrm{t})$, which is given by

$$\hat{x}^1(t+1) = \left[x^1(1) - \frac{\hat{u}}{\hat{a}}\right] e^{-at} + \frac{\hat{u}}{\hat{a}}$$

- Forecast model

To calculate the estimation of raw data, an inverse calculation (IAGO) is applied to calculate the forecast value from the 1-AGO. Hence, the forecast model is given by:

$$\widehat{x^0}(t+1) = \widehat{x^1}(\mathrm{t}+1) - \widehat{x^1}(t)$$

3.3.5 The Development Coefficient in GM (1, 1)

The parameter a is one of the 2 parameters in the solution of the ordinary differential equation.

$$\frac{dx^1}{dt} + ax^1 = u$$

The opposite number of parameter a is defined as the development coefficient, which has a proper range between (-2, 2). Deng (2000) used exponential series simulation test to define threshold value for parameter$a$. Julong drew the conclusion that when development coefficient (-a) was less than 0.3, GM (1, 1) had a 98% 1-step forecast accuracy. When $-a$ is between 0.3 and 0.5, the forecast for long term is in accurate. A calibration must be applied to the GM (1, 1) model when $-a$ ranges from 0.8 to 1. If $-a$ is large than 1, the forecast is meaningless. From the analysis, we can detect that the GM (1, 1) model works better when the development coefficient (-a) is very small.

3.4 A Comparison between the 2 Forecasting Results

There are many ways to measure the accuracy of a forecast model. The most 2 popular measurements are MAD and SEE.

The definition of the 2 measurements are given by

- Mean Absolute Deviation (MAD):

$$\mathrm{MAD} = \frac{\sum_1^n |y_n - F_n|}{n}$$

- and Sum of Squares for Forecast Error (SSE):

$$\mathrm{SSE} = \sum_{1}^{n} (y_n - F_n)^2$$

Where:

y_n = actual value of time series at time n

F_n = forecasted value at time n

n = number of time periods

In this paper, we test MAD and SSE of the estimations from these 2 forest models respectively and choose the more accurate one to perform the forecast of the throughput of Shanghai Shengdong International Container Terminal.

3.5 Berth Throughput Models

3.5.1 Introduction of Berth Throughput

Berth throughput capacity measures the number of containers a terminal can handle in a certain period. The period of measurement is usually to be one year, so the unit of the throughput capacity is TEU/ year. Subject to the definition, a berth throughput capacity means the maximal number of TEU a berth can handle in a year time. Only when a terminal operates in an ideal situation, it is possible for the terminal to reach the theoretical berth throughput capacity. These ideal situation includes the following conditions.

- Ideal environmental condition

The terminal always operates in a nice weather condition and perfect hydrology condition all the year around. The terminal never shuts down for a bad weather or severe hydrology situation.

- Ideal berth production condition

The number of quay cranes assigned to a vessel always reaches the maximum. All the quay cranes are well maintained and the quay crane drivers are so skillful that the quay cranes can run in a full speed. The chassis or AGVs always arrive at the right position at the right time. There are no congestions or delays at the quay side. Every department cooperates smoothly and works efficiently.

- Ideal shipping condition

Regarding the ships calling at the terminal, all the ships arrive the terminal right on the schedule. Pilot, mooring, inspection, inspection are done in minimal time. The stowage plans are made perfectly so there is no reshuffling at all.

In such a perfect situation, the berth can reach the theoretical throughput capacity. However, the practical scenario is completely different, so the theoretical throughput volume cannot be reached in the real situation. The following charter shows the factors which have influence on the berth throughput capacity.

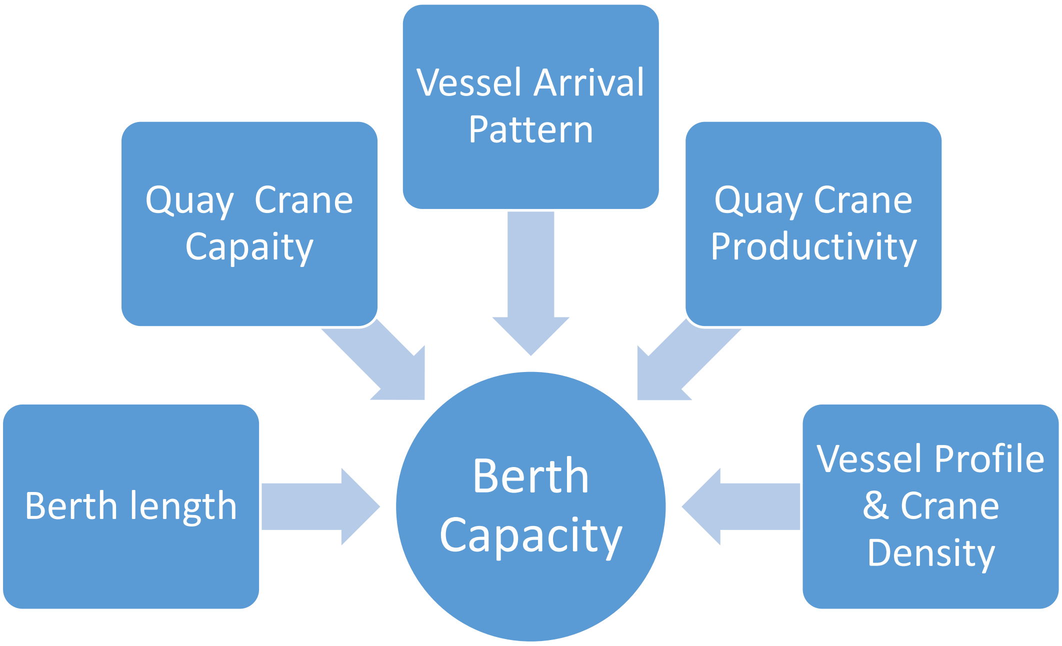


Figure 3-1 The Berth Capacity
Source: Saanen, 2013

The figure 3-1 demonstrates the main 5 factors which determine the berth capacity. Some factors can be further detailed. Take the quay crane productivity as an example. The quay crane productivity is an aggregate result of the productivity of the quay crane itself and the number of quay cranes assigned to a vessel. With the increasing vessel size, a trolley spends more time in movement, when it is handling an ocean container vessel. Reshuffling containers and removing the hatch cover also take time and reduce productivity of a quay crane. The crane driver’s skill also determines how many boxes a quay crane can handle in a certain period of time.

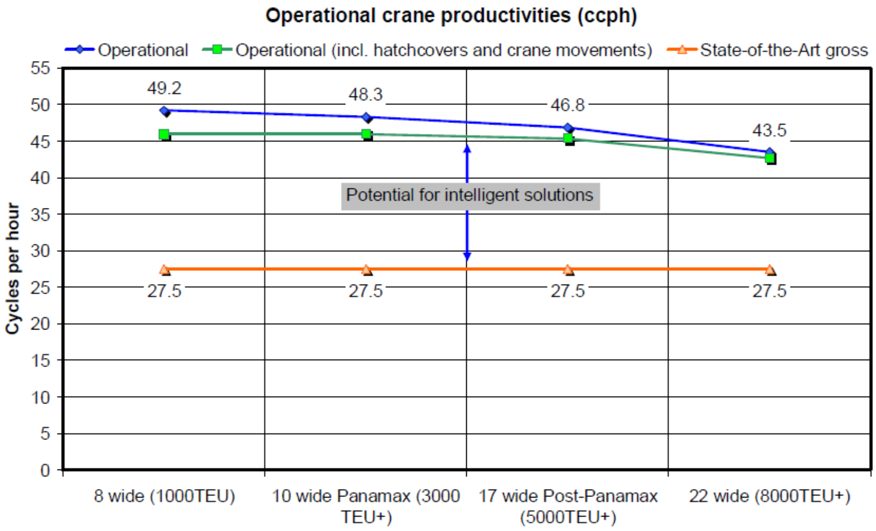


Figure 3-2 Theoretical Quay Crane Productivity and the Practical Quay Crane Productivity
Source: Saanen (2004)

In the following study, the paper gives a further detailed analysis on these factors and then, proposes the formula which the paper uses to calculate the berth handling volume.

3.5.2 The Vessel Hour Productivity (p) (in TEU/ hour ·vessel)

Vessel hour productivity measure how many containers can by handled in an hour for a certain vessel. This parameter consists 4 variables, which are the productivity of a quay crane (p_1), the number of quay crane assigned to a vessel (n), the TEU ratio (k_1) and the reshuffling rate (k_2). The aggregated impact of all these 4 factors determines the vessel hour productivity.

- the productivity of a quay crane (p_1) (in box/ hour)

The productivity of a quay crane is one of the main determinants in the vessel hour productivity. As we discussed in section 3.5.1, the ideal productivity for a quay crane is much higher than the practical situation. With the technology development, some quay cranes can perform 50 moves in an hour. However, in a practical situation, the quay crane productivity is limited by the by the driver skill, stowage plan, vessel type, weather condition etc. All of these factors reduce the productivity of a quay crane. The average productivity ranges between 20-35 boxes/hour. To survival from the competition, the quay cranes in a hub port should be more efficient. Then, the terminal can attract more ocean vessel to call at the terminal. The highest quay crane productivity record for Shanghai Shengdong International Container Terminal was 97 boxes/ per hour. The record was created by a double 40-foot quay crane. However, in the practical situation, the gross productivity for Shanghai Shengdong International Container Terminal is 37.78 box/ hour, which is far less than the operational productivity but higher than the average productivity of Chinese sea port. (Du et al, 2012).

	Quay Crane Productivity	Ecph*
	( ) Kinematic quay crane specification (trolley, hoist) ( ) Type of vessel, stowage plan Technical productivity	55
	(-) Sway, crane-driver skills (-) Disturbances due to lashing, positioning, twist lock handling Operational productivity	50
	(-) Waiting for waterside transportation system Net productivity (target / output simulation)	40
	(-) Break-downs (-) Meal-breaks (-) Shift effects (-) Hatch cover handling (-) Bay changes Gross productivity (target, net -10%)	35

*(equipment cycle per hour)

Table 3-1 Relation between Productivities
Source: Saanen (2004)

- the number of quay cranes assigned to a vessel

The number of quay cranes available to a vessel also determines the vessel hour productivity in a large scale. A critical factor to this parameter is the length of a ship. If the quay crane assignment is too density, the 2 adjacent quay cranes have a negative impact on each other. Hence, a dense quay crane assignment reduces the productivity. Fortunately, an ocean vessel has a long LOA and evenly distributed bay plan, so it is easy to assign more quay cranes to an ocean vessel without mutual negative influence. By regression analysis, Chang (2006) gave the relation between the LOA and the number of quay cranes by the formula

$$\mathrm{n} = \mathrm{int}(\ 0.0026 * \mathrm{L} - 0.1266)$$

Where

n = the maximal number of quay cranes can be assigned to a vessel

L = the length of all

The correlation of these 2 variables is 0.92, which demonstrates a good accuracy of the formula. However, in the practical situation, the number of the available quay cranes is limited by the quay crane scheduling plan, the breakdown of equipment, the stowage plan etc. Hence, the operator always cannot assign the maximal number of quay cranes to an ocean vessel.

- the TEU ratio (k_1)

The TEU ratio measures the ratio of 20-foot container to 40-foot container. The calculation formula for TEU factor is given by

$$\text{TEU ratio} = \frac{number\ of\ 20\ foot\ container + 2 * number\ of\ 40\ foot\ container}{the\ total\ number\ of\ container\ handled\ by\ the\ terminal}$$

However, Shanghai Shengdong International Container Terminal also handles 45-foot container, so the paper revises the TEU ratio formula. The paper takes 2.25 as the conversion coefficient for a 45-foot container. Then, the formula is given by

$$\text{TEU ratio} = \frac{20\ foot\ container + 2 *\ 40\ foot\ container + 2.25 * 45\ foot\ container}{20\ foot\ container + 40\ foot\ container + 45\ foot\ container}$$

During the loading and discharging process, the productivity of the quay crane is counted in boxes/hour. However, the vessel hour productivity is in TEU/ hour·vessel, so TEU ratio is used to coherent these two different units. The TEU ratio fluctuates between 1 and 2, which depends on the status of the port and the vessel destination. In china, because the in-land river vessels ship more 20 foot containers than 40 foot containers, the TEU ratio of feeder port is lower than 1.4. For the hub port, especially the ports which handle the Europe route and North American route, the 40 foot containers account a higher percentage, so the TEU ratio is also higher. The statistic also shows that the input containers have a higher TEU ratio then output containers.

- Reshuffling rate (k_2)

The shipping lines spare no efforts to avoid the reshuffling not only for the operation cost reason, but also for the time cost reason. Staying at a terminal does not bring any profit to the shipping line companies. Only sailing can make money. As a result, when the master makes the stowage plan, he should avoid the reshuffling. However, in the real situation, the reshuffling is unavoidable. Because the call size and the complication in the stowage, a big ocean vessel usually has a higher reshuffling rate than a small vessel. The statistic result of the relation between the vessel size and the reshuffling rate is given by the following table.

Table 3-2 The Relation between the Vessel Size and the Reshuffling Rate

	The vessel size (in TEU)		
	200-1,801	**1,801-5,000**	**≥5,000**
K_2 (in %)	0-5	0-7	0-7

Source: Ministry of Transportation of China (2008)

Hence, the vessel hour productivity is calculated by the product of these 4 parameters. The formula is given by

$$P = p_1 * n * K_1 * (1 - K_2)$$

Where

p_1=the productivity of a quay crane

n = the number of quay crane assigned to a vessel

K_1= the TEU ratio

K_2= the reshuffling rate for the containers

3.5.3 The Daily Berth Throughput Volume

The daily berth throughput volume is determined by the call size of the vessel (Q), the non-productive time for a vessel (t_f), the vessel hour productivity (p), the quay crane operation time in one day (t_g), and the berth utilization rate (Ap). Among these 5 factors, the vessel hour productivity (p) has been discussed in the previous section 5.3.2, so in this section, the paper focus on the rest 4 parameters.

- The call size of the vessel

The call size is decisive in the calculation of the throughput capacity, however, the call size changes from vessel to vessel. The hinterland market is an important factor which affects the call size. A hub port usually has a big hinterland which can provide high cargo volume, so the call size of the vessel calling at the hub port is very big. For the same reason, the port that operates the North America route and the West Europe route has a big call size. Besides, the newly built ports have competitive advantages over the old ports. Because the new ports usually introduce a well-developed controlling system in the operation process, the new quay cranes can be more efficient than the old quay cranes. All of these reasons make a new port competitive in the market. Newly built terminals are easier to have big call size at the berth side. The statistic data are used in the following chapter to calculate the real throughput volume in Shanghai Shengdong International Container terminal.

- The berth time for a vessel

The berth time starts from entering the berth and ends at the exiting the berth. The whole berth time can be divided into 2 parts which are the productive time and the non-productive time. The productive time refers to the time when a vessel is handled by the quay cranes. The non-productive time is all the berth time excluding the productive time. The main components of the non-productive time are the pilot time, the berthing time, the inspection time, the preparation time etc. The following figure shows the relation between relevant times a ship spends at the terminal.

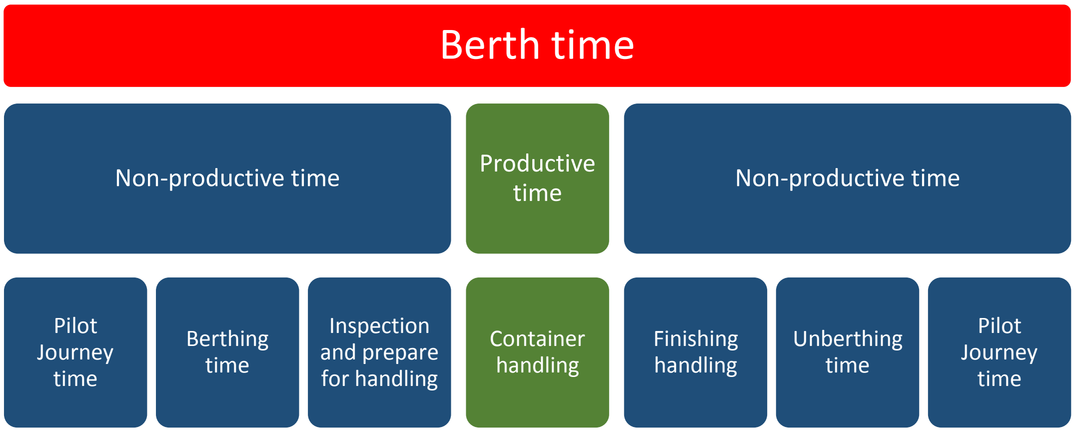


Figure 3-3 Berth time
Source: Compiled by author based on Saanen (2004)

Regarding to a vessel, the productive time (in day) is equal to the call size (Q) divided by the production of vessel hour productivity and the quay crane operation time ($p * t_g$). The non-productive time (in day) is calculated in the same way, which equals the non-productive time (t_f) divided by the day time (24 hours). Then, the sum of the productive time and the non-productive time is the berth time (in day).

