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WORLD MARITIME UNIVERSITY

Shanghai, China

AN ANALYSIS ON IMPROVEMENT OF STORAGE YARD MANAGEMENTIN IN THE COMPREHENSIVE TERMINAL

TAKETHE STORAGE YARD PROBLEM OF DHL IN JUNGONG LU TERMINAL FOR EXAMPLE

By

XU YAN

China

A research paper submitted to the World Maritime University in partial fulfillment of the requirements for the award of the degree of

MASTER OF SCIENCE

INTERNATIONAL TRANSPORT AND LOGISTICS

2013

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DECLARATION

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the University.

……

……

Supervised by

Professor Wei Liu

Shanghai Maritime University

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First of all, I'd like to show my great respect and sincere thankfulness to Professor Shuo Ma for giving this chance for me to study in ITL as a postgraduate. During this two-year study, I appreciate the continuous help and care from Ms. Fangfang Hu and Ms. Zhengfei Jiang, who are in charge of ITL program as the representatives from Shanghai Maritime University. Moreover, I want to show my deepest appreciation to all the professors both from World Maritime University and Shanghai Maritime University who used to provide me all these marvelous and meaningful courses. Their knowledge will lead me to reach the higher level of study.

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ABSTRACT

Title of Research paper: **An Analysis on Improvement of Storage Yard Management in the Comprehensive Terminal——Take the Storage Yard Problem of DHL in JungongLu Terminal For Example**

Degree: **Master of Science in International Transport and Logistics**

This dissertation is the study of the storage yard improvement, combined with general solutions and real case analysis.

First of all, the background of different kinds of storage yards in the different kinds of terminals would be discussed. From the general solutions for improving the storage yard operation, the author tried to find the pros and cons compared with AHP model, which was the methodology being used in the dissertation to solve the real problem.

Secondly, the paper was focused on the bulk yard in the comprehensive terminal and there is a real case analyzed in the paper. By means of building AHP model, the author tried the best to help to solve a practical problem about storage yard in one specific terminal. Normally AHP model is used for choosing the appropriate location of the storage yard but in this paper the author combined the location problem with determining the most rational solution to improve the storage yard. The author could get essential data from one exact company but however there was also some data which was too confidential to be published. Therefore, the result was collated and examined as the highest level of reliability as the author could obtain.

Finally, the result of this paper would be aimed to find a more scientific and rational way for solving the similar bulk yard problem in the comprehensive terminal.

KEYWORDS: Storage yard, Yard management, Comprehensive terminal, Analytic Hierarchy Process model

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
DEDS	Discrete Event Dynamic System
IEEE	Institute of Electrical and Electronics Engineers
PYSOP	Port Yard Storage Optimization Problem
FCL	Full Container Load
CY	Container Yard
CFS	Container Freight Station
RTG	Rubber-type Gantry Crane
RMG	Rail-mounted Gantry Crane
SIPG	Shanghai International Port (group) Co, Ltd

Chapter 1 Introduction

1.1 Background and research significance

With the development of global economy, business among different countries is becoming more and more important and profitable. In order to be more competitive in the global market so as to attract more customers, shipping is playing a very important role in the international trade market nowadays. For the purpose of the economies of scale, the trend of large-sized vessel is inevitable which leads to the rapid development of containerization. As a result of that, more and more terminals of ports are now emphasizing on enlarging the yard spaces only for containers. But the fact is that based on the features of bulk cargoes themselves, the transportation of [1]bulk cargoes are not possible to be replaced by container vessels in the near future. So in order to reduce the cost for the bulk cargo transportation, apart from building larger bulk vessels, from the perspective of the port, the optimization of yard space for bulk cargo becomes predominant.

[1] Here by saying "bulk cargoes", the author means dry bulk cargo, wet bulk cargo and break bulk cargo.

With the global economic resurgence, the demand for bulk cargo transportation is increased correspondingly. As one of the most important export and import countries in the international trade and shipping industry, China faces a lot of challenges from port building at the same time. In order to meet the need of larger bulk vessels, on the one hand, the ports should take immediate actions to adjust the sizes of quay berths accordingly. On the other hand, to increase the utilization of the existing storage yard is also feasible and less costly.

Cargo storage yard is one of the key facilities of the terminals. Meanwhile, whether the management of cargo storage yard is effective or not, the decisions of the management team directly influence the throughput capacity, the operation costs, the berth time, costs of the vessels and above all the mere benefits of both port enterprises and cargo owners per se. So how to make the cargo storage yard more efficient becomes the most important problem.

A lot of attempts to increase the efficiency of the utilization of storage yard have taken place. Some ports try to increase the ability of loading and unloading cargoes by purchasing more machinery equipments. Some ports employ the up-to-date state-of-the-art information technology system instead of the paper work and handy operations. Another economical way is to optimize the existing space of storage yard in order to avoid wastes of space and money for both sides of the ports and the cargo owners.