- Berth Utilization rate

Berth Utilization Rate is a critical measurement for the port operation. The Ministry of Transport of P.R.C defines the calculation formula as following:

$$A_p = \frac{T_{oc}}{T_{ca}}$$

Where:

A_p= the berth utilization rate

T_{oc}= the occupancy time of a berth

T_{ca}= the calendar year

However, the formula does not take the length of the quay and the length of the vessels into consideration. In the practical condition, small barges sometime share the berths. In such a situation, a berth is no longer the smallest unit, because some berths are integrated together to serve a few vessels. Hence, the terminal calculates the berth utilization rate in the following formula (Saanen, 2004)

$$A_p = \frac{T_{oc}}{T_{ca}} = \frac{\sum_1^n vesssl\ length\ * service\ time}{the\ quay\ lenth * measurement\ period}$$

The occupancy time (T_{oc}) starts form the vessel berthing to a berth and ends at the unmooring from a berth. The berth utilization rate relates to the benefit of the shipping companies as well as the port operator. From the shipping companies prospective, a low berth utilization rate means the high accessibility to the berth operation. On the opposite, a low berth utilization brings loss to the port operator. As a result, the berth utilization rate is a tradeoff between the port operators' benefits and shipping companies' benefits. The optimal berth utilization rate ranges from 0.6 to 0.7, which depends on the practical situation of the calling port. When the berth utilization is higher than 0.8, the ships probably wait in line at the roadstead for mooring.

- Daily berth throughput volume (in TEU/day)

Daily berth throughput volume means how many TEUs go through the quay side. In mathematics, the berth throughput volume equals the berth call size (Q) divided by the berth time and then, multiplied by the berth utilization rate. In formula, the daily berth throughput volume is given by

$$\begin{cases} D_t = \dfrac{A_p * Q}{\dfrac{Q}{P * t_g} + \dfrac{t_f}{t_d}} \\ P = n * p_1 * K_1 * (1 - K_2) \end{cases}$$

Where

D_t= the daily berth throughput volume

A_p= the berth utilization rate

P = the vessel hour productivity

t_g= quay crane operation time in one day

Q = the call size of a vessel

t_f= the non-productive time

t_d= the number of hours in a day.

n = the number of quay crane assigned to a vessel

p_1=the productivity of a quay crane

K_1= the TEU factor

K_2= the reshuffling rate for the containers

3.5.4 The Annual Berth Throughput Volume

The operation days in a year have a direct impact on the berth throughput volume. Although ports always hope to be 24h a day, 365 days a year available, many ports cannot really achieve this in-deed. To assure the safety in the vessel handling process, a port stops loading or unloading in a bad weather. A bad weather, such as the foggy or storm, will probably stop the operation for a few hours. The ports that are located along the Chinese south coast line usually stop the vessel operation in summer, because typhoon makes the operation risky. The operation days for most Chinese ports range from 330 days to 350 day in a year.

The annual berth throughput volume equals the daily throughput volume times the number of operations days in a year. The calculation formula is given by

$$P_t = T_y * D_t$$

Where:

P_t= the annual throughput capacity

T_y= the yearly operation days

D_t= the daily berth throughput volume

3.6 Conclusions

In chapter 3, the paper introduces the 2 forecast models and the berth throughput volume model separately. Because the paper chooses 2 forecast models, SSE and MAD are employed to assess the performances of these 2 models. Then, the paper selects the parameters in the calculation of berth throughput. Basing on these parameters, the paper gives the way to calculate the berth throughput volume.

Chapter 4 Empirical Findings

In this section, the author introduces the empirical findings regarding the throughput and the berth capacity. Section 4.1 focuses on the variables which have influence on the throughput. The author analyzes these impacts on the throughput of Shanghai ports. Section 4.2 and 4.3 are about the berth capacity. Brief introductions about the berth layout and berth operation are given in 4.2 and 4.3 respectively.

4.1 Variables in the Throughput

- The world Economy

The maritime shipping industry is a global industry, which has a close relation with the world economy. We all know that the world economy slumped in 2008, so as the shipping industry. The following figure demonstrates the throughput of Shanghai Port from year 2002 to year 2012.

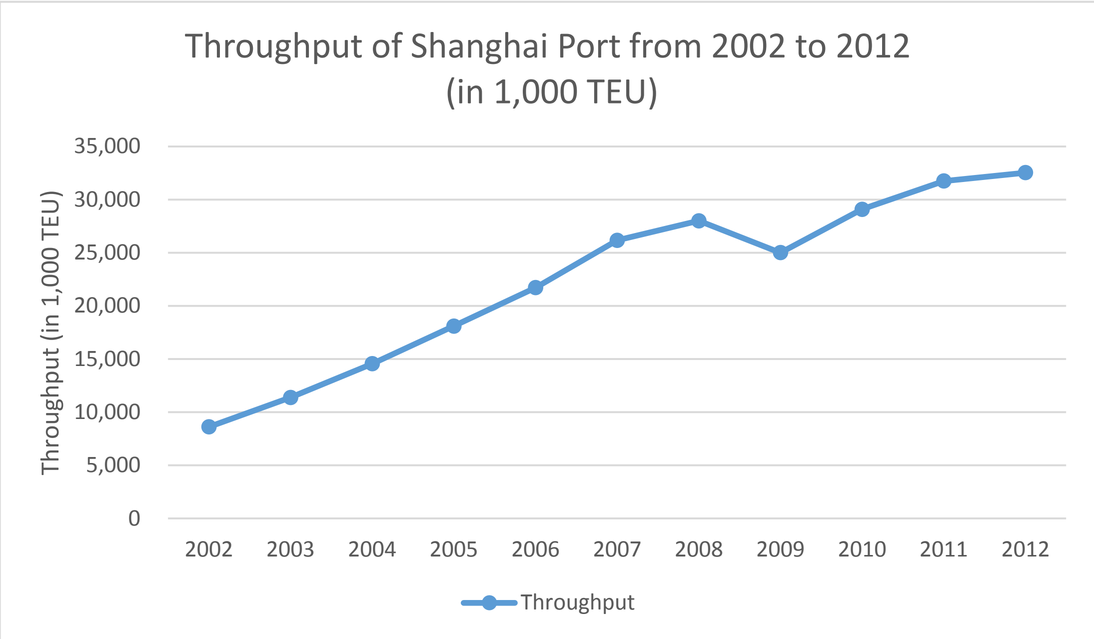


Figure 4-1 The Throughput of Shanghai Port from year 2002 to year 2012
Source: Shanghai International Port Group

As a result of the world financial crisis, the sea born trade volume decreased dramatically in 2009. As an important node in the world trade, Shanghai port suffered a lot from the financial crisis. The table shows that Shanghai Port got a negative increase in year 2009. After the year 2009, the global economy is undergoing a slow recovery, so as throughput of Shanghai Port.

- The supply of port operating service

As the largest port in the world, Shanghai port has 9 container terminals which are PICT, SECT, SGICT, SHICT, etc. All of these container terminals have the capacity to handle the post panamax container ships, so the competition between these terminals is quite fierce. In a micro-economy view, the relation between these container port operators is a monopolistic competition. Any port operator’s market strategy can affect the throughput of other container terminals.

- The geographic location of the port

The geographic location has also has a huge impact on the throughput. A port which is close to the main ocean channel and has a deep draft, is quite attractive to ocean liners. Besides the hydrological conditions, geographic qualification also includes the weather conditions. A port always wants to operate continuously in a year without any shutdown. The weather conditions are as important as the hydrological conditions, because a good weather conditions promise the work days in a year,

Shanghai Port has 9 container terminals, however, 7 of them are located along the mouth of Yangtze River. Because Yangtze River brings a lot of sediment from the upstream, the drafts of the 7 container terminals are not deep enough to handle the 6^{th} and 7^{th} generation container vessels. Hence, Shanghai government decided to build 2 new container terminals on the Yangshan Island that is located in the East Ocean. Shanghai Shengdong International Container Terminal is one of these 2 newly built container terminals, which has a -16 meter draft. With the draft advantage, the terminal can moor the vessel without waiting for the tidal water, which is a high attractiveness to the ocean liners.

- Transshipment containers

According to the definition, throughput measures the number of TEUs going through the quay. Hence, 1 input TEU or 1 output TEU counts as 1 TEU, and 1 transshipment TEU counts 2 TEUs. Because each transshipment containers need to be handled twice at the quay side, a terminal which handles more transshipment container, has a higher throughput volume.

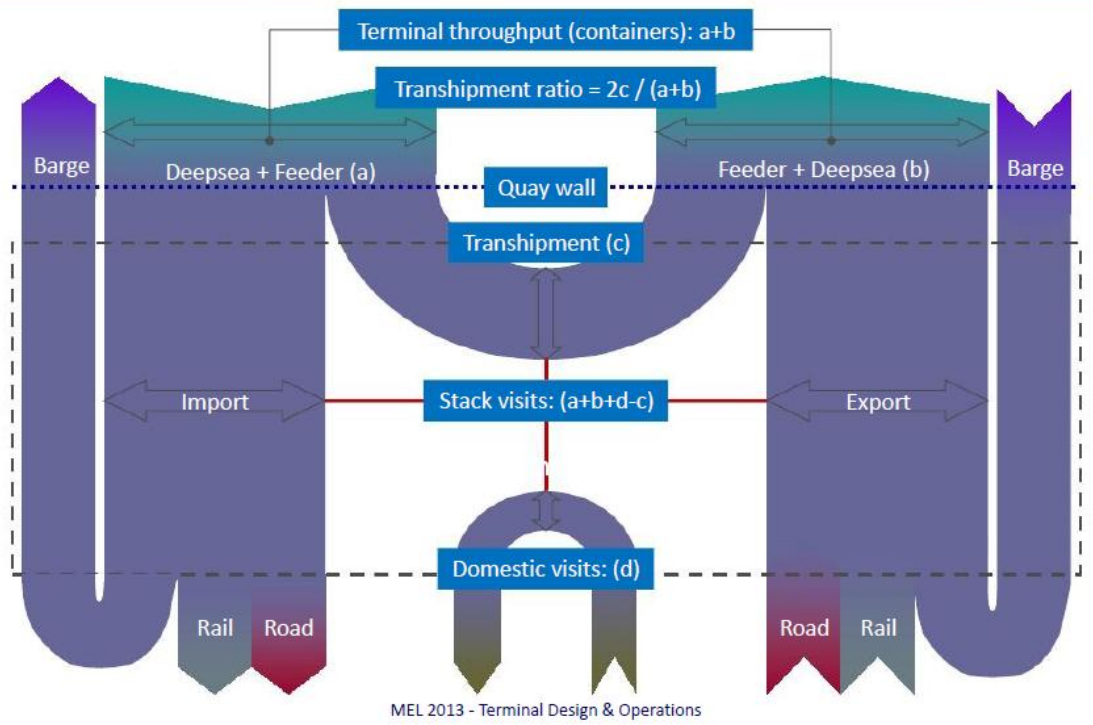


Figure 4-2 Transshipment ratio
Source: Saanen (2013)

Among all the 9 container terminals of Shanghai Port, Shengdong Container Terminal has the largest transshipment volume. The paper selects the throughput volume of SSICT from year 2006 when the terminal started operation, and then, calculates the transshipment ratio. The table 4-1 shows that the transshipment containers account for nearly half of the throughput of Shengdong International Container Terminal. The figure also indicates that the terminal acts as a hub port at the Chinese east coast line. The hinterland of the terminal covers the Yangtze Delta, where the manufactures have a large export volume.

Table 4-1 The Transshipment Volume and the Transshipment Ratio of SSICT

Year	Transshipment volume (in TEU)	The transshipment ratio
2006	1,392,930	0.43
2007	3,054,500	0.50
2008	2,704,273	0.47
2009	2,406,337	0.51
2010	2,498,679	0.43
2011	3,142,883	0.44

Source: Compiled by the author based on *China Ports Year Book 2008-2012*

- Change in the Industry Structure on the Shipping Demand

In the past decade, Chinese industry went through a paradigm shifting change. The proportion of primary industry in the GDP kept decreasing. Secondary industry and tertiary industry developed at a high speed, which created a huge demand on the container shipping industry. Because of the change in the industry structure, China is regarded as the engine of world economy. China is named as the world factory. Many manufactures have established factories in the Yangtze Delta area, so the demand of the ocean shipping is vast. Thousands of containers are shipped from China to other countries every day. Hence, the change in industry structure assures a huge demand on container shipping.

- Exogenous environment of the port

Exogenous environment of the port means the impacts from the departments relating to port industry. Because many parties and apparatus take part in the container transportation process, such as the customs, forwarders, barge companies, Inspection and Quarantine Bureau etc. If all of these parties can co-operate smoothly and efficiently, the port will be quite competitive and attractive to the shipping line companies.

In one word, many factors have influence on the throughput of a certain port and some of them are difficult to be analyzed quantitatively. The history data show that the Chinese port throughput rises in a decreasing growth rate. In 2002, the throughput in growth rate reached 26.50%, which is a peak value after 21st century. After year 2002, the growth rate decreased year after year. Because the world crisis hit the shipping industry in 2009, the growth rate reached the bottom. After that, the growth rebounds but maintains in a decreasing trend. A possible explanation to the downward growth rate is that the throughput base is getting bigger and bigger, so the growth rate decreases.

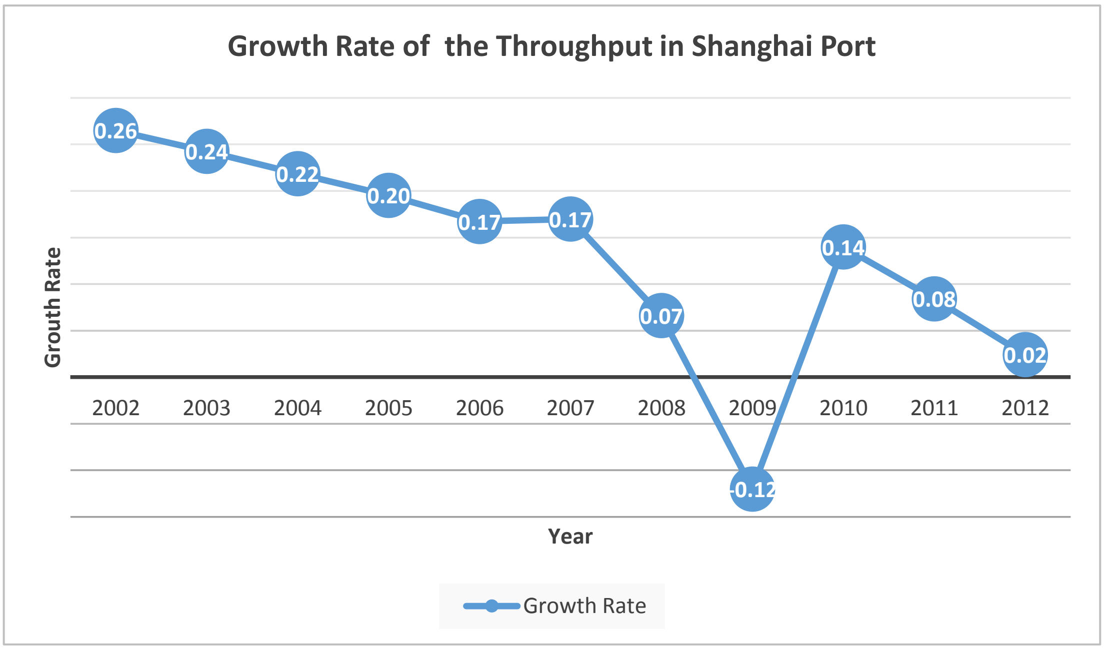


Figure 4-3 Growth Rate of the Throughput in Shanghai Port
Source: Compiled by author

4.2 The Terminal Layout and Handling Technology

4.2.1 Berth Geometry and Condition

Berth is one of the most important components of the terminal facilities. The mooring, loading, unloading and unmooring operation all happen along the berth. According to the geologic feature at the apron, there are 3 berth layouts, namely the linear quay layout, the pier layout, and the excavated dock layout. Coastwise quay layout is the most wildly used design, because the quay crane assignment and the apron design in the coastwise quay are the simplest. Shanghai Port and Taiwan port have terminals which belong to the coastwise design. Linear quay design makes use of the nature sea line, so the construction of the berth is easy. Nevertheless, a breakwater is needed to protect the berth area from the influence of the sea wave in the linear design terminal. Jetty makes the artificial apron in the sea, so the jetty adds the berth area. Osaka port accepts the jetty design. However, the artificial apron of the jetty makes the apron operation more complicated than the linear layout. Excavated dock performs a high ship handling productivity, because vessels can be loaded or unload from both sides of the vessels. Many world class ports have the excavated dock at the apron, such as Amsterdam port and Hamburg Port. Besides the efficient ship handling, the slide-in berth can protect vessels from the sea wave. However, the excavated docks also have some defects. The construction of excavated dock is sophisticated. Because of the sedimentation problem in the excavated dock design, the maintenance of the excavated dock is costly, which is a heavy burden on the terminal operator.