In this dissertation, the author tries to analyze the general solutions for the improvement of storage yard operation in the comprehensive terminals. And then narrow the scope down to take one of the main comprehensive terminals of Shanghai Port as an example. By optimizing the storage yard operation of one cargo owner, which is conducted based on the Analytic Hierarchy Process (AHP) model, the

author wants to find the potential regular pattern of improving the yard management based on the scientific methodology instead of historical experience or manual operations which may be eventually beneficial from both cargo owner's and terminal's perspectives.

1.2 Significance of the storage yard in the comprehensive terminals and its existing problems

1.2.1 Significance of storage yard in the comprehensive terminals

As we all know, comprehensive terminals deal with different types of cargoes. Apart from containers, the storage yard in the comprehensive terminals have to stock numerous different units of bulk cargoes which are unable to be stacked or stocked easily like containers. So the storage yard plays a very predominant role in a lot of aspects from the perspective of the terminals. For instance, as one of the most important considerations of all the terminals, apart from cost issue, a major issue is that the terminal must be able to turn the vessels around as quickly as possible. From this point of view, with the rational planning and coordination in the storage yard it can improve the movement activities to a far more efficient extent so that to solve this problem. Moreover, although a lot of terminal operators pay more attention to implement quay side equipment technology to satisfy the new standard of port performance required to minimize mega-vessel port stay. [2]However, however, the productivity will not solemnly increase from faster quay cranes but only if the storage and retrieval of cargoes from the storage yard can be done efficiently.

[2]http://ls.shmtu.edu.cn/en/events/498.htm

1.2.2 Existing problems

First of all, the storage yards of comprehensive terminals are different from that of the container terminals. The container yards are easier to be operated because theyare more standardized based on the facts that containers have united sizes, such as TEU (Twenty-foot Equivalent Unit), FEU (Forty-foot Equivalent Unit), or some other standardized units. But in the comprehensive terminals there are big amount of bulk cargoes as well, like steel, iron ore, grains and so on. It's very difficult to stack them or sometimes even just put them together and this directly leads to the low utilization of space of the storage yard.

Secondly, based on the fact that the profit of container transportation is getting higher and container business is developed very quickly with the growth of global economy. According to this tendency many terminals have increased their container business and enlarged the space of container yards. More and more multi-function berths have been turned to container terminals by port operators in order to make more money. The space of storage yards for bulk cargo has been decreased and the construction of which is ongoing contraction. But meanwhile, the market demand of bulk cargo transportation is not decreased at all which leads to congestion in the terminals and restriction of developing the business of bulk cargo transportation. In the long term, it will even influence the competitive abilities of the terminals if the storage yards can't be effectively managed.

1.3 Research approach and methodology

The main goal of this dissertation is to analyze the current situations and optimal solutions of storage yard management in the comprehensive terminals and then take one of the most important comprehensive terminals of Shanghai Port, Jungong Lu terminal, as an example. Furthermore, in order to give one feasible solution, the topic will be narrowed into the optimal solution of the storage yard operation of one specific cargo owner in that terminal by means of building the Analytic Hierarchy Process (AHP) model. From the perspective of cargo owner, the result aims to help them to determine the optimal solution of current storage yard management in order to save the costs in the terminal. Meanwhile, from the terminal's perspective of view, the AHP model can be a more reliable and scientific way, compared to previous solutions which were mainly based on the historical experience, for improving the yard operation, like sizing the yard space and improve customer satisfaction, etc. By doing so, it can also help terminal to improve the terminal utilization and attract more cargo owner so as to increase benefits. In order to achieve the above mentioned goals, first of all in the dissertation it will discuss the general features of the storage yards including container yard and bulk yard. But the author will focus more attention on the improvement of bulk yard operation in the comprehensive terminals. And then introduce Analytic Hierarchy Process (AHP) model which is used in the dissertation to solve the practical problem. After this, the analysis is about how to build the general optimal system for the normal comprehensives terminals. And then collect the history data about the cargoes from one specific cargo owner that came into the storage yard, like the type, quantity and stack space of cargoes, the time that vessels spend in the berth, etc. Next step is trying to build the AHP model and after solving this model we can get a best solution to realize goal of improving storage

yard operation. Finally, to give the writer's recommendation for the optimal solution of improving the storage yard management.

Based on the fact that Jungong Lu terminal is the main comprehensive terminal of Shanghai Port which deals with a lot of different shapes and units of cargoes, it's hardly possible to work out the most reasonable space of the storage yard only through calculating the amount of cargoes which are lying in the terminal. Therefore it becomes a very typical problem which should follow DEDS (Discrete Event Dynamic System). It is very difficult to choose the best solution from the numerous potential choices based on different points of views. On the other hand, it is very costly from both time and money points of view to build real storage yard to solve the problem. So Analytic Hierarchy Process (AHP) model turns out to be the most feasible and effective way to choose a best solution to improve the storage yard operation by setting reasonable criterions and scientific means of calculation. In this paper, according to the data from cargo owner and the plan of sizing the storage yard, the optimal solution will be conducted by mathematics formulations and AHP models.