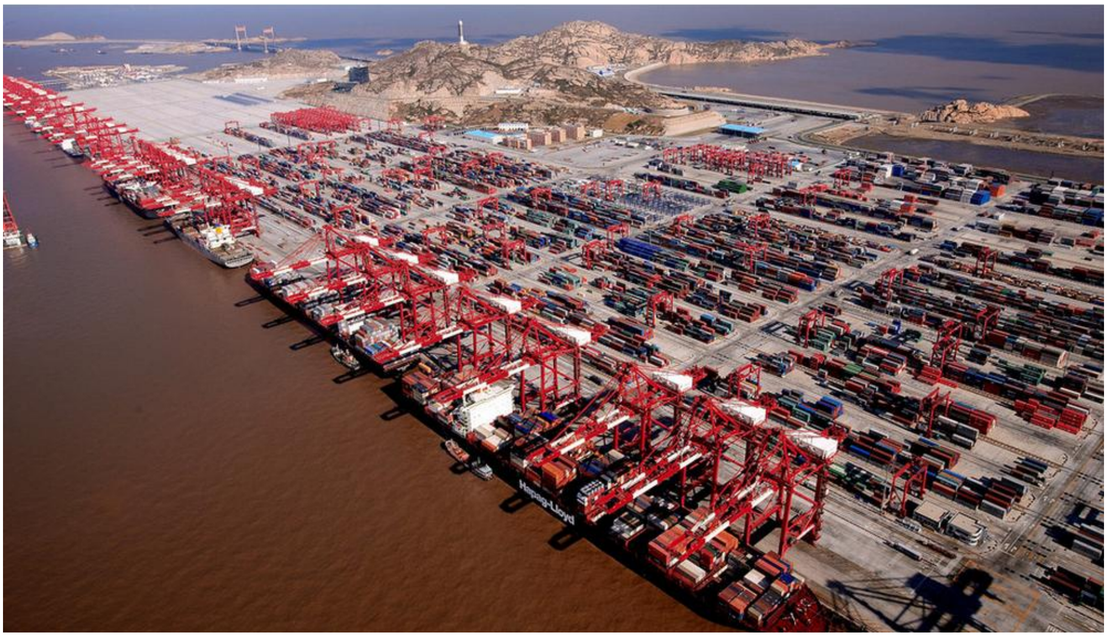


Figure 4-4 A Bird View of SSICT (First Phrase Construction)
Source: Compiled by the author

Because Shanghai Shengdong International Container Terminal is located at a deep sea island there is no limits on the quay length in the geographic prospective. A linear design is taken by the terminal. The whole quay construction project consists of 2 phrases. When first phrase construction was finish in Dec 2005, a 1,900-meter-long quay wall was built. Although the port authority announced that the port throughput capacity was 2,200,000 TEU, the real throughput was 3,236,000 TEU in year 2006, 47% higher than the data given by the port authority. In the next year, the second phrase quay construction was completed as well. After the expansion, Shanghai Shengdong International Container Terminal has a 3000-meter-long quay wall, which includes 9 berths. Because of the geographic advantage, the port adopts a coastwise quay design. Among the 9 berths, berth 1# to berth 6# are relatively big berths, the draft of which are -16m. The draft of Berth 7# and 8# are -13.5m and the rest 9# berth is -11.5m. With a -16 meters draft, the terminal has an unparalleled draft advantage, which means a lot of 7th generation ships can be handled without waiting for tide.

Table 4-2 The Draft of the Berths

Berth	1#	2#	3#	4#	5#	6#	7#	8#	9#
Draft (m)	16	16	16	16	16	16	13.5	13.5	11.5
DWT (*1,000 ton)	70-100			50-70				30	

Source: compiled by the author based on the data from port authority

Table 4-3 Design Vessel Type

	Vessel Size (in TEU)	LOA (in meter)	Width (in meter)	Depth (in meter)	Draft (in meter)	DWT (in tonnage)
Ocean lines	5,520	280.0	39.8	23.6	14.0	69,285
	6,418	318.2	42.8	24.4	14.0	84,900
	8,000	345.0	45.3	25.0	14.0	100,000
	10,000	390.0	47.7	27.2	16.0	140,000
In land sea lines and near sea lines	1,152	170.2	28.4	14.0	9.65	20,000
	1,696	201.0	28.4	15.5	10.7	33,340
	2,761	236.0	32.2	18.8	12.0	40,000
Barge	268	101.0	17.5	7.8	5.2	6,350
	424	123.0	20.5	8.7	6.0	7,000

Source: Compiled by the author based on the terminal design report.

4.2.2 Seaside Operations

Because of the uncertainty in the call size, the shipping arrival pattern, the weather condition, the seaside operation is very complicated. In theory, the seaside operation consists of the following procedures.

- Ship arrival

The ships arrive at the anchoring point, and then, send a requirement to the controlling center for mooring at the berth. If the berth is available, the terminal operator approves the requirement and sends the tugs to help the ships moor at the berth. Otherwise, the ships have to wait at the anchoring point for berthing.

As a deep sea port, Shanghai Shengdong International Container Terminal provides the loading and unloading operation for the international shipping lines. The terminal operates the ocean liners from 12 routes, such as Mediterranean route, East America route, North America route, South America route, West America route, Europe route, West Africa route, the Middle East route, etc. All of the top 15 shipping line companies have ships calling at the terminal. The production control system used by the terminal is TOPS 4.0, which is responsible for the vessel plan, stowage, yard management, and 24-hour plan etc. 45 ocean lines call regularly at Shanghai Shengdong International Container Terminal regularly in a week. The following table shows the number of the vessels calling at the terminal in a year time. From the data, we can see that the terminal is very busy. According to the shipping schedule, the average time a container spends at the quay side is 15.5 hours. Because the call size for the barges and inland vessel are very small, the operation to a barge only takes 3-6 hours.

Table 4-4 The Number of Vessels Calling at SSICT in a year

Month	TEU	Ocean Vessels	Inland vessels and barges	Total
Jan	400,626	156	378	534
Feb	400,096	154	358	512
Mar	420,232	181	382	563
Apr	470,011	171	482	653
May	510,215	183	478	661
Jun	524,053	185	473	658
Jul	550,659	213	531	744
Aug	580,330	235	500	735
Sep	560,811	214	434	648
Oct	560,536	214	451	665
Nov	550,119	213	432	645
Dec	480,005	213	437	650
Total	6,007,697	2,332	5,336	7,668

Source: Shao et al. (2008)

- Ship handling

After mooring, the quay cranes are assigned to the certain bay to unload and load the containers. In the input process, the box is unloaded from the ship and put on the truck which is waiting under the crane. Then, the truck brings the container to yard, and the yard handling machine stacks it on the yard. The output handling process is reversed. The output container is loaded on the truck by the yard handling machine, and then, the truck brings the box to the assigned quay crane, which loads the box on board. To make things smooth and efficient, the control center makes vessel operation plans before vessels arrival. In some western ports, the yard handling machines and the truck/chassis are fully automated, the control tower let them know what to do and where to go.

Because Shanghai Shengdong International Container Terminal is mainly designed to handle the ocean container vessel, the width of the jumbo ocean container ship puts a high requirement on the outreach of the quay cranes. To operate the big vessels, Shengdong International Container Terminal brought 34 quay cranes from Shanghai Zhenhua Port Machinery Co., Ltd. The outreach of the quay cranes is 65 meters, so all of the quay cranes are able to operate the biggest container vessel the in the world. Among the 34 quay cranes, 12 of them are double 40 foot container quay cranes, which can hoist 2 40-foot containers or 4 20-foot containers at one time. All the quay cranes are able to lift a 60-ton container and the maximal hoisting height is 43 meters. The rail gage of the quay crane is 30.48 meters and 4 truck lanes cross under the quay crane.

In the real operation, the terminal operator takes a mixed quay cranes scheduling policy, which means that the double 40-foot container quay cranes and double 20-foot container quay cranes handle a vessel simultaneously. However, these double 40-foot container quay cranes do not show a productivity as the operator expects. Because the 40-foot container quay cranes has not been wildly used in the world wide, the stowage plan is not made in a double 40-foot container quay crane handling way. Under an ideal condition, the 40-foot container quay crane could be quite productive. The statistics show that when the terminal was handling the Zeebrugge of China Shipping, the highest productivity for the 40-foot container quay crane was 97.7 boxes/ hour (Bao and Jin, 2008).

- Unmooring

After all the vessel operation is done, the vessel leaves the port under the guidance of the pilot.

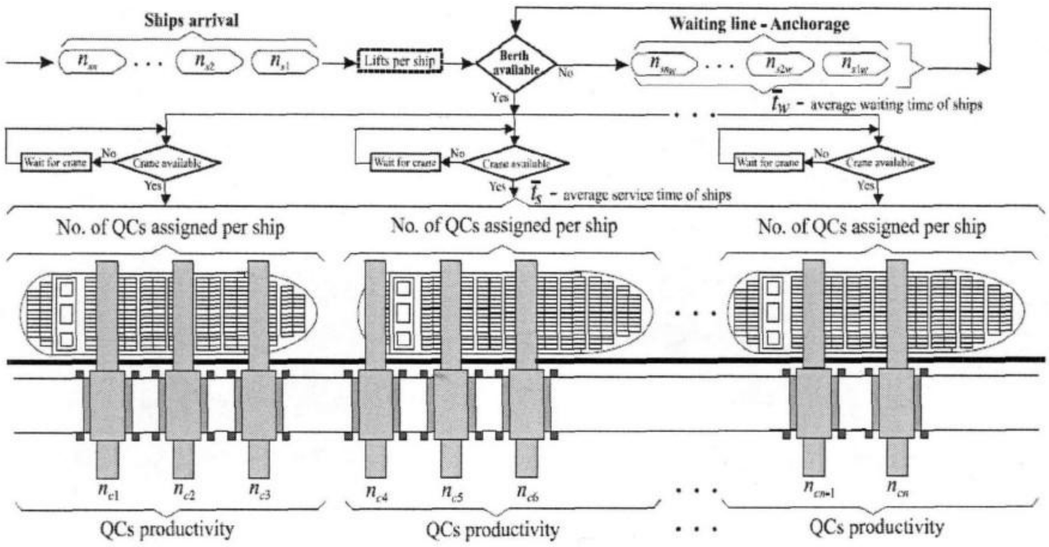


Figure 4-4 The Flow Diagram of Seaside Operation
Source: Container Terminal Berth Utilization Research (Ji 2010)

4.2.3 Yard Operation

Container yard is an area where containers are stored. The yard handling operation efficiency also has an impact on the berth side. When the yard operates smoothly, the trucks can bring the containers to the quay cranes on time. A smooth container traffic ensures that there is no time wasted in waiting, so the quay cranes can work at their full capacity. However, if the yard handling work is poorly organized, the reshuffling, waiting and mistakes at the yard can reduce the productivity of quay cranes.

The land area of Shanghai Shengdong International Container Terminal is 2.4 million square meter and the yard area is 1.49 million square meter where all the containers are staked horizontally to the quay wall. The dimension of the yard is 3000 meters long and 500 meters wide. The yard stack volume is 150 thousand TEU including 3,528 TEU for RF containers and 2,296 TEU for dangerous goods containers. Considering the yard utilization rate and the wheel-pressure at the yard, the terminal chooses the RTG as the yard handling facilities. The lifting weight for the RTG is 40 tons and the hoist height is 18.2 meters. 220 trucks are responsible for the horizontal transport. To handle the large throughput volume, the terminal operator takes a 1 over 5 stacking policy at the container yard.

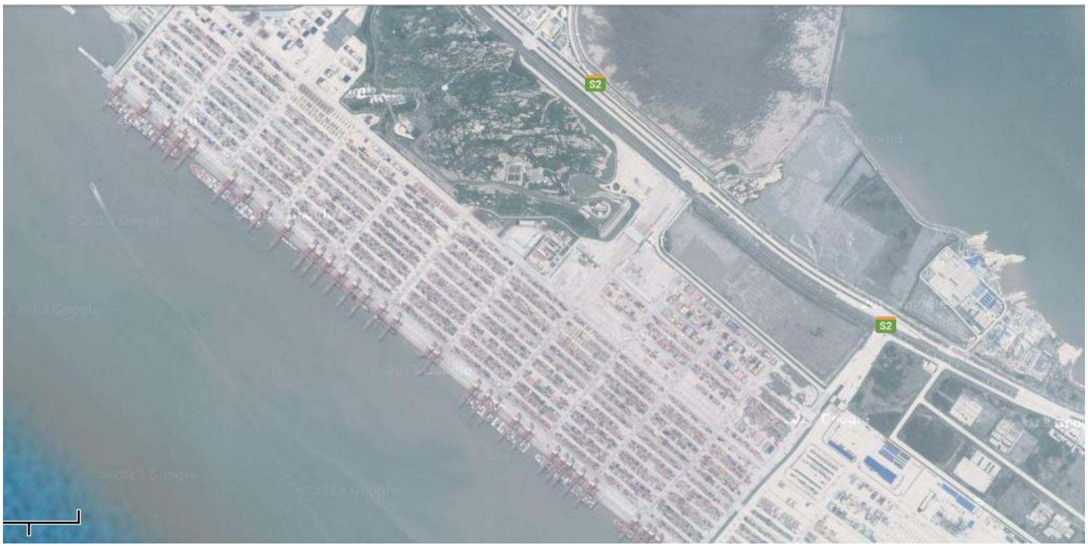


Figure 4-5 The Photo of the Yard in SSICT
Source: Compiled by the author

The following charter shows the container stacking strategy adopted by the terminal. After the ship arrivals the berth, the control center chooses the stacking strategy depending on the call size of the vessel. If the call size is less than 500 TEU, all the containers are stacked at the block which is closest to the berth. When the call size is higher than 500 TEU but less than 1500 TEU, the containers are stacked at the 2 closest blocks randomly. If the call size is larger than 1500 TEU, the containers are stacked at the 3 closest blocks randomly.