1.4 Structure

Chapter one gives an introduction of the dissertation followed by the background of the global and domestic storage yard study, especially in the comprehensive terminals. Moreover, the main goal of this thesis as well as the methodology, the structure and literature review is also conducted in the first chapter. In the second chapter, the author makes the analysis on the utilization of storage yard based on

some indicators which are important for both container terminals and bulk cargo terminals and then discusses those specific factors which are important for storage yard in the comprehensive terminals. Chapter three will give a brief introduction of Analytic Hierarchy Process (AHP) model and its general usage in yard operation field in the terminal. The following chapter four will narrow the point of view of the thesis into a case study. In this chapter, it will first give brief introductions of both terminal and the bulk cargo yard of the cargo owner in the specific terminal and then the author will collect data, introduce the specific evaluation indexes according to the real situation in that comprehensive terminal, build Analytic Hierarchy Process (AHP) model, do calculation based on the necessary mathematics formulas, and finally choose the optimal result. Last but not least, chapter five will be an important chapter because the author will provide conclusion and recommendations according to the research that has been made in all the previous chapters.

1.5 Literature Review

Since I started to search the related researches about the optimization of the storage yard space, I have found plenty of domestic and foreign studies about this problem from different points of view.

First of all, there are numerous studies on how to set the space of storage yard. For example, we can see in Journal of Qingdao Ocean Shipping Marines College (2007), one research paper introduces the main variables of storage yard space, like annual throughput capacity, ways of loading/unloading, layout of the storage yard, equipped machines, management of storage yard. In particular, when the layout of the storage

yard is fixed, the amount of daily storage containers directly influences the space of storage yard. In B. Rodrigueset al.'s article of IEEE Transactions on Automation Science and Engineering (2004), authors stated that [3] the port yard storage optimization problem (PYSOP) at the Port of Singapore originates from certain space allocation needs and the yard space is very possible to be changed in accordance with different time periods which are requested. So the result of this basic problem can be commonly used in port operation or other applications in the terminals.

Secondly, mathematically speaking, we can see that terminals belong to DEDS (Discrete Events Dynamic System). [4]In control engineering, DEDS is explained as a discrete-state, event-driven system of which the state evolution depends entirely on the occurrence of asynchronous discrete events over time. There are some topics which are included in DEDS, such as Automata theory, Petri Net, Discrete Event Simulation, Queuing theory, etc, and have been applied into the past researches. Mordeson, et al. (1996) analyzed the applications of fuzzy algebra in Automata theory and Coding theory. Sheng-Uei Guan, et al. (1998) built a prioritized Petri net model and analyzed its application in distributed multimedia systems. Dezhong Huang (2009) applied Queuing theory to schedule the system of agriculture vehicles. Ismail, et al. (2007) used Discrete Event Simulation as a modeling tool to do the research on the routing process in GPSR ad hoc network routing protocol. Hui Hongqi (2009) used Queuing Theory to solve the problem of urban public transit dispatch. But it is observed that these methods are not massively used in the researches about ports and furthermore we can find that the simulation model is most commonly used in the ports related studies due to the fact that it is one of the most effective and economical way to get the optimal space capacity. Simulation models can be realized by different software, such as Flexsim, SIMUL8, Humming Bird,

[3] http://www.researchgate.net/publication/3448848_Port_yard_storage_optimization
[4] http://en.wikipedia.org/wiki/Discrete_event_dynamic_system

Arena, etc. As a result of the above mentioned, this paper aims to solve the problem by building the simulation model on Arena.

Last but not the least, apart from a lot of theoretical papers about storage yard or DEDS, we can also find many researchers have applied their studies into real and specific cases. For instance in the paper of Wang Rongming, et al. (2005), by using WITNESS simulation language, the authors built the simulation model to analyze the overall design of Wai Gaoqiao Phrase V container terminal. In the paper of Hong Changqing, et al. (2007) there is a discussion related with the way to improve the management of the bulk cargo terminal in WISCO industrial port. These papers can give me more detailed information about the real port and make my mind clearer on how to do some more practical study because my paper is not only related to a specific port but the scope is even more narrowed into one storage yard of a logistics company.

Although the purpose of numerous studies has been to optimize the storage yards, most of them are related with the yards of container terminals but not break bulk cargo terminals. For instance, Yin Lipeng (2012) analyzed the optimization of the yard function area of container terminal based on Flexsim. Yang Mei (2006) did the research on the management strategy of optimizing storage yard of container terminal in QQCT. Yang Man (2011) studied how to optimize the resources allocation and deployment of the container yard. All these papers point out the factors which are important for optimizing the storage yard, but as we all know container yard and the storage yard of break bulk cargo terminal are not the same. The differences between these two kinds of storage yards lead to the problem that the optimal space capacity of the container yard can't be simply applied to the yards of break bulk cargo terminal.

Moreover, compared to the container yard, the bulk yard of comprehensive terminal has more variables and uncertainties. This leads to the fact that so far a lot of researches and decisions which have been made on the bulk yard space of comprehensive terminals are based on the previous experience. Meanwhile, lack of scientific modeling makes many researches stop at the academic stage and the results of them are not so practical and valuable. Therefore, it is very important to have a general standard to make the optimization of yard space more applicable for comprehensive terminal. Simulation model is a relative new and effective method for solving this problem because it can save a lot of time and costs if the result is probable to be proved wrong. And the utilization of different software to build the simulation model has a huge space for further study.

Chapter 2 Research on the management of storage yard

2.1 Differences between container yard and bulk yard

Before the discussion of the differences between two main kinds of storage yards, the container yard and bulk yard, from the perspective of the author, the differences derived from different terminals will also influence the layout, the shape, the transportation environment, or other factors that may influence the utilization of the storage yard. So author would like to give a brief description of the different kinds of terminals.

2.1.1 Differences between container terminal and comprehensive terminal

There are many kinds of terminals which can be identified by their different functions, among which the author would like to discuss the two most important ones: container terminal and comprehensive terminal (or multi-purpose terminal). As we all know, with the development of globalization the vessels are now going further

and further than before. On the one hand in order to carry more cargoes during one long-distance trip, the sizes of the vessels are continuously increased. Moreover, based on the economies of scale, this trend of bigger vessels are inevitable. On the other hand, containerization improves the utilization of the larger vessels to an impressively efficient level, which also brings a lot of profits to the container vessels. Therefore, the need of container terminal is increased simultaneously in the port industry and in the recent years, many ports apart from building more container terminals, they even attempt to change themselves from a comprehensive port to a container port so that to seek for more profits.

But this kind of attempt is not so easy. First of all, a comprehensive terminal, which can handle containers, with maybe one conventional berth, wants to change directly into a container terminal and will consequently suffer from serious financial risks. Because the traffic environment in the container terminal needs to be developed far more effectively than that one of the comprehensive terminal otherwise it will lead to a big problem of under-utilization. Because [5]the construction of just one container terminal "unit" can add a million tones to the capacity of the port in one step. Thus, this can be identified as the first difference between container terminal and comprehensive terminal. The difference is that container terminal needs to be much larger in size than comprehensive terminal. When we talk about container terminal, the first idea that comes into our mind is its sheer size. It has to be equipped with longer quay to accommodate the bigger container vessels which are comparatively larger than general break bulk vessels. And at the same time the water depth at the quay has to be deeper so as to accommodate those larger vessels as well. Moreover, a container terminal has to have a wider space for storage of import containers and transshipment of export containers and a larger place for handling machines

[5] ITL05TML-CONTAINER TERMINAL PLANNING AND MANAGEMENT

specifically for containers, which are bigger than normal ones, to move freely. All of the above factors lead to the most obvious difference between container terminals and comprehensive terminals.

Secondly, it is known to all that comprehensive terminals are as important as container terminals due to the fact that based on the features of many other cargoes, such as bulk cargoes, the transportation of them are not possible to be totally conducted by containers in the near future. Like iron ore, coal and grains, they occupy a very big proportion of the bulk cargo in the global seaborne trade and we can see from Figure 1 that the demands of them are still increased.

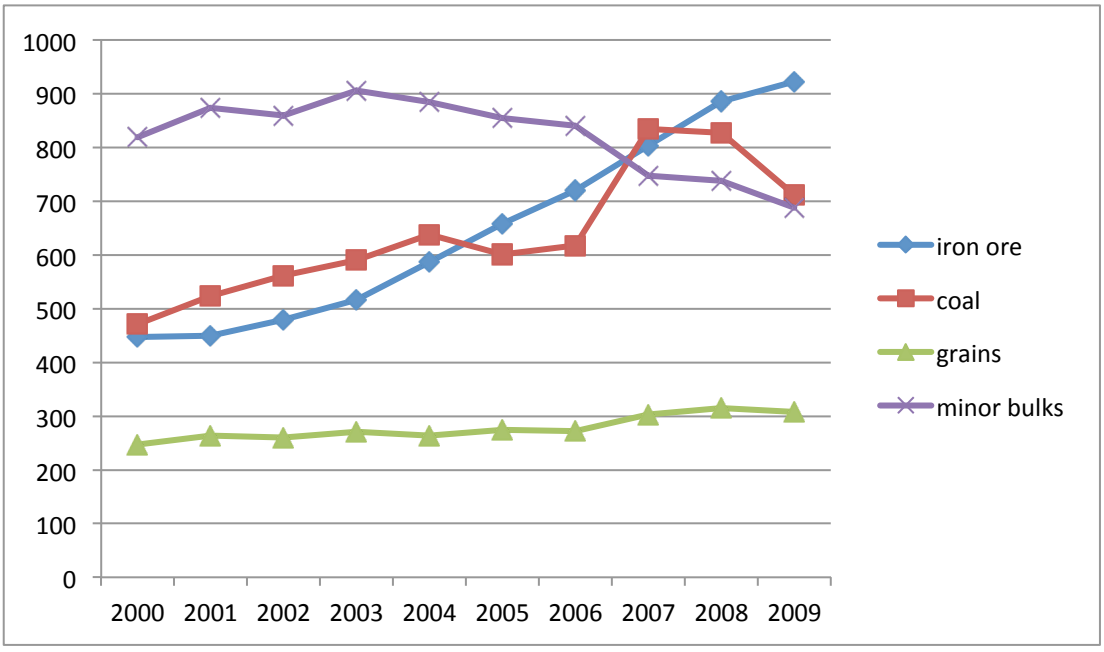

Figure1: The internationaldry bulk seaborne trade volume (million tons)