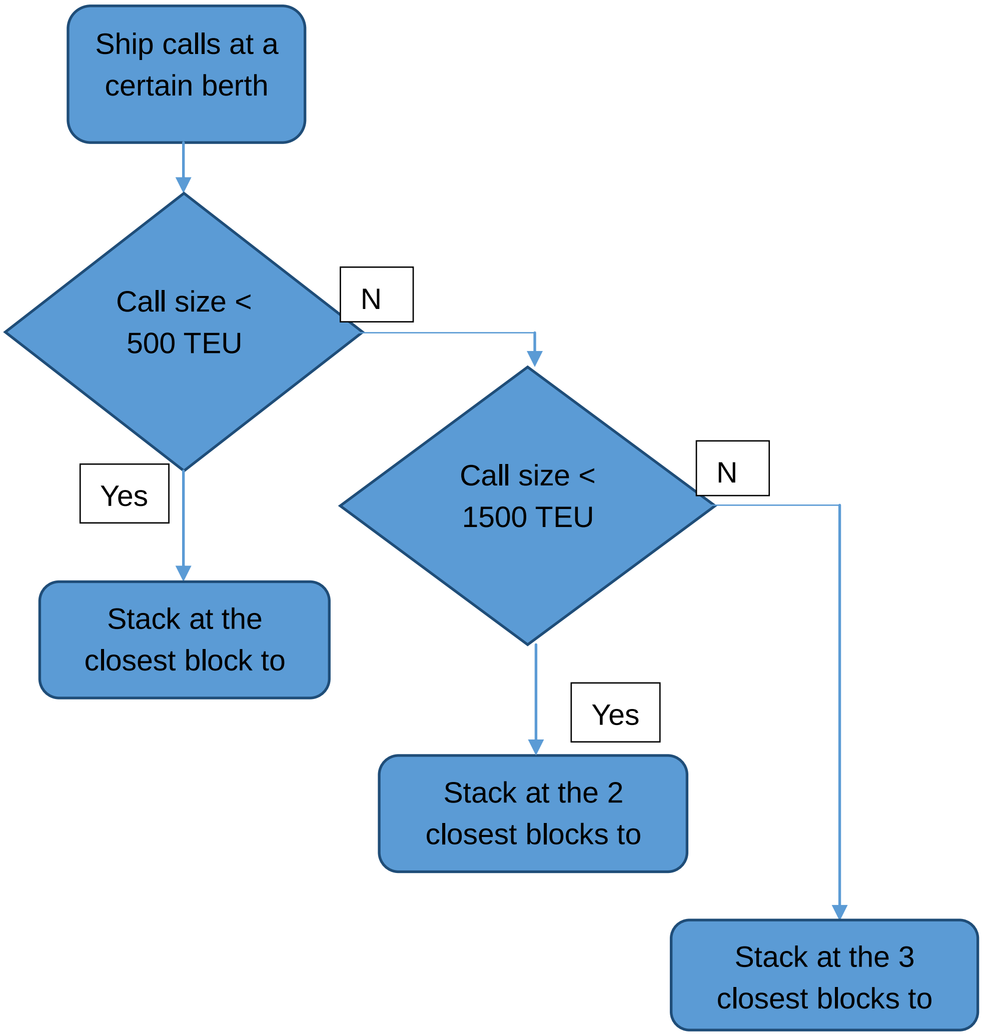


Figure 4-4 The Stacking Strategy
Source: (Sha et al., 2013)

The yard of Shengdong International Container Terminal is the first automated yard in China, where all the yard operations are conducted by remote control system. With the help of the control system YP and TPS, the stack and pickup operations are fully automated, which not only increases the productivity but also assures the safety in the yard area. Because of these automated facilities, a truck spends less than 30 minutes in picking a container up from the yard, which is very productive.

4.3 Conclusion

In the empirical findings chapter, the paper gives the basic knowledge regarding to the study. Combining with the practical situation of Shanghai Port, the author analyzes the impacts of different factors on the throughput of Shanghai Port. Besides the throughput volume, the quay side operation process is also explained in this chapter. Although there may be some small difference between terminals, the basic skeleton is always the same.

Chapter 5 Throughput Forecast at SSICT

5.1 Throughput Estimation with Exponential Smoothing

The Shanghai Shengdong International Container Terminal has started the business since the end of 2005. The detailed throughput volume of the terminal is listed in table 5-1.

Table 5-1 The Throughput of SSICT from 2005 to 2012

SSICT	
year	Throughput (in TEU)
2005	174,034
2006	3,236,000
2007	6,007,697
2008	5,636,998
2009	4,638,234
2010	5,750,330
2011	7,133,342
2012	7,550,082

Source: *China Ports Year Book 2005-2012*

From the table, we can see that the throughput in the first 2 years was incredibly low, because the size of the calling vessel was limited and the work load for the quay was very low in year 2005. In year 2006, the terminal operated while the second phrase project was under construction. The whole construction did not finish until the end of 2006. After 2 years' test operation, the terminal started a formal operation in year 2007. Because of the test operation, the throughput data of the first 2 years cannot reflect a real productivity of SSICT. The author makes the estimation based on the data from second half year of 2007. To make the forecast more accurate, the paper chooses the throughput volume in a half year time span. From the table, we find an increasing tendency of the throughput after year 2008.

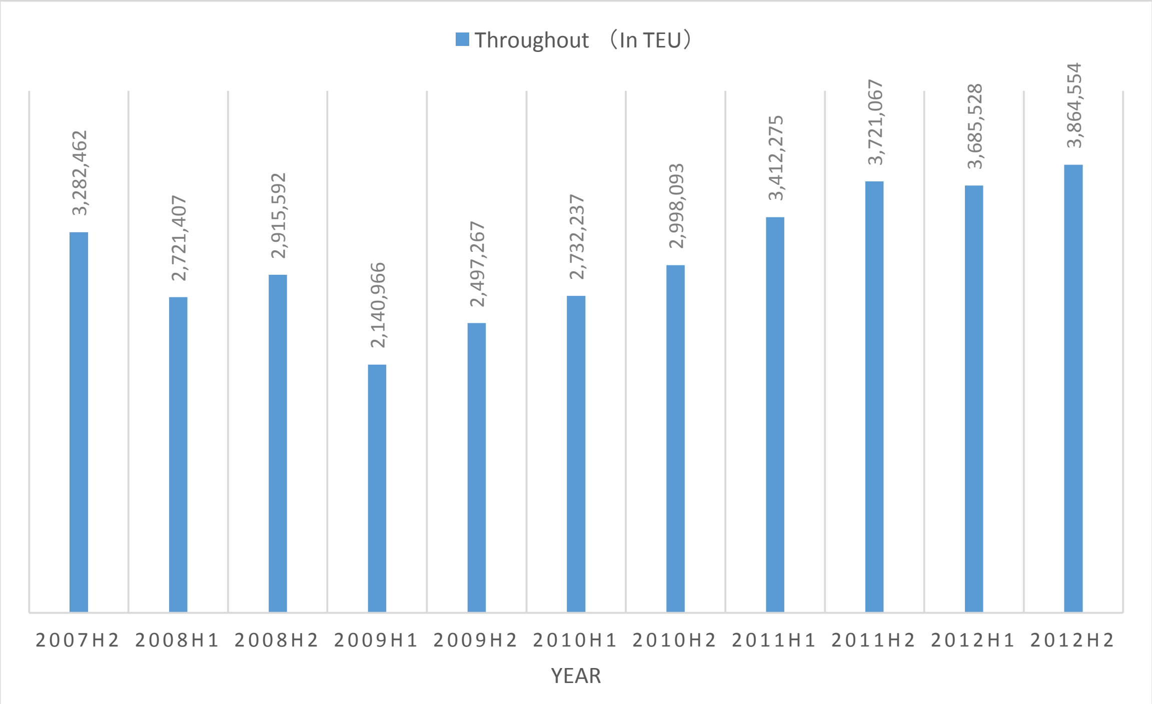


Figure 5-1 The Throughput of SSICT from year 2008
Source: *China Ports Year Book 2008-2012 and Containerization*

Since the throughput gradually increases and there is no evident seasonal variation in the half year throughput volume, Holt's exponential smoothing is a feasible method to analyze the data and produce an estimation.

The smoothing formula is given by:

$$\begin{cases} S_{t+1} = \alpha * y_{t+1} + (1-\alpha)(S_t + T_t) \\ T_{t+1} = \beta * (S_{t+1} - S_t) + (1-\beta)T_{t+1} \end{cases}$$

Where:

S_t= the estimated level for time period t

y_t= time series at time period t, t⩾0

T_t= the estimated trend for time period t

α= smoothing constant for the level, $0 < \alpha < 1$

β= smoothing constant for the trend, $0 < \beta < 1$

We use the following formula to estimate the throughput in period t.

$$F_{t+n} = S_t + nT_t$$

Where:

F_{t+n} = the forecast value for the period (t + n)

S_t = the estimated level for time period t

T_t = the estimated trend for time period t

n = forecast period

Firstly, the paper uses the linear regression model to calculate the initial level (S_0) and the initial trend (T_0). The regression model is established by

$$\mathrm{y} = \mathrm{ax} + \mathrm{b}$$

Where:

x = the independent variable x=0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

y = the throughput from second half year of 2007 to second half year of 2012

Excel is used to process the regression analysis. The data in the regression analysis are selected from second half year of 2007 to second half year of 2012, and the regression result is given by

$$\mathrm{y} = 111{,}153\mathrm{x} + 2{,}532{,}549$$

According to the Holt's model's definition, the initial level (S_0) takes the intercept coefficient 2,532,549 and the initial trend (T_0) takes the slope value 111,153.

After the initialization, the paper uses *Table* function to select the level smoothing constant α and trend smoothing constant β. The initial value for variable α and β are 0.01, and the step size of α and β are 0.01. Hence, the *Table* produces 10,000 forecast results of 10,000 combinations of α and β. SSE of all the results will be tested. Then, the α and β which produce the smallest SSE will be chosen to forecast the throughput.

The paper uses Excel to test the SSE of all the 10,000 combinations, part of the SSE calculation results with different α or β are given by the following table.

Table 5-2 The SSE of Holt's Model (in 1,000,000,000)

		α						
		0.5	0.6	0.7	0.79	0.8	0.9	1
	0.01	1,090	1,056	1,036	1,029	1,029	1,038	1,063
	0.1	1,183	1,141	1,116	1,107	1,108	1,119	1,151
	0.2	1,267	1,220	1,194	1,187	1,187	1,204	1,246
	0.3	1,340	1,294	1,268	1,263	1,264	1,288	1,345
	0.4	1,410	1,366	1,341	1,338	1,340	1,374	1,450
β	0.5	1,483	1,439	1,411	1,411	1,414	1,461	1,564
	0.6	1,559	1,509	1,476	1,481	1,485	1,553	1,690
	0.7	1,634	1,573	1,536	1,550	1,556	1,651	1,835
	0.8	1,705	1,628	1,590	1,621	1,629	1,762	2,003
	0.9	1,767	1,674	1,642	1,696	1,708	1,888	2,201
	1	1,819	1,712	1,694	1,781	1,797	2,035	2,437

Source: Compiled by the author

From the table, we can see that the smallest SSE equals 1,029,668,176,285 with α = 0.79 and β =0.01. Hence, the exponential smoothing model and the forecast formula are given by

$$\begin{cases} S_{t+1} = 0.79 * y_{t+1} + 0.21 * (S_t + T_t) \\ T_{t+1} = 0.01 * (S_{t+1} - S_t) + 0.99T_{t+1} \end{cases}$$

$$F_{t+n} = S_t + nT_t$$

The initial value for t is 0, and the exponential smoothing forecast result is summarized in the following table.

Table 5-3 The Estimation with α = 0.79 and β =0.01

Year	Half year	Throughput	t	S(t)	T(t)	Estimation
2007	2	3,282,462	0	2,532,549	111,153	
2008	1	2,721,407	1	2,705,089	111,767	2,643,702
	2	2,915,592	2	2,894,857	112,547	2,816,855
2009	1	2,140,966	3	2,322,918	105,702	3,007,404
	2	2,497,267	4	2,482,851	106,244	2,428,620
2010	1	2,732,237	5	2,702,177	107,375	2,589,095
	2	2,998,093	6	2,958,499	108,865	2,809,552
2011	1	3,412,275	7	3,339,843	111,589	3,067,364
	2	3,721,067	8	3,664,444	113,719	3,451,433
2012	1	3,685,528	9	3,704,981	112,988	3,778,163
	2	3,864,554	10	3,854,771	113,356	3,817,969

Source: Compiled by author

5.2 Throughput Forecast with GM (1, 1) model

In the previous section, the exponential smoothing estimates the throughput from 2008 to 2012. To make the GM estimation consistent with the Holt's model, we select the throughput volume from year 2008 and the time span of the throughput volume is also a half year.

Let the original sequence as the following table shows

Table 5-4The Initial Sequence of the Raw Data

$\boldsymbol{x^0(1)}$	$\boldsymbol{x^0(2)}$	$\boldsymbol{x^0(3)}$	$\boldsymbol{x^0(4)}$	$\boldsymbol{x^0(5)}$
2,721,407	2,915,592	2,140,966	2,497,267	2,732,237
$\boldsymbol{x^0 6}$	$\boldsymbol{x^0(7)}$	$\boldsymbol{x^0(8)}$	$\boldsymbol{x^0(9)}$	$\boldsymbol{x^0(10)}$
2,998,093	2,998,093	3,412,275	3,721,067	3,685,528

Source: Compiled by the author

The 1-AGO is calculated by the formula given by

$$x^1(t) = \sum_{n=1}^{t} x^0(n)$$

Put the $x^0(n)$ into the formula and then, the 1-AGO is given by

Table 5-5 The 1-AGO of the Raw Data

$x^1(1)$	$x^1(2)$	$x^1(3)$	$x^1(4)$	$x^1(5)$
2,721,407	5,636,998.50	7,777,965	10,275,231	13,007,469
$x^1(6)$	$x^1(7)$	$x^1(8)$	$x^1(9)$	$x^1(10)$
16,005,561	19,417,836	23,138,903	26,824,431	30,688,985

Source: Complied by the author

Let matrix B= $\begin{bmatrix} -\frac{1}{2} * (x^1(2) + x^1(1)) & 1 \\ -\frac{1}{2} * (x^1(3) + x^1(2)) & 1 \\ \vdots & \vdots \\ -\frac{1}{2} * (x^1(10) + x^1(9)) & 1 \end{bmatrix}$.

Put X^1 into matrix B, and we get the matrix B as follows.

$$B = \begin{bmatrix} -4{,}179{,}203 & 1 \\ -6{,}707{,}482 & 1 \\ -9{,}026{,}598 & 1 \\ -11{,}641{,}350 & 1 \\ -14{,}506{,}515 & 1 \\ -17{,}711{,}698 & 1 \\ -21{,}278{,}369 & 1 \\ -24{,}981{,}667 & 1 \\ -28{,}756{,}708 & 1 \end{bmatrix}$$

Let B^T equals to the transpose of matrix.

Let y equals to the transpose of matrix of raw data sequence starting from t=2.

$$y = (X^0(2), X^0(3), \dots, X^0(10))^T = \begin{bmatrix} 2{,}915{,}592 \\ 2{,}140{,}966 \\ 2{,}497{,}267 \\ 2{,}732{,}237 \\ 2{,}998{,}093 \\ 3{,}412{,}275 \\ 3{,}721{,}067 \\ 3{,}685{,}528 \\ 3{,}864{,}554 \end{bmatrix}$$

The least-square estimation of the equation set is given by:

$$\hat{U} = \begin{bmatrix} \hat{a} \\ u \end{bmatrix} = (B^T B)^{-1} B^T y = \begin{bmatrix} -0.063 \\ 2{,}130{,}934 \end{bmatrix}$$

Hence the parameter a= -0.063 and parameter u= 2,130,934.

The fraction $\frac{u}{a}$ is given by

$$\frac{u}{a} = \frac{2{,}130{,}934}{-0.063} = -33{,}649{,}528$$

Substitute -0.063 for parameter a, – 33,649,528 for parameter $\frac{u}{a}$ and 2,721,407 for $x^1(1)$ in the time response equation which is given by

$$\begin{cases} x^1(t) = \left[x^1(1) - \frac{u}{a}\right] e^{-a(t-1)} + \frac{u}{a} \ (\text{t} \geq 2) \\ x^1(1) = 2{,}721{,}407 \end{cases}$$

The estimation equation is given by

$$\widehat{X^1}(t) = 36{,}370{,}934 * e^{0.063(t-1)} - 33{,}649{,}528 \quad (\text{t} \geq 2)$$

We can calculate the estimated 1-AGO $\widehat{X^1}\left\{\widehat{x^1}(1), \widehat{x^1}(2), \widehat{x^1}(3) \ldots \widehat{x^1}(10)\right\}$ from the formula above. In this case the 1-AGO is given by

Table 5-6 The Estimation of the 1-AGO

$\widehat{x^1}(1)$	$\widehat{x^1}(2)$	$\widehat{x^1}(3)$	$\widehat{x^1}(4)$	$\widehat{x^1}(5)$
2,721,407	5,098,920	7,631,848	10,330,349	13,205,247
$\widehat{x^1}(6)$	$\widehat{x^1}(7)$	$\widehat{x^1}(8)$	$\widehat{x^1}(9)$	$\widehat{x^1}(10)$
16,268,074	19,531,112	23,007,450	26,711,032	30,656,711

Source: Compiled by the author

Finally, an inverse calculation is applied to calculate the forecast values from the 1-AGO. Hence, the forecast values are calculated by the formula

$$\widehat{x^0}(t+1) = \widehat{x^1}(t+1) - \widehat{x^1}(t)$$

The estimation results of the GM (1, 1) model are summarized in the following table.

Table 5-7 The Estimation of GM (1, 1) (in TEU)

Year	Half year	Throughput	Estimation	t
2008	1	2,721,407	2,721,407	1
	2	2,915,592	2,377,513	2
2009	1	2,140,966	2,532,928	3
	2	2,497,267	2,698,501	4
2010	1	2,732,237	2,874,898	5
	2	2,998,093	3,062,826	6
2011	1	3,412,275	3,263,038	7
	2	3,721,067	3,476,338	8
2012	1	3,685,528	3,703,581	9
	2	3,864,554	3,945,679	10

Source: Compiled by the author

5.3 A Comparison between the 2 Forecast Approaches

The paper forecasts the throughput from 2008 to 2012 by Holt's exponential forecast model and GM (1, 1) model respectively. To decide which model describes the throughput fluctuation better, the SSE and MAD for the 2 forecast models are calculated and compared

Table 5-8 The Comparison between the 2 Forecast Models

			Holt's Model		GM (1, 1) Model	
year	**Half year**	**Throughput**	**Estimation**	**Residual**	**Estimation**	**Residual**
2008	**1st half year**	2,721,407	2,643,702	77,705	2,721,407	0
	2nd half year	2,915,592	2,816,855	98,736	2,377,513	538,079
2009	**1st half year**	2,140,966	3,007,404	-866,438	2,532,928	-391,962
	2nd half year	2,497,267	2,428,620	68,647	2,698,501	-201,234
2010	**1st half year**	2,732,237	2,589,095	143,142	2,874,898	-142,661
	2nd half year	2,998,093	2,809,552	188,540	3,062,826	-64,734
2011	**1st half year**	3,412,275	3,067,364	344,911	3,263,038	149,237
	2nd half year	3,721,067	3,451,433	269,634	3,476,338	244,729
2012	**1st half year**	3,685,528	3,778,163	-92,635	3,703,581	-18,053
	2nd half year	3,864,554	3,817,969	46,585	3,945,679	-81,125
MAD			219,697		183,181	
SSE			1,029,668,176,285		597,271,469,480	

Source: Compiled by the author

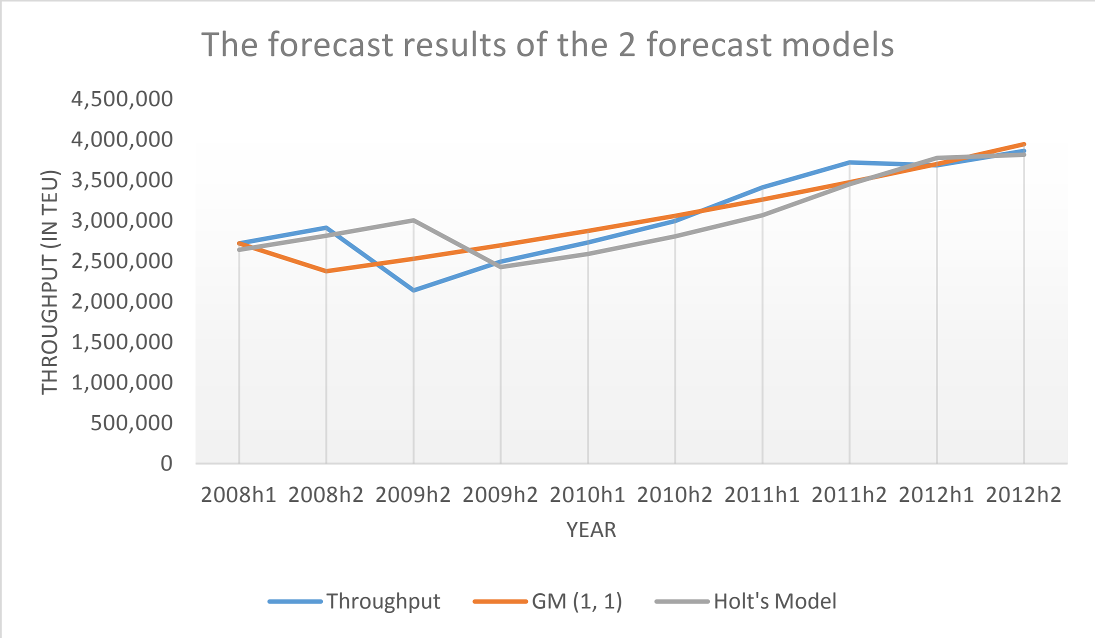


Figure 5-2 The Comparison between the Forecast Results of the 2 Forecast Models
Source: Compiled by the author

The line charter above gives a visualized comparison between the estimations of the Holt's Model (grey line), the GM (1, 1) Model (red line) and the raw data (blue line). It is obvious that the GM (1, 1) model performs a more accurate estimation than exponential smoothing model. In the figure 5-2, we can see that the Holt's model lags behind the real data at least three times (in the second half year of 2009, the first half year of 2011 and the first half year of 2012). By introducing the 1-AGO, the GM (1, 1) model performs a better smooth effect. As a result the red line fits the develop tendency of throughput better. Except for the dump in the second half year of 2008, there is no big fluctuations in the red line.

To give a quantitative analysis on the forecast accuracy, the paper introduces the SSE and MAD to measure the accuracy of the 2 forecast models. From the table, we can see that the SSE for exponential model is 1,029,668 $*10^6$ while the SSE for GM (1, 1) model is 597,271$*10^6$. From the MAD perspective, the MAD of exponential model is 219,697 while the MAD of GM (1, 1) model is 183,181. By comparing the MAS and SSE, we can find that the GM (1, 1) fits the trends better than the exponential smoothing model. The exponential fluctuates up and down severely, so it is not applicable in this case.

There are 2 reasons can explain why GM (1, 1) fits the tendency better. Exponential smoothing performs well in an upward tendency, however, the throughput does not keep increasing after 2008.Because the financial crisis hit the world in year 2009, the throughput of that year dropped a lot. It is the dropped that tortures the trend, so the exponential smoothing forecast cannot describe the trend well. Although the whole development tendency is increase, the drop in 2009 decreases the forecast accuracy of exponential forecast. Secondly, the sample is very small, so the exponential tendency is weak in such a short period. As a result, the exponential smoothing forecast result is distorted.

However, GM (1, 1) model produces a more accurate estimation in a small sample scenario. The GM (1, 1) model adopts the first stage Accumulated Generating Operation which smoothes the dump in 2009. As a result, GM performs a better tendency estimation than the exponential smoothing forecast. Deng (2000) gave the threshold values for development coefficient a. In his research, Deng drew the conclusion that if (-a) was less than 0.3, GM (1, 1) model has a satisfactory forecast accuracy, which can be used in a long run forecast. From the development coefficient perspective, we believe that the GM (1, 1) model fits the sample well because the development coefficient $-a = 0.063$ which performs a satisfactory forecast accuracy in this case.

5.4 Throughput Forecast

After the comparison of the estimation result, the author takes GM (1, 1) as the forecast model to forecast the throughput in the following 3 years. The forecast model is given by

$$\begin{cases} x^1(t) = 36{,}370{,}934 * e^{0.063(t-1)} - 33{,}649{,}528 \\ x^o(t) = x^1(t) - x^1(t-1) \end{cases}$$

Where
t = the time series, t starts from year 2007. (t≥ 2)

Substitute t by 11, 12, 13 … 16, and calculate the 1-AGO of the $x^1(t)$, Then, use inverse calculation to work out the forecast $x^o(t)$

Just take the throughput of the first half year of 2013 as an example. The throughput is given by

$$\begin{cases} x^1(11) = 36{,}370{,}934 * e^{0.063*10} - 33{,}649{,}528 = 34{,}860{,}313 \\ x^o(11) = x^1(11) - x^1(10) = 34{,}860{,}313 - 30{,}656{,}711 = 4{,}203{,}602 \end{cases}$$

The throughput in 2013 to 2015 can be done in the same way. The forecast results are summarized in the following table.

Table 5-9 The Forecast of the Throughput from Year 2013 to 2015 (in TEU)

Year	Half year	Throughput Forecast $x^o(t)$	Yearly Throughput	t
2013	1st half year	4,203,602	8,81,987	11
	2nd half year	4,478,385		12
2014	1st half year	4,771,130	9,854,143	13
	2nd half year	5,083,012		14
2015	1st half year	5,415,281	11,184,551	15
	2nd half year	5,769,270		16

Source: Compiled by the author

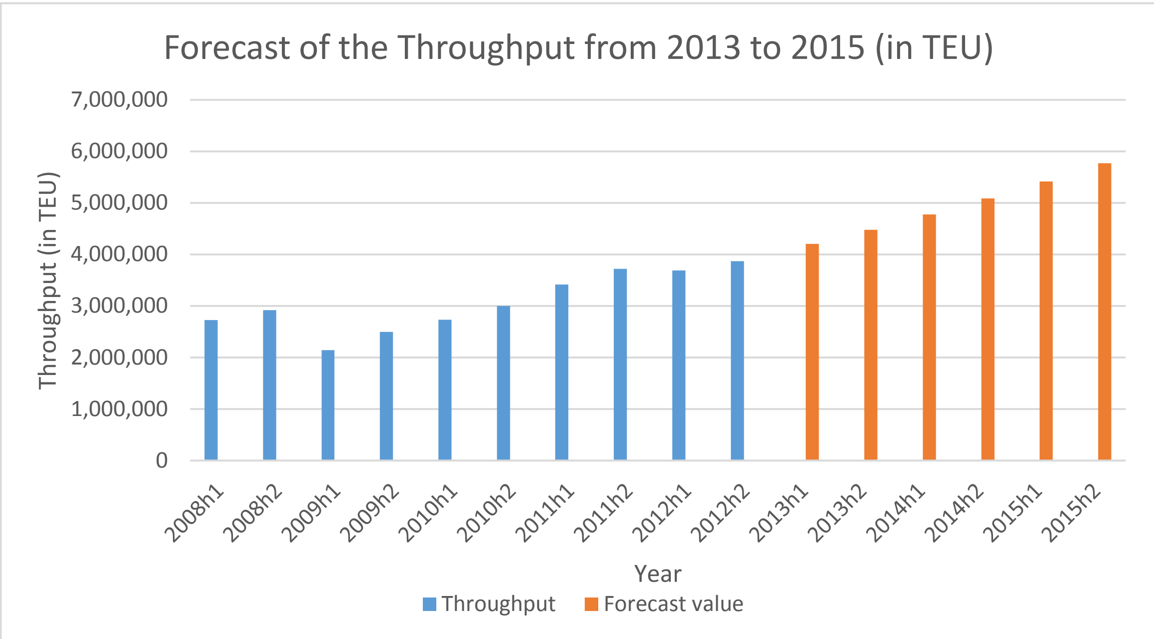


Figure 5-3 Forecast of the Throughput from Year 2013 to 2015 (in TEU)
Source: Compiled by author

5.5 The Interpretation of the Throughput in Shanghai Port

The charter below is a visualized display of the throughput of the 6 main container ports, which are owned by Shanghai International Port Group, from year 2003 to year 2012. In the charter, we can see Shanghai Shengdong International Container Terminal dominates the largest market share among the 6 container terminals.

Except the year 2008 and 2009, the throughput in Shanghai Shengdong International Container Terminal (the dark blue line) shows a strong momentum in growth, however, the SSICT (the light blue line) and SECT (the grey line) seem to start losing market share. Because we cannot find an obvious upward trend or downward trend in the throughput, the throughput of ZCT (the red line) and SMCT (the yellow line) turns to a stable tendency after year 2007. The SGCT (the green line) is the newest container terminal, which is located Yangshan Island. The SGCT did not start business until 2008, so there is a strong growth momentum in recent years. After the analyses, we can divide all the 6 main container terminals into 3 groups. The first group consists of CZT and SMCT, the throughput of which seems to stabilize in the future. The second group includes SECT and PICT. From the charter, there is a downwards slop in the in the throughput of these 2 container terminals. The SSICT and SGICT belong to the third group, which are the 2 newest container terminal in Shanghai. These 2 container terminals operate 16 berths, and account roughly 44% market share of Shanghai Port container operation. The charter demonstrates an upward trend in the throughput of these two terminals.

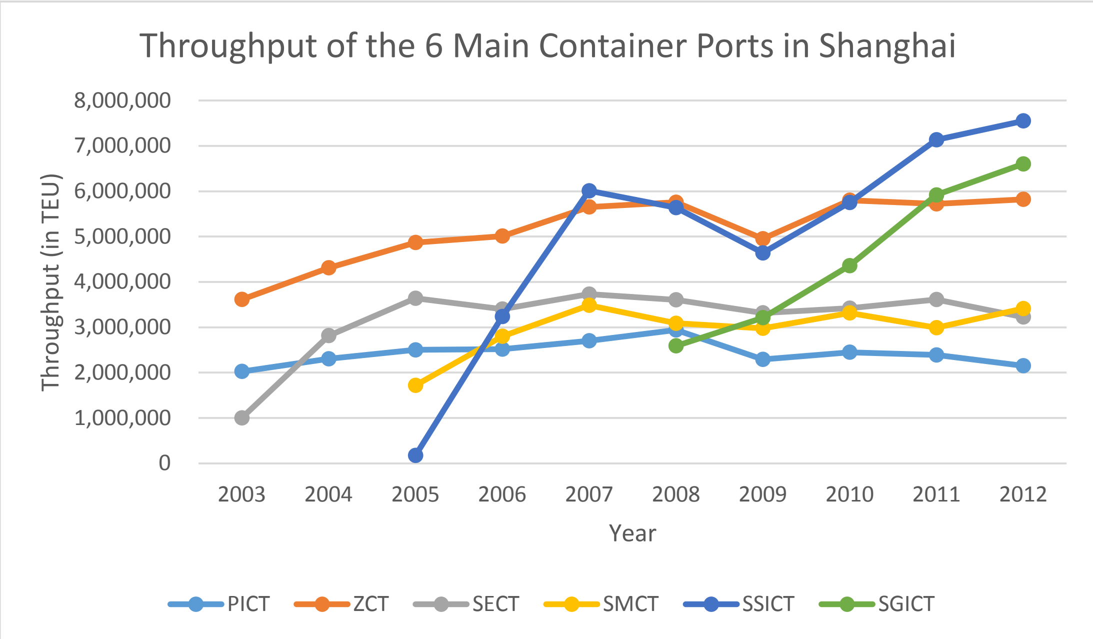


Figure 5-4 Throughput of the 6 Main Container Ports in Shanghai
Source: Compiled by the author

To give a further analysis on the Shanghai container terminal market, the paper calculates the market share of these 6 main container terminals, and the results are given by the following charter. In year 2012, the 2 container terminals from group 3 accounted roughly 44% share of the whole container market in Shanghai port. Because the continuously increase in the throughput of Shanghai Port, the rest 4 container terminals suffer from losing market shares. Such a shift in the market paradigm results that Shanghai Shengdong International Container Terminal dominates the container market of Shanghai Port. The following graph shows the market changing tendency in Shanghai Port.

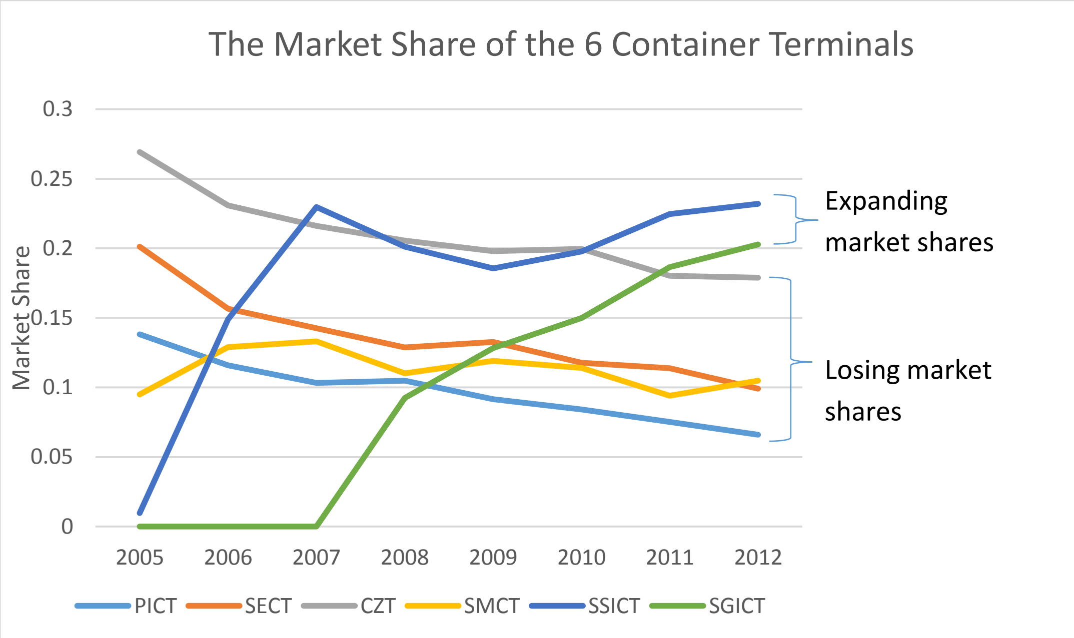


Figure 5-5 The Market Share of the Main 6 Container Terminals
Source: Compiled by author

From the market share perspective, Shanghai Shengdong International Container Terminal is the largest one among the six main container terminals owned by Shanghai International Port Group. In order to study the market share of Shanghai Shengdong International Container Terminal in a quantitative way, the paper performs uses the GM (1, 1) model to forecast the throughput of the whole Shanghai Port in the next 3 years. To keep the sample number identical to the previous GM (1, 1) model, the paper selects the data from the 2nd half of year 2008 to 1st half of year 2013, so there are 10 samples selected.