Source: Clarkson

Especially in China, there is a huge amount of bulk cargoes which have to be transported to different provinces in the hinterland. Although the benefits from handling bulk cargoes may not be as considerable as handling containers, the existing

needs of the transportation among different areas consolidate the importance of comprehensive terminals.

Based on the fact that comprehensive ports not only can handle containers but also can load/unload many other cargoes, which turns out to be the second difference between container terminals and comprehensive terminals: flexibility. As a comprehensive terminal or sometimes we call it "multi-purpose" terminal, it has to be adequate to handle different kinds of vessels including container vessels, semi-container vessels, and general vessels and so on. Due to this reason, there has to be a combination of handling equipments in the comprehensive terminals in order to lift and carry this range of cargo types. This is the also the key aspect that why comprehensive terminals are more flexible than container terminals. Moreover, this flexibility can also be figured out in a beneficial way that [6]there is a possibility of conversion of a pair of conventional general cargo berths into one multi-purpose facility, at far less expense and upheaval than replacing them with a container terminal.

2.1.2 Differences between container yard and bulk yard

Literally speaking, container yard is the area for placing containers. But actually apart from storing the containers, container yard also plays an important role in handling with loading/unloading of full containers and empty containers, transshipment and interchange of containers, and so on. Container yard is usually divided into three parts: marshaling yard, rear container yard and van pool. Among

[6] ITL05TML-CONTAINER TERMINAL PLANNING AND MANAGEMENT

these yards, marshaling yard is the one which is responsible for stacking the containers temporarily when the vessels are berthing and by doing so to improve the efficiency of loading and unloading cargoes. Rear container yard is the place for storage of containers as well but it emphasizes more on the interchange of full containers and empty containers. And it is also the place to conduct the transshipment of FCL (Full Container Load) from CY (Container Yard) to CY. Van pool is the place for collection, storage, and interchange of empty containers. It is built exclusively under the condition that the terminal is lack of enough container yard space or CFS (Container Freight Station) and sometimes it can be managed separately from the container yard.

Based on these three different yards that we can see the container yard must be very extensive and more specifically within the various areas in the container yard there are large-scale equipments, such as RTG (Rubber-type Gantry Crane) and RMG (Rail-mounted Gantry Crane), than bulk yard in order to ensure the efficiency of moving containers free of obstructions.

As per the bulk yard, the other main difference between container yard and bulk yard is the allocation of cargoes within the yard. The way of container yard to allocate the containers is easier due to the fact that we can simply think about first, if the container is full or empty; second, if the container needs to be imported, exported, or transshipped. But the allocation issue of bulk yard becomes far more complicated by reason of different features of different cargoes which lead to the result that they have to be stacked in different ways and in different areas within the bulk yard. For example, for the bulk cargoes of different cargo owners, if the types and the properties of which that will not influence or even damage each other then they can be put in the same area within the bulk yard. This is the most common way from the perspective of bulk terminal to stack the cargoes based. Moreover, the cargoes in the

bulk yard can be divided by different destinations as well and this kind of allocation is suitable for those bulk yards which have shorter storage periods but at the same time have big quantity of transshipment cargoes. For instance, the cargoes are going to be separately stored according to different means of transportation, like road, railway or shipping.

2.2 Research on the improvement of storage yard from the perspective of rationalization of yard space in the comprehensive terminal

2.2.1 The factors that influence the storage yard management

The main factors that influence the storage yard space include:

(a) Average storage period:

This is the factor that indicates the average time (unit: day) of cargo to be stored in the storage yard. Normally it is calculated from the day that cargo is put into the storage yard till the day that cargo is taken off. This is a very predominant factor because by minimizing it can help to decrease the amount of overstock and at the same time increase the turnover rate of the berthing vessels so as to improve the service standard of quick dispatch and help to avoid the congestion in the terminal.

Average storage period = Ton-days of cargo stored/Tons of cargo in storage per day

Moreover, when we try to analyze this factor in a precise way, we should make the report period as longer as possible due to the fact that the longer the report period is, the more real situation it can reflect. Because usually there are plenty of cargoes that have been moved into the storage yard before the report period. So if the report

period is too short then it will subsequently give rise to the illusion that the average storage period is short as well. Meanwhile this illusion can cause big problems to the terminal operation.