Let the original sequence as the following table shows

Table 5-10 The Initial Sequence of the Raw Data

$x^0(1)$	$x^0(2)$	$x^0(3)$	$x^0(4)$	$x^0(5)$
14,184,000	11,671,000	13,329,000	13,856,000	15,213,000
$x^0 6$	$x^0(7)$	$x^0(8)$	$x^0(9)$	$x^0(10)$
15,316,000	16,424,000	15,864,000	16,664,000	16,326,000

Source: Compiled by the author

The 1-AGO is calculated by the formula given by

$$x^1(t) = \sum_{n=1}^{t} x^0(n)$$

Put the $x^0(n)$ into the formula and then, the 1-AGO is given by

Table 5-11 The 1-AGO of the Raw Data

$x^1(1)$	$x^1(2)$	$x^1(3)$	$x^1(4)$	$x^1(5)$
14,184,000	25,855,000	39,184,000	53,040,000	68,253,000
$x^1(6)$	$x^1(7)$	$x^1(8)$	$x^1(9)$	$x^1(10)$
83,569,000	99,993,000	115,857,000	132,521,000	148,847,000

Source: Complied by the author

Establish matrix B as follows

$$B=\begin{bmatrix} -25{,}855{,}000 & 1 \\ -39{,}184{,}000 & 1 \\ -53{,}040{,}000 & 1 \\ -68{,}253{,}000 & 1 \\ -83{,}569{,}000 & 1 \\ -99{,}993{,}000 & 1 \\ -115{,}857{,}000 & 1 \\ -132{,}521{,}000 & 1 \\ -148{,}847{,}000 & 1 \end{bmatrix}$$

Let $y = (X^0(2), X^0(3), \ldots, X^0(10))^T = \begin{bmatrix} 11{,}671{,}000 \\ 13{,}329{,}000 \\ 13{,}856{,}000 \\ 15{,}213{,}000 \\ 15{,}316{,}000 \\ 16{,}424{,}000 \\ 15{,}864{,}000 \\ 16{,}664{,}000 \\ 16{,}326{,}000 \end{bmatrix}$

The least-square estimation of the equation set is given by:

$$\widehat{U} = \begin{bmatrix} \hat{a} \\ u \end{bmatrix} = (B^T B)^{-1} B^T y = \begin{bmatrix} -0.036 \\ 12{,}129{,}244 \end{bmatrix}$$

Hence the parameter a= -0.036 and parameter u= $12{,}129{,}244$

The fraction $\frac{u}{a}$ is given by

$$\frac{u}{a} = \frac{12{,}129{,}244}{-0.036} = -332{,}861{,}216$$

Substitute -0.035 for parameter a, 12,129,244 for parameter u and 14,184,000 for $x^1(1)$ in the time response equation, then we get the time response equation given by

$$\begin{cases} x^1(t) = 347{,}045{,}216 * e^{-0.036(t-1)} - 332{,}861{,}216 \quad (\mathrm{t} \geq 2) \\ x^1(1) = 14{,}184{,}000 \\ x^o(t) = x^1(t) - x^1(t-1) \quad (t \geq 2) \end{cases}$$

Where

t = the time series, t starts from the 2nd half year of 2007. (t≥ 2)

Substitute t by 11, 12, 13… 17 and calculate the 1-AGO of the $x^1(t)$. Then adopt the inverse AGO process to calculate the forecast value $x^o(t)$

Here we take the throughput of Shanghai Port in the 2nd half year of 2013 as an example. The throughput of Shanghai Port in 2013 is given by

$$\begin{cases} x^1(7) = 347{,}045{,}216 * e^{-0.055*6} - 4332{,}861{,}216 = 166{,}740{,}266 \\ x^o(7) = x^1(7) - x^1(6) = 166{,}740{,}266 - 148{,}864{,}635 = 17{,}236{,}045 \end{cases}$$

The throughput in the next 3 years can be done in the same way. The forecast results are summarized in the following tables.

Table 5-12 The Forecast of the Throughput from Year 2013 to 2015 (in TEU)

Year	Half year	Throughput Forecast $x^o(t)$	Yearly Throughput	t
2013	1st half year	16,326,000	35,111,676	10
	2nd half year	17,875,631		11
2014	1st half year	18,538,951	37,765,835	12
	2nd half year	19,226,885		13
2015	1st half year	19,940,346	40,620,627	14
	2nd half year	20,680,282		15

Source: Compiled by author

After the forecast of the throughput in Shanghai, the paper calculates the market share of SSICT port and summarizes the forecast results and the market share in the table below.

Table 5-13 The Throughput Forecast in SSICT and Shanghai Port (in TEU)

	Year	SSICT	Shanghai Port	Market Share
Raw Data	2006	3,236,000	21,710,000	14.9%
	2007	6,007,697	26,152,000	23.0%
	2008	5,636,998	28,006,000	20.1%
	2009	4,638,234	25,002,000	18.6%
	2010	5,750,330	29,069,000	19.8%
	2011	7,133,342	31,739,000	22.5%
	2012	7,550,082	32,529,000	23.2%
Forecast	2013	8,681,987	35,111,676	24.7%
	2014	9,312,466	37,765,835	24.7%
	2015	11,184,551	40,620,627	27.5%

Source: Compiled by author

The table above demonstrates the history data of the market share and the future forecasts. From the table, we conclude that the throughput of Shanghai Shengdong International Container Port accounts for approximately 1/4 market share of the whole throughput. In 2007, the port reached the peak of the market throughput. In the next year, the world economy slumped down and Shanghai Guandong International Container Terminal also started business. These 2 factors squeezed the market share of Shanghai Shengdong International Container Terminal to 18.6% in year 2009. After year 2009, the shipping industry started to recover from the world financial crisis, so the market share of Shanghai Shengdong International Container Terminal increases again. The upward trend in the forecast is identical to the increasing tendency demonstrated in Figure 5-2. Because the geographic advantage and the efficient berth facilities, these 2 terminals will attract more ocean vessels and become the growth points of the throughput. In the future, the main increment of the throughput of Shanghai port will come from these 2 new terminals. .

5.6 Conclusions

Firstly, the author uses both 2 forecast models to estimate the throughput in Shanghai Port. Because the GM (1, 1) model has a lower MAD and SSE, the author forecasts the throughput in the next 3 years by GM (1, 1) model. Secondly, the author explains why GM (1, 1) produces more accurate forecasts than exponential smoothing model in this case. Finally, an analysis on the increase in throughput of SSICT is given from the market share perspective.

Chapter 6 Berth Throughput Calculation at SSCIT

6.1 Data Selection and Berth Throughput Calculation

Shanghai Shengdong International Container Terminal represents one of the most well developed container terminals among all Chinese container terminals. The terminal is located at the west-south side of Yangshan Island. Among all 9 berths operated by the terminal operator, 1#-6# berths are assigned to the ocean container vessels, which have a relative big call size. 7#-9# berths are smaller than 1#-6# berths, so these berths are assigned to the feeders or inland river container vessels. The call size at 7#-9# berth are smaller. Because of the difference in the call size, the handling volumes of the 2 groups of berths are treated separately. The data the paper used in the berth throughput calculation are explained in the following bullets.

Figure 6-1 The Location of SSICT
Source: Compiled by the author

- Yearly operation days (T_y)

Although the terminal is located on an ocean island, the terminal operator spares no effort to ensure a continuously operation. Since the terminal started business in year 2005, the annual operation days have never been less than 350 days. In this case, the T_y equals 350 days a year (Tian, 2010).

- Berth utilization rate (A_p)

According to the statistic from Shanghai Maritime Safety Administration, the berth utilization rate of Shanghai reached 72% in 2012 (Yang, 2012).

- Productivity of a quay crane (p_1)

In the section 4.1, the author gives an introduction of quay cranes. In theory, the productivity is beyond 50 moves per hour. However, in the practical situation, the operation speed is lower. The weather condition, the skill of the crane driver and the berth-yard controlling system together have an aggregate impact on the quay crane productivity. In this case, the paper takes 37.78 boxes/ hour (Du, 2012) as the quay crane productivity.

- TEU ratio (K_1)

The number of 20 foot container, 40 foot container and 45 foot container handled by Shanghai Shengdong International Container Terminal is summarized in the following table.

Table 6-1 The Structure of the Throughput from 2007 to 2011 1.57

	Input containers (in TEU)			**Output containers (in TEU)**			**TEU ratio**
Year	**20 foot**	**40 foot**	**45 foot**	**20 foot**	**40 foot**	**45 foot**	
2007	433,051	537,837	1,819	793,349	1,087,847	9,536	1.57
2008	408,138	532,195	3,990	690,949	1,023,511	16,837	1.59
2009	381,103	475,992	2,997	542,628	810,386	13,702	1.59
2010	535,370	536,058	1,904	661,072	1,015,308	14,267	1.57
2011	500,365	745,262	4,057	769,385	1,272,831	19,487	1.62

Source: China Ports Year Book 2008-2012

Takes year 2011 as an example, the input of 20 foot full container was 500,365 and the output is 769,385 in 2011. Because the majority of vessels calling at the terminal are ocean liners from West-Asia route, the throughput of 40 foot full container was more than 20 foot full container. In 2011, the input of 40 foot container was 745,262, and the output was 1,272,831. TEU ratio in 2012 is calculated by the formula given by

$$\text{TEU ratio} = \frac{20\ feet\ container + 2 *\ 40\ feet\ container + 2.25 * 45\ feet\ container}{feet\ container + 40\ feet\ container + 45\ feet\ container}$$

Hence, the TEU ratio of Shanghai Shengdong International Container Terminal equals

$$TEU\ Ratio = \frac{(500{,}365 + 769{,}385) + 2 * (745{,}262 + 1{,}272{,}831) + 2.25 * (4{,}057 + 19{,}487)}{500{,}365 + 769{,}385 + 745{,}262 + 1{,}272{,}831 + 4{,}057 + 19{,}487}$$

$$= 1.61$$

The paper takes the average TEU ratio of the past 5 years to calculate the berth throughput volume, so the average TEU ratio is 1.59.

- Number of quay cranes assigned to a vessel (n)

The most ocean liners are assigned to berth 1#-6# berth, because the draft of 1#-6# is deeper than 7#-9#. Regarding to the ship size, the ocean liners calling at the terminal are 5th and 6th generation container vessels from Asia-West route and Asia-America route are dominant. The LOA of these vessels ranges from 300 to 400m and the average number of quay cranes assigned to an ocean liners is 5. Because the LOA of in-land river vessels or feeder vessels is smaller than the ocean liners, less quay cranes can be assigned to the in-land river vessels. In average, 2.5 quay cranes operate an in-land river vessel or a feeder vessel.

- Reshuffling rate (K_2)

The reshuffling rate takes 0.05 to the ocean liners and 0.03 to the inland river vessel and feeder vessels. Hence, the practical number of boxes per minute equals $p_1 * (1 - K_2)$, for the berth 1#-6#, the productivity is 37.6 boxes per hour which is roughly identical to the number 37.78 boxes per hour (Du, 2012*)*

- Productivity for a vessel in an hour (p)

Productivity for a vessel is given by

$$P = n * p_1 * K_1 * (1 - K_2)$$

Where

p_1= Productivity of a quay crane

n =Number of quay cranes assigned to a vessel

K_1= TEU ratio

K_2= Reshuffling rate

Regarding the berth 1#-6#, the productivity for a vessel is calculated by

$$P_{1-6} = n * p_1 * K_1 * (1 - K_2) = 5 * 37.78 * 1.59 * (1 - 0.06) \approx 282\ \mathrm{TEU/h \cdot vessel}$$

Regarding the berth 7#-9#, the productivity for a vessel is calculated by

$$P_{7-9} = n * p_1 * K_1 * (1 - K_2) = 2.5 * 37.78 * 1.59 * (1 - 0.04) \approx 144\ \mathrm{TEU/h \cdot vessel}$$

- Call size of the vessel (Q)

The 5th and 6th generation container vessels can bring 8,000 and 13,600 TEU on board in maximum respectively. The container capacity for the inland river vessel and the feeder is less than 4000 TEU. The call size for 1#-6# and 7#-9# equal 3200 TEU and 1500 TEU respectively (Sheng, 2013).

- Quay crane operation time (t_g)

The quay crane operation time takes 22.5 hours a day for all the berths.

- Non-productive time (t_f)

The pilot and mooring equals 2.5 hours for the big vessel and 1.5 hours for the feeders. Then, the preparation for the quay crane is 0.5 hours, during which, the customs finish the inspection. The average time for unmooring and leaving the berth is 1 hour. Hence, t_f equals 4 hours for an ocean liner and 3 hours for a feeder.

- The number of hours in a day (t_d)

  t_d equals 24 hours a day

All of the parameter included in the calculation of throughput capacity is summarized in the following table. ·

Table 6-2 The Parameter of the Berth Handling Volume

Term	Notation	Berth 1#-6#	Berth 7#-9#
The yearly operation days	T_y	350	350
Berth utilization rate (in %)	A_p	0.72	0.72
Productivity of a quay crane (in boxes /hour)	p_1	37.78	37.78
Number of quay cranes assigned to a vessel	n	5	2.5
TEU ratio	K_1	1.59	1.59
Reshuffling rate (in %)	K_2	0.06	0.04
Vessel hour productivity (in TEU/hour·vessel)	p	282	144
Call size of the vessel (in TEU)	Q	3200	1500
Quay crane operation time (in hours)	t_g	22.5	22.5
Non-productive time (in hours)	t_f	4	3
The number of hours in a day	t_d	24	24

Source: Compiled by author

The paper calculates the throughput capacity for the 2 groups of berth separately, and then, the whole throughput capacity is the sum of the 2 groups.

The throughput volume for the 1#-6# berth is given by

$$P_{1-6} = 6 * P_t = 6 * \frac{T_y * A_p}{\frac{Q}{P * t_g} + \frac{t_f}{t_d}} * Q = 6 * \frac{350 * 0.72}{\frac{3200}{282 * 22.5} + \frac{4}{24}} * 3200 = 7{,}217{,}061 TEU$$

The throughput volume for the 7#-9# berth is given by

$$P_{7-9} = 3 * P_t = 3 * \frac{T_y * A_p}{\frac{Q}{P * t_g} + \frac{t_f}{t_d}} * Q = 6 * \frac{350 * 0.72}{\frac{1500}{144 * 22.5} + \frac{3}{24}} * 1500 = 1{,}930{,}469\ TEU$$

Hence, the whole throughput volume for Shanghai Shengdong International Container Terminal is given by

$$P_{1-9} = P_{1-6} + P_{7-9} = 7{,}217{,}061 + 1{,}930469 = 9{,}147{,}530\ TEU$$

6.2 Interpretations and Re-thinkings

After the calculation, the current berth throughput volume for Shanghai Shengdong International Container Terminal is 9.15 million TEU. Comparing with the throughput forecast in section 5.4, the author concludes the port productivity will reach it's up level limitation in 2 years. How to increase the throughput capacity of the terminal is a question that is discussed in following sections

6.2.1 The Efficiency of the Quay Crane

According to the statistics from *China Ports Year Book 2012,* the moves per hour for the quay cranes in Shanghai Shengdong International Container Terminal is 37.78. Although this is very efficient from the perspective of crane operation, the highest average productivity is 39.60 boxes per hour in QingDao Qianwan Container Terminal. Even compared with SSICT itself, the terminal performed a 97 boxes/ hour productivity in the past. Hence, it is reasonable to believe the quay productivity can increase further. These 2 terminals are similar in many ways and the detailed information is given by the table below.

Table 6-3 The Detailed Information about SSICT and QQCT

Terminal		**SSICT**	**QQCT**
Quay length (in m)		3000	3400
Draft (in m)		34	39
Number of quay cranes	**Double 20 foot crane**	21	37
	Double 40 foot crane	13	2
Quay crane productivity (boxes/ hour)		37.78	39.60
TEU ratio		1.59	1.52
Quay crane productivity (boxes/ hour)		59.9	60.1

Source: Compiled by the author based on the official data on the company report

Comparing these 2 terminals, the paper finds that QQCT has a higher quay crane density and less double 40 foot cranes than SSICT, however, the quay cranes at QQCT perform better than the quay cranes at SSICT. Although the quay crane productivity of QQCT is only a little bit higher than SSICT, QQCT does not have an advantage in the handling equipment. SSICT has 11 more double 40 foot container quay cranes than QQCT. Considering the equipment advantages and the low quay crane density at SSICT, the paper concludes that SSICT should be more productive at the quay side. If SSICT optimizes the product process, the quay crane productivity can be increased further.

6.2.2 The Number of the Quay Cranes

The number of the quay cranes is also a very important factor which has a big impact on the berth capacity. Because the number of quay cranes which are assigned to a container vessel depends on the following 3 factors: the stowage plane of the vessel, the length of the vessel and the number of quay crane available. Now days, the shipping liners have recognized the importance of the berth productivity, so they store the containers on board in an evenly separated way. Such stowage plans allow terminal operators to assign more quay cranes to a vessel simultaneously. Secondly, the length of the vessel also affects the number of quay cranes assigned to a vessel. In theory, the 5^{th} and 6^{th} container vessels can be assigned 7-10 cranes for loading and unloading simultaneously. Because terminals do not have enough quay cranes available at the quay side, the number of quay cranes assigned to a 5^{th} or 6^{th} generation vessel is 3-5 in the practical situation. The number of quay cranes limits the vessel productivity. More quay cranes means a higher quay cranes availability to a vessel. Although a high quay crane density brings difficulties in quay side controlling and dispatching, the increase in vessel productivity will bring benefits to the operators. The paper introduces the quay crane density to describe the number of quay crane per 100-meter. Shanghai Shengdong International Container Terminal has a 3 km meter quay wall and 34 quay cranes at the quay side. Hence, the number of quay cranes per 100 meter is 1.13 unit. Although 1.13 quay crane per 100-meter is a high density in the mainland of China, many international container terminals have a higher quay crane density. The paper collects the data from the world famous terminal operators such as PSA and DP world and summarizes the quay length and the number of quay cranes in the following table.

Table 6-4 The Quay Crane Density

Terminal	Quay crane number	Quay length (in meter)	Quay crane Density (in units/meter)
Shanghai Shengdong International Container Terminal	34	3,000	1.13
Qingdao Qianwan Container Terminal	39	3400	1.14
Keppel Container Terminal	39	3,200	1.22
Tanjong Pagar Container Terminal	27	2,300	1.17
HIT Terminal 4, 6, 7	39	2,987	1.31
Brani Container Terminal	32	2,600	1.23

Source: Compiled by author based on the official website of QQCT, PSA and HIT

Comparing with the port of PSA and DP world, we can see that Shanghai Shengdong International Container Terminal still has some room to put 1 or 2 additional quay cranes at the quay side. On the perspective of throughput per meter at the quay side and the throughput per quay crane, Shanghai Shengdong International Container Terminal also falls behind the first world class terminals. The author compares the throughput volume, quay length and the number of quay cranes of Hongkong HIT terminal and Shanghai Shengdong International Container Terminal. The figures are summarized in the following table.

Table 6-5 The Productivity of the Quay Cranes

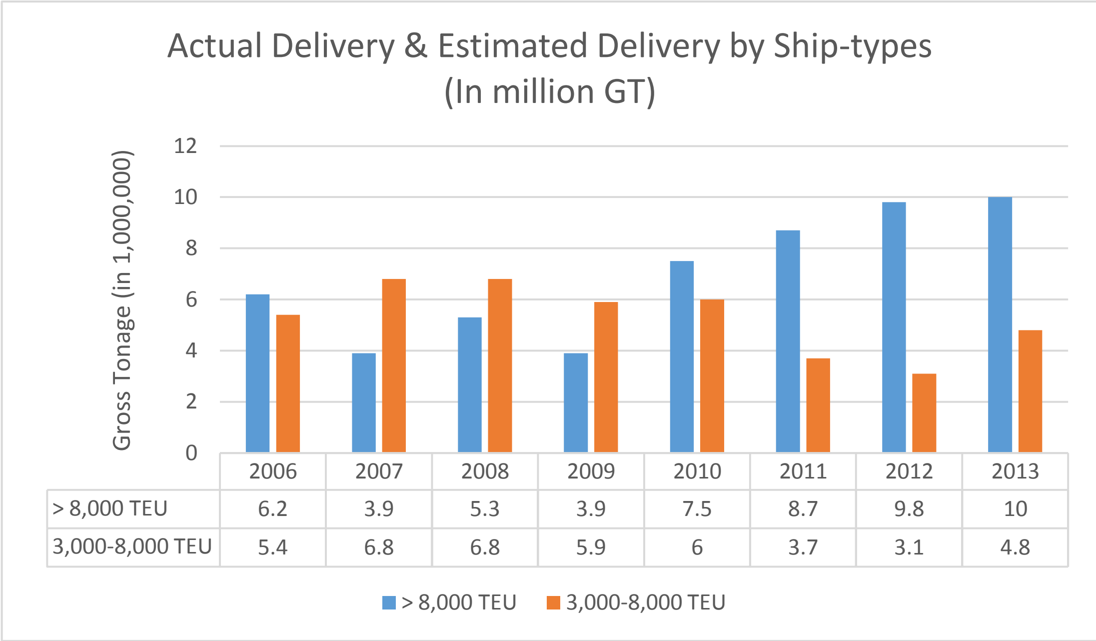
Terminal	Shanghai SSICT terminal	Hongkong HIT termial
Quay length (in m)	3,000	5,076
Number of quay crane	34	65
Throughput in 2012 (in TEU)	7,550,082	17,475,000
Throughput per meter (in TEU/M)	2,517	3,443
Throughput per quay crane (in TEU/ Unit)	222,061	268,846

Source: compiled by the author based on the HIT and SSICT official report.

Hong Kong HIT Terminal has more quay cranes in a limited space than SSICT, however, the terminal still operates smoothly and efficiently. The high quay cranes density produces a high quay crane productivity. Hence, adding additional quay cranes at the quay berth is a probably solution to increase the berth throughput volume of SSICT.

6.2.3 The Ship Size and Call Size

Now days, because of the economic scale and fuel efficiency (Wijnolst and Wergeland, 1999), the ship yards build more and more jumbo vessels which can carry more than 8,000 TEU on board. For example, among all the 198 container vessels owned by Maersk, 58 of them have a carrying capacity over 8,000 TEU (A.P. Moller Maersk Group 2013). The percentage of the 6^{th} container vessels counts roughly 30%. In 2013, Maersk even launched the biggest container vessel, the triple E on 2^{nd} July. From the observation, we can conclude that the 6^{th} or even higher generation vessels are quite attractive to the shipping companies by the cost advantage in the long run. According to the forecast from World Shipyard Monitor (The shipbuilders’ Association of Japan 2013), the DWT of the jumbo vessels to be launched in 2013 will reach 100 million ton, which reaches a peak in the past ten years.



	2006	2007	2008	2009	2010	2011	2012	2013
> 8,000 TEU	6.2	3.9	5.3	3.9	7.5	8.7	9.8	10
3,000-8,000 TEU	5.4	6.8	6.8	5.9	6	3.7	3.1	4.8

Figure 6-2 Actual Delivery & Estimated Delivery by Ship-types
Source: The shipbuilders' Association of Japan (2013)

The increasing vessel size is an irreversible trend in the short term. Because the call size relates to the ship size, a big container vessel usually brings more container to container terminals. Besides the call size itself, the increasing vessel size also has other influences on the berth operation. The big LOA[1] makes it possible for the terminal operator to assign more quay cranes simultaneously to handle the vessel. The market share of a terminal also determines the call size (Bottema, 2013). The higher market share that a terminal occupies, the bigger the call size is. In the figure 7-1, there is a big increase in the number of boxes handled when the call size is higher than 1,000 TEU. Because a big call size assures a continuously operation of quay crane, the percentage of the non-productive time of a big call size (higher than 1,000 TEU) is lower than the small call size (less than 1,000) TEU. In the scenario that the vessel is bigger than 1,000 TEU, the number of quay cranes assigned to the vessel seems to be limited by the number of quay cranes available at the quay side. If the terminal adds the quay cranes at the quay side, the operator can make full use of the LOA of jumbo vessels. Instead of moving a quay crane from bay to bay, the simultaneous operation can save the non-productive time. As a result, the berth throughput capacity rises further.

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[1] LOA: Length over All

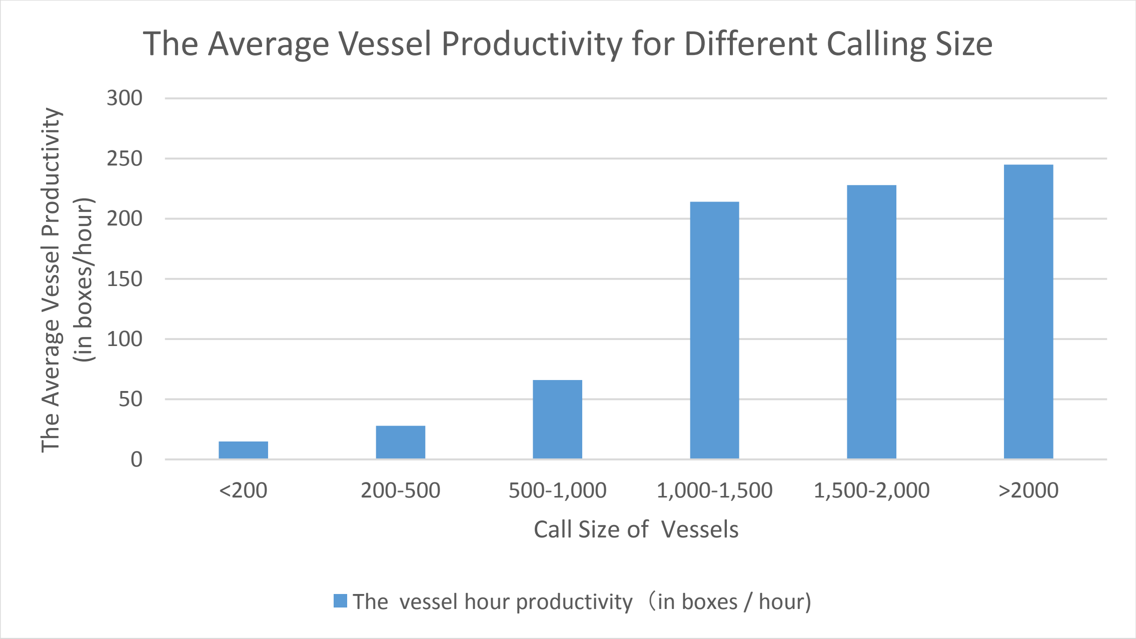

Figure 6-3 The Average Vessel Productivity with Different Call size
Source: *Yu and Tan (2012)*

Combining the conclusions in section 7-1 and section 7-2, the author proposes that Shanghai Shengdong International Container Terminal can optimize the berth operation by adding quay cranes and increasing call vessel sizes. According the layout of the terminal, the design of the berth can handle the 5^{th} generation and 6^{th} generation container vessels. Hence, introducing more ocean container vessels calling at the terminal not only increases the berth productivity, but also makes full use of the terminal facilities. Additionally, increasing the terminal market is another effective way to increase the berth capacity.

6.2.4 The Berth Utilization Rate

Saanen (2004) gave the calculation formula as follows

$$\text{Berth utilization rate}=\frac{\sum_1^n vesssl\ length*service\ time}{the\ quay\ lenth*measurement\ period}$$

From the formula, we can see that the denominator is fixed after the construction of the terminal finishes. The variables consists of the 3 parameters included in the numerator. However, terminal operators can do nothing to the vessel length. The only 2 parameters that terminals can control are the service time and the number of the vessels served by the quay cranes. We have discussed them in the section 7.1, so the rest the terminal can do to improve the berth utilization rate is handling more vessels in a certain period. From the perspective of a terminal operator, increasing the berth utilization is critical way to add the throughput capacity. There are a few possible solutions for a terminal operator to increase the berth utilization rate by serving more vessels. For example, expansion the terminal navigation channel can avoid the congestions on the water way and then, more vessels can enter the terminal in a certain period in a smooth traffic condition. Actually, Shanghai Maritime Safety Administration has been expanding the navigation channel for Shanghai Shengdong International Container Terminal. The vice president of Shanghai Maritime Safety Administration announced that after the expansion, the unidirectional navigation channel would become a bidirectional navigation channel. The average time a vessel spends on waiting for a berth will reduce from 3 hours to 1.75 hours. As a result, the berth utilization rate would increase from 72% to 84% (Yang, 2012). The expansion of the navigation channel makes the vessel enter or exit the terminal faster.

6.3 Sensitive Analysis

Sensitive analysis is a way to calculate the change in the berth throughput capacity when an independent variable increases or decreases in a certain percentage. Through the sensitive analyses, it is easily for us to quantify the impacts of a certain change in the parameters on the berth throughput capacity. The parameters included in the berth throughput capacity formula are berth utilization rate (Ap), the productivity of a quay crane (p_1), the number of quay cranes assigned to a vessel (n), TEU ratio (k_1), reshuffling rate (k_2), productivity for a vessel (p), call size of the vessel (Q), quay crane operation time (t_g), the non-productive operation time (t_f), the number of hours in a day (t_d). Because of the productivity formula given by

$$P = n * p_1 * K_1 * (1 - K_2)$$

The sensitivity of parameter n, p_1, and k_1 are the same. Hence the paper takes the productivity of a quay crane (p_1) as a representative of these 4 parameters and studies the sensitivity of the following 4 parameters: the berth utilization rate (Ap), the productivity of a quay crane (p_1), reshuffling rate (k_2), call size of the vessel (Q). The results of the calculation are listed in the following table.

Table 6-6 The Single Variable Sensitivity Analysis (in TEU)

Changes in the parameter	call size (Q)	Quay crane productivity (P)	Berth Utilization rate (Ap)	Reshuffle rate (k_2)
-30%	8,291,290	6,902,565	6,403,271	9,269,826
-20%	8,627,719	7,688,763	7,318,024	9,229,181
-10%	8,908,945	8,436,146	8,232,777	9,188,416
0	9,147,530	9,147,530	9,147,530	9,147,530
10%	9,352,491	9,825,464	10,062,283	9,106,524
20%	9,530,470	10,472,262	10,977,036	9,065,395
30%	9,686,467	11,090,026	11,891,789	9,024,145

Source: Compiled by the author

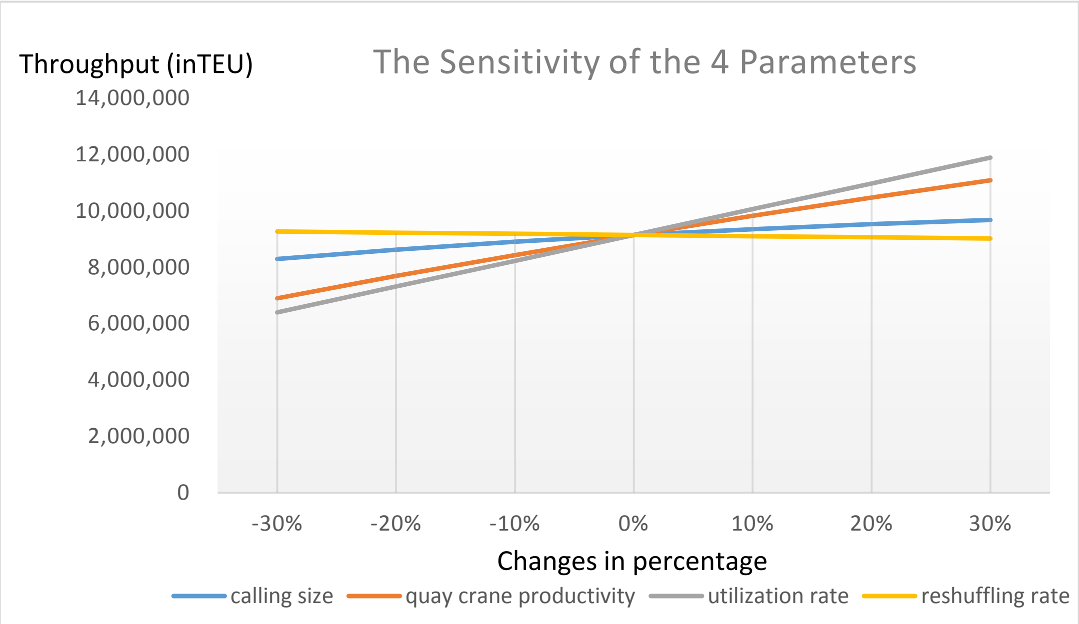

Figure 6-4 The Sensitivity of the 4 Parameters
Source: Compiled by the author

The figure 7-1 above is a visualized display of the sensitivity of these 4 parameters. It is obvious that the berth utilization affects the berth throughput capacity strongly, however, the reshuffling rate has a least impact on the berth throughput capacity. The call size also has a relatively subtle influence on the berth throughput capacity. The sensitivity calculation shows that the throughput capacity will increase from 9,147,530 TEU to 11,891,789 TEU if the berth utilization rate reaches 84% in

2013(Yang, 2012), as the vice president of Shanghai Maritime Safety Administration said.