(b) Volume of cargo in storage per unit area:

This factor means the tons of cargoes which are actually stacked in the storage yard per efficient area (m^2).

Volume of cargo in storage per unit area

=average tons of cargoes in storage per day/average efficient area (tons/m^2)

Under the condition when this factor grows closer to the quota tones in storage per unit area and at the same time the average storage period gets shorter then we can get the conclusion that the storage yard is fully used and the management of storage yard goes very well.

(c) Tons of cargo in storage per day:

This factor reflects the average tons of cargoes which are stacked in the storage yard during a certain period. The bigger the average number of this factor is, the closer it is to the total amount of yard capacity.

Tons of cargo in storage per day

=Ton-days of cargo stored/number of days during certain period

This factor can reflect the condition of yard capacity utilization but it has to be analyzed together with average storage period in order to get more precise information. Moreover, when this factor grows bigger and at the same time the average storage period is decreased this means that the yard capacity has been fully used and the turnover rate will be increased as well.

(d) Operational storage capacity per effective unit area:

This is the factor which shows the maximum allowance amount of cargoes that can be stored per effective unit area in the storage yard on the premise of guaranteeing both the safety of storage yard and cargoes. This factor can be calculated for single kind of cargo or can be calculated in an average way so as to be shown for different kinds of cargoes.

$$\overline{\beta} = \frac{1}{\sum \frac{\alpha_i}{\beta_i}} \text{ (tons/m}^2\text{)}$$ [7]

$\overline{\beta}$——average operational storage capacity per effective unit area

β_i——operational storage capacity per effective unit area of certain kind of cargo

α_i——the portion of the total amount of certain cargo compared to the amount of the whole storage

Moreover, this factor is also influenced by many other elements, like types of cargoes, natures of cargoes, packing form, storage period, stacking form, surroundings, and so on.

7http://wiki.mbalib.com/wiki/%E5%8D%95%E4%BD%8D%E9%9D%A2%E7%A7%AF%E4%BD%BF%E7%94%A8%E5%AE%9A%E9%A2%9D

(e) Coefficient of storage yard utilization:

This factor reflects the average utilization level of the storage yard space during a certain period and the closer it approaches to 100%, the better utilization level is conducted by the storage yard. In addition to this, in order to make the analysis in a precise manner, this factor should be analyzed in combination with average storage period. If the utilization rate of storage yard space is higher and at the same time average storage period can be proved to be shorter then we can get the information about the storage yard that the turnover rate of which is relatively high. Moreover, as a result that it will help to enlarge the throughput capacity of the storage yard in order to gain more profits.

Coefficient of storage yard utilization

=Average ton-days of cargo stored/Average storage yard capacity×100%

However, we can't simply use this sole factor to analyze the whole usage condition of the storage yard. For example, if we think the utilization of the storage yard is high only because of the fact that the average storage period is long and the ton-days of cargo stored is big then this will certainly lead to the misunderstanding of the real condition of the storage yard. On account of that we have to consider the possibility that certain cargoes may stay for a long time, as a result of which it will lower the turnover rate of the storage yard. So the terminal will only be beneficial from the high storage yard utilization under the condition that both productivity and the quick dispatch of the terminal can be guaranteed.

(f) Number of turnarounds of storage capacity:

This factor means that the average time of the cargoes to be stored in the storage yard during certain period of time. It is also an indicator that shows the frequency of yard equipment utilization. The bigger this factor is, the more frequent the turnaround is. There are two ways to calculate this factor.

(1). Number of turnarounds of storage capacity

=number of days during certain period/average storage period

This formula is based on the factor of time and calculates the turnaround period and shows the average usage of time for the storage yard during certain period.

(2). Number of turnaround of storage capacity

=tones of storage during certain period/average storage yard capacity

This formula is based on the yard capacity to calculate the turnaround time and it shows the frequency of yard capacity utilization which is in other words the workload of the storage yard during certain period.

For the purpose of increasing the turnaround times, apart from trying to decrease the storage period, at the same time we have to take full advantage of the yard capacity and increase the tones of the storage yard.

(g) storage yard capacity:

This factor is an essential indicator for calculating the throughput capacity of the storage yard. How to determine storage yard capacity depends on the efficient

storage yard space, operational storage capacity per effective unit area, types of cargoes, safety conditions and so on.

$V=A\times\beta$

V——storage yard capacity (tons)

A——efficient storage yard space

β——operational storage capacity per effective unit area of certain cargo (tons/m^2)

This factor is an essential indicator of calculate the throughput capacity of the storage yard.

Additional to the above factors, based on the characters of bulk cargo, there will be a lot of logistic processing work, such as stack transfer, stow in block and tack integration, which may be applied to the cargoes which have already been stored in the bulk yard as well. How to manage these necessary logistic works will somehow influence the storage yard utilization as well.

2.2.2 The significance of the rationalization of storage yard space

Nowadays, with the development of globalization and modernization of the port industry, more and more port enterprises are trying to increase the transportation efficiency of bulk cargo and decrease the berthing time of the vessels in order to improve the economic benefits of ports themselves and moreover for their terminals as well. By continuously reinforcing the technical reform of comprehensive terminals, especially bulk terminals, the ports attempt to realize the specialization, large-size,

informatization and intellectualization of the comprehensive storage yards. In the recent years, most of the biggest international ports are transforming towards the third generation of ports, like Rotterdam port and Singapore port. In order to catch up with this tendency of development, more and more domestic main ports, like Shanghai port, Dalian port, Tianjin port, Qingdao port and so on, have been building the third generation of comprehensive terminals and bulk terminals strictly adopting the contemporary formats. By doing so it dramatically enhances the international competitiveness of China's bulk cargo transportation.

Storage yard plays a very predominant role in the process of improving the transportation capabilities of the newly-built third generation terminals. However, the more important thing is not to make the storage yard as big as we can because it will be a waste from the perspective of the port but to optimize the space of the storage yard. On the one hand, how to determine a reasonable, feasible and optimal space of the storage yard which can satisfy the huge amount of cargoes go through it every day and at the same time not to occupy the limited space of the port become two vital problems that the port enterprises have to resolve. However, on the other hand port enterprises can benefit a lot from the storage yard if they successfully conduct the optimal yard space. Because first of all, optimization of the yard space can rationally manage the limited space of the whole port and fulfill the goal of maximizing the yard profits and minimizing the yard space at the same time. Secondly, optimization of the yard space can help to avoid the waste of port space and can do good to shorten the transshipment time within the storage yard. Thirdly, through rational allocation and usage of machineries in the storage yard to optimize the yard space, it can help to upgrade the mechanical operating level so as to increase the work efficiency and productivity of the terminals/port.

2.3 Analysis on the general methodologies of improving the storage yard management

Fuzzy computing and genetic algorithm are two kinds of methodologies, which can be used for calculating the yard space in order to improve the management of storage yard and make it operate in an optimized way, but they are mostly used for container yards. Due to different natures of bulk cargo, the size of bulk yards can't be easily calculated in terms of square meters. The reason is that different types of cargo are stored in different ways and at the same time different ways of storing lead to different size of storage yards. In other words, the cargo which can be packed in frames (wooden cases, pallets, etc) is easy to be stacked and form layers of frames. The higher the layer of stacked frames, the more space can be saved in the storage yard in general. Another type of cargo cannot be stacked in layers. Different cargo, like pipes for example, is stored in rolls and not one on top of the other as we saw before, hence, bigger size of storage yard is needed in order to appropriately store this sort of cargo. From the perspective of terminal operator, it is not possible to provide the exact size that cargo owner wants according to the dynamic cargo flow. At the same time, from the perspective of or cargo owner, it is not possible to change the size of storage yard time to time according to the dynamic amount and size of cargo. As a result, quantitative methods of calculating the size of storage yard are not proper and comprehensive enough for solving this problem. The other method that both terminal operator and cargo owner are commonly using to decide the size of storage yard only is, for example, their previous experiences. But the result from historical experiences is not scientific enough. Therefore, AHP (Analytic Hierarchy Process) model becomes a very effective solution for this problem. By using this model, it is helpful not only to choose a more appropriate location of storage yard in

the terminal but also to obtain a more rational size for cargo owner. This methodology, compared to the purely experience, is not only more scientific but also more cost saving. In this dissertation, the author will use AHP model to conduct the improvement of bulk yard management based on a real case study to see how feasible and efficient to solve the storage yard related problem in this methodology.

Chapter 3 Analysis on the current conditions of improvement of storage yard management

3.1 Analysis on the general solutions of improving the storage yard management

Storage yard is a very important node of port throughput system by playing a role in buffering. This means that it helps to realize the buffering between loading the import cargoes alongside with evacuation and congregating the export cargoes as well as loading them on board. Therefore, the efficiency of storage yard operation directly influences the efficiency of loading/unloading cargoes in the port. Due to the necessity of improving the usage of storage yard so as to reinforce the ability of cargo storage and increase the cargo turnover rate, a lot of solutions have been implemented in order to solve this problem. For example:

(a) Collection and analysis of basic data

As it is commonly known, the cargo is one of the most important factors that influence the throughput ability of the port. Some major influential indicators of cargo are different types, features, batch quantities, packing forms, unit weights, and transportation forms and so on. For example, some physical or chemical properties of

cargo like volume weight or vulnerability will directly affect the working efficiency of the handling machinery and stevedores; packing form and packing strength will have an impact on operational storage capacity per effective unit area in the storage yard; different batch quantities can somehow determine the storage capacity by influencing the throughput rate of storage yard.

Therefore, in order to improve the storage yard operation, collection and analysis of basic data of different cargoes becomes essential and inevitable. The accumulation of data is a continuously long-term task and nowadays can be conducted by computer application technologies instead of manual recording so that it can help to adjust the storage conditions more punctually as well as more correctly. There are some mainly-influential data of storage yard like yard space, efficient space, coefficient of storage yard utilization in different time period, operational storage capacity per effective unit area, cargo weight, market situation and so on. By means of organizing and analyzing these basic data, it enables us to optimize the storage mode and at the mean time to reduce the blindness, increase the perceptiveness and contain the maneuverability during the improvement of cargo-handling technology.

(b) Optimization of the storing mode in the storage yard

Due to the fact that most of cargoes will be stored in the storage yard for a period of time during their transshipment, thus whether the condition of yard utilization is efficient or not will directly influence the throughput capacity of berth in the terminal. Moreover, yard utilization can reflect to some extent that whether collecting and distributing system works well or not in the terminal. The goal of operating the storage mode in the storage yard is to connect and adjust the relationship between the stock rotation and the storage of cargo. By doing so, we try to find if there is a

potential of improving the storage capacity, while at the same time maintaining the high level of turnover rate.

The storage mode can be simplified into the combination of pile location and mechanical channel. In other words, pile location reflects the storage capacity and mechanical channel affects the velocity of turnover of the cargo's collecting and distributing system in the terminal. These two factors mutually affect and restrict each other, which means that with the increase of the quantity of mechanical channels quicker cargo turnaround is achieved, while at the same time the utilization rate of effective area in the storage yard will be lower which may also lead to lower storage capacity. On the contrary, under the condition that if more pile locations will be built, then it is more possible to get higher utilization rate of effective area in the storage yard and at the same time the storage capacity can be increased as well. But this will result in the decrease of the mechanical channels numbers which means lower cargo turnover rate due to the limited space of storage yard. Therefore, as time passes by the storage mode has to be adjusted and developed by means of being changed from "small-tonnage pile type with easy storage" to "small-tonnage pile type with intensive storage" and finally into "large-tonnage pile type with intensive storage". During this kind of development, the storage mode is constantly improved for the purpose of finding a rationalized point to realize the match of storage capacity and transportation channels so that to have the optimum balance.

(c) Research and develop new kinds of storage technology according to the change of cargo types.

Marketing environment is one of the most important external factors which directly correlate with the efficiency of the terminal productivity. In consequence, from the

perspective of terminal, it is very essential to have the quick response towards the market information which is changing constantly and at the same time to have the predictive parsing so as to estimate the growth points accurately. For instance, recently in the domestic market some grains, like corn, have been presenting a certain appearance that when they are evacuated from the storage yard they take on the tendency of wrapper-less. After analysis we can easily get the conclusion that by doing so cargo owners can save certain amount of costs from purchasing the packing bags for the grains. So that, combined with the existing conditions of storage yard, it is predominant to research and develop the new storage mode, the new technology of collecting and distributing system according to the change in the market in advance for the purpose of consummating the yard functions, reducing the investment risks as well as increasing the profits.

The adjustment in the storage yard can be realized in two ways. First of all, we can choose the proper storage mode according to different types of cargoes. As the modern pattern of collecting and distributing system, it is preferential to choose the mode of “small-tonnage pile type with easy storage” so as to guarantee the efficiency of cargo transportation within the terminal and satisfy the current need of production at the same time. After that, based on the maturity of the ancillary facilities, like handling technology, machinery capacity, etc, the storage mode can be extended to “large-tonnage pile type with extensive storage” in order to improve the storage capacity accordingly. Secondly, the adjustment can be conducted by exploring the more effective handling technology. In other words, this means we can focus on designing a more appropriate pattern of cargo stack, formulating the process flows which are easier to be operated, optimizing the operational segments of handling technology, designing some special tools to ensure the handling productivity of stacking/unstacking of cargoes and so on.

(d) Adaption to the market and cost control

Nowadays, many complex and profound changes have been taken place in the terminal management environment and the market competition is becoming increasingly fierce. In order to survive and develop under such a challenging condition, for the sake of creating profits in the terminal, it's quite vital to readapt to the external environment, renovate the operation principles, and control the costs from a business point of view. As we all know that storage protection is one of the necessary conditions to ensure the storage capacity and straw covering materials is the foundation of implementing the storage protection. So apart from seeking for the benefit maximization within the existed yard area, paying more attention to control the costs of straw covering material becomes another feasible method to improve the storage yard management as well. Such kind of cost control can be realized through improving the quality of straw covering materials, optimizing the original covering process, choosing the new type and lighter materials so as to reduce the costs and meanwhile lower the labor intensity of the operators.

3.2 Brief introduction of Analytic Hierarchy Process model and its significance for improving the storage yard management

3.2.1 Introduction of Analytic Hierarchy Process model

Analytic Hierarchy Process (AHP) model was formally presented by American operational research expert, Tomas Saaty, in the middle of 1970's. It is an analytic method which is systematized, hierarchical and as well as the integration of qualitative and quantitative. Owing to its practicability and effectiveness in the

matter of solving complicated decision problems, AHP model was very soon attracted the attention and extensively used worldwide