To give a further analysis of the sensitivities of these parameters, the paper produces a bivariate analysis on the problems. In this case, the paper focuses on the 2 most sensitive parameters in the berth handling volume, namely the berth utilization rate and the quay crane productivity. The paper summarizes the aggregate sensitive of berth utilization rate and the quay crane productivity in the following table. The first line of the table means the changes in the berth utilization in percentage and the first column of the table means the changes in the quay crane productivity. The berth throughput volumes are summarized in the cross points with corresponding berth utilization and the quay crane productivity.

Table 6-7 The Bivariate Sensitivity Analysis (in 1,000 TEU)

		Changes in the berth utilization rate						
		-30%	**-20%**	**-10%**	**0**	**10%**	**20%**	**30%**
Changes in the quay crane productivity	**-30%**	4,832	5,522	6,212	6,903	7,593	8,283	8,973
	-20%	5,382	6,151	6,920	7,689	8,458	9,227	9,995
	-10%	5,905	6,749	7,593	8,436	9,280	10,123	10,967
	0	6,403	7,318	8,233	9,148	10,062	10,977	11,892
	10%	6,878	7,860	8,843	9,825	10,808	11,791	12,773
	20%	7,331	8,378	9,425	10,472	11,519	12,567	13,614
	30%	7,763	8,872	9,981	11,090	12,199	13,308	14,417

Source: Compiled by the author

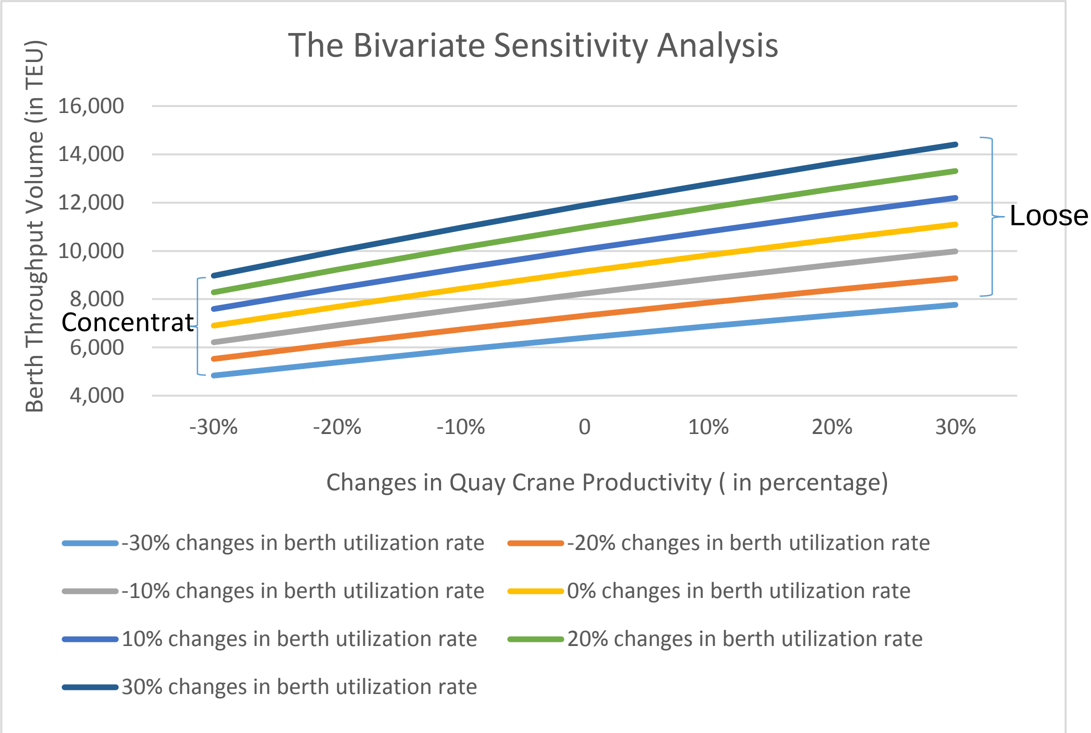

Figure 6-5 The Bivariate Sensitivity Analysis
Source: Compiled by the author

Figure 6-4 gives a clear demonstration of the results of bivariate sensitivity analysis. In the charter, the lines are concentrated when the quay crane productivity is low, so the changes in the berth utilization do not make a big different when the quay crane productivity is low. With the increase in the quay productivity, the lines become looser and looser. Hence we can conclude that the changes in berth utilization rate influence the berth throughput volume severely in a high quay crane productivity scenario. On the other word, the berth throughput volume is more sensitive to the berth utilization rate in a productive quay crane scenario than in an unproductive quay crane scenario.

6.4 Direct Transshipment from vessel to vessel

Because the transshipment container accounts nearly 45 percent of all the throughput and there is an increasing sign in the future, a direct transshipment from vessel to vessel is a solution to make the transshipment operation more efficient. Hark et al. (2010) proposed a direct transshipment solution, which means transshipping a container from an ocean liners to a barge directly. The following figure shows how direct transshipment works.

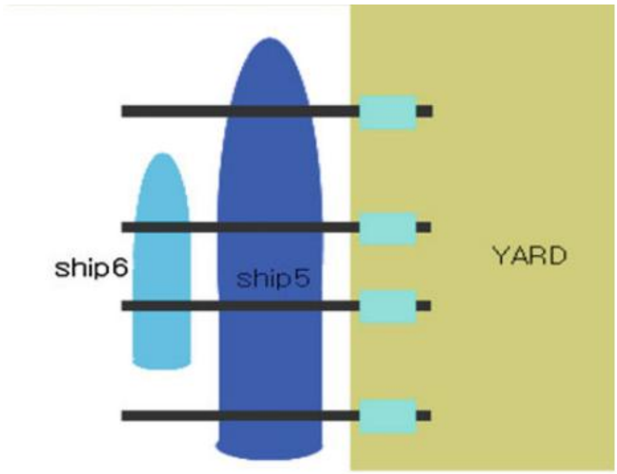

Figure 6-6 Direct Transshipment
Source: Hark et al. 2010

In the direct transshipment operation, the containers do not enter the yard anymore, so the direct transshipment not only increases the efficiency of quay side operation but also reduces the stress on the yard operation. However, the direct transshipment puts a high requirement on the berth facilities. As we can see from the Figure 7-2, the direct transshipment needs the big outreach of the quay crane, which should cover the width of an ocean liners and a barge. Because the outreach of the quay cranes is 65 meters long in Shanghai Shengdong International Container Terminal, the terminal is able to implement the direct transshipment on the prospective of the quay side facilities. Besides the outreach challenge, the shipping schedule is another critical problem. When the terminal practices the direct transshipment, the barge and the ocean liner should follow shipping schedule more strictly. Otherwise, the time is wasted in waiting and efficiency drops. According to the calculation made by Hark (2010), if the waiting time is short and the transshipment volume is long, the direct transshipment still benefits both the terminal and the shipping companies. Conversely, a long waiting time and low transshipment volume is what we should avoid. In such a low transshipment volume scenario, the terminal should not perform the direct transshipment.

6.5 Conclusions

The calculation shows that the berth throughput volume is 9,147,530 TEU. Although the berth throughput volume can satisfy the current market demand, we should make some changes to prepare for the increase in the market demand in the future. By the comparison of the SSICT with other terminals, the paper points out that SSICT has the potential to increase the berth throughput volume through the changes in berth utilization rate and quay crane productivity. These 2 aspects are the 2 most sensitive factors to the berth throughput volume. According to the sensitivity analysis, the berth utilization rate is the most critical factor to the berth throughput volume. If the berth utilization increases by 1%, the berth throughput volume will also increase in the same scale. Hence, the improvements in the berth utilization rate reflect directly on the berth throughput volume. The sensitivity analysis also shows that the increase in the quay cranes productivity expands the berth capacity in a large scale. For example, if the quay cranes productivity increases by 10% on the basis of current productivity, the berth throughput volume will increase by 9.31%. We can conclude from the calculation that quay cranes productivity is also highly related to the berth throughput volume. The terminal can increase the quay cranes productivity by optimizing the handling plane, improving the quay crane scheduling and employing the skillful quay crane drivers. Next, the paper proposes a bivariate sensitive analysis, which focuses on the aggregate impacts of quay cranes productivity and the berth utilization. The results of the bivariate sensitivity analysis suggest that the terminal should give a priority to the improvement on the berth utilization rate. A same change in the quay cranes productivity contributes more TEU to the berth throughput volumes in a high berth utilization rate scenario than in a low berth utilization scenario. Because a too much high berth utilization rate does harm to the shipping companies, the terminal operator can increase these 2 factors simultaneously to avoid doing harm to the shipping companies. Finally, the author gives direct transshipment thought to increase the quay side efficiency.

Chapter 7 Conclusions and Outlooks

7.1 Introduction

After the world crisis in 2008, the shipping industry starts a new round of booming. The throughput in SSCIT has increased for 4 consecutive years. What is the future development tendency is something important to the terminal operator. Only by knowing the throughput demand in the future, the terminal operator can make the proper strategy to handle market demand.

Chapter 7 makes the conclusion of the research topic and gives some outlook of the future research. Section 7.2 contains the main findings of this dissertation and section 7.3 is about the suggestions to the further study.

7.2 Main Findings and Conclusions

The paper starts from the throughput forecast of Shanghai Shengdong International Container Terminal. GM (1, 1) forecast model is established to forecast the throughput of SSICT and Shanghai port in the following 3 years. Then, the paper analyzes the throughput volume from the market share perspective and demonstrates the possibility of the throughput forecast.

To determine the berth throughput volume, the paper makes a detailed analysis on the factors which have impacts on the berth throughput volume. Besides the qualitative analyses, a berth handling volume formula is introduced to calculate the berth throughput volume. The forecast results and the berth throughput volume are summarized in the following figure.

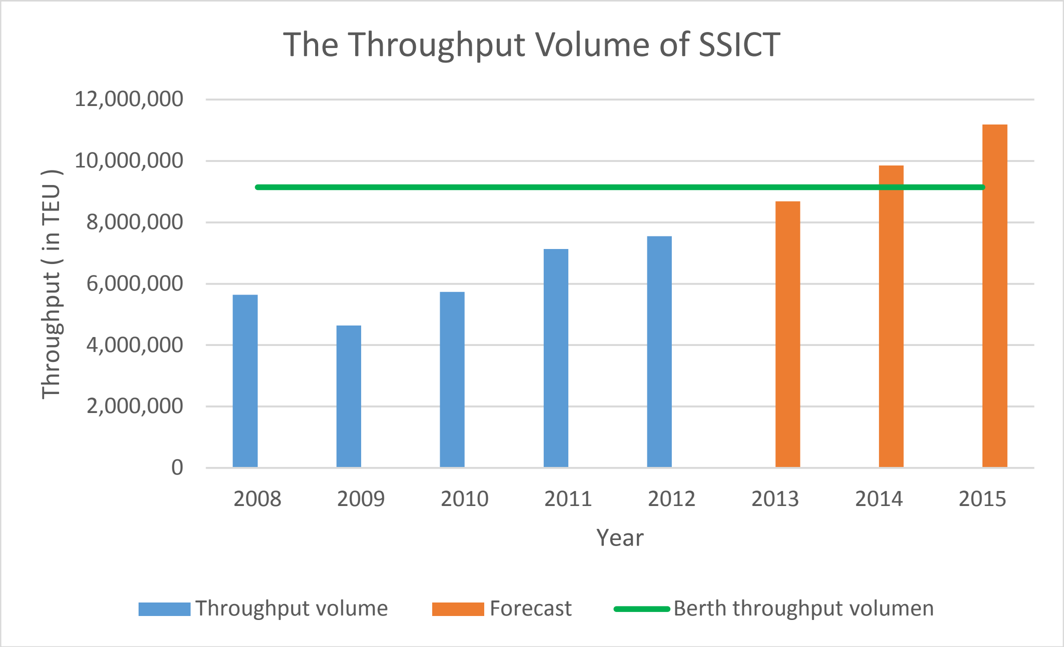

Figure 7-1 The Throughput Volume of SSICT
Source: Compiled by the author

The forecast shows an increasing tendency on the throughput volume of SSICT, which means that the terminal is facing an expanding market. By comparing the throughput forecast and the berth throughput volume, the paper concludes that the terminal still can meet the market demand in year 2013. However, the berth throughput volume will meet a limit in the future. It is necessary for the terminal operator to optimize the berth operation in the future. Otherwise, the berth throughput volume may become a bottle neck of the throughput capacity of the terminal.

The sensitive analyses give suggestions to the terminal about how to increase the berth throughput volume effectively. 4 factors are included in this part. Among all the 4 factors, the crane productivity and the terminal utilization rate are the most 2 sensitive factors, which have a big influence on the berth throughput capacity. According to the sensitive analyses, the berth can improve the berth utilization rate first, because the berth utilization rate has a direct impact on the berth throughput volume. If the berth utilization rate approaches the limit, the terminal operator can increase the quay cranes productivity as an alternative solution. In this case, the throughput volume will be 11,184,551 TEU in year 2015. If berth utilization rate will increase to 84%, as the port authority announced, the terminal still needs to increase the quay cranes productivity by 10%. Then, the terminal can handle the market demand in year 2015. Another alternative is 20% increase in the quay cranes productivity and 10% increase in the berth utilization, then, the berth throughput volume will reach 11,519,487 TEU. The terminal still can meet the market demand.

Additionally, the paper compares SSICT with other world class terminal and then, gives some advice to improve the berth side productivity.

7.3 Further Research Outlook

The research pays a lot of attentions on the throughput forecast and the berth throughput volume calculation. However, there are still some works should be done by the future research.

1. The terminal throughput capacity is determined by the least throughput capacity among berth capacity, yard capacity, and the gate capacity. All the three factors have mutual impacts and determine the terminal capacity comprehensively. Because the time is limited, the author only studies the berth throughput volume in the paper. It is necessary to study the yard capacity and the gate capacity in the future studies. Only when we take all the 3 factors into consideration, we can determine the whole terminal capacity.
2. Because of the test operation in the beginning 2 years, the sample the author choses to make the throughput forecast starts from year 2008. A small sample reduces the forecast accuracy in some extent. As time goes on, we can get more data. If we make the throughput forecast on the basis of a big sample, the forecast will be more accurate. Apart from the data, the models included in the paper are 2 very common forecast models. There are some complicated models which may perform better than the GM (1, 1) model, so the future study can try some different forecast approaches with more history data.
3. Next to the SSICT, there is another world class terminal called SGICT. The research does not take the impact of SGICT into consideration. However, in the practical situation, these 2 terminals compete with each other. Any change in one port may have impacts on the other, and vice versa. These 2 terminals influence each other, just like a game theory. Whether it is feasible to run the terminal in a co-operation way in some extent is another interesting question. When the shipping industry is prospective, how to exist in the market in a win-win way instead of in a rival way is beneficial to both terminal operators.

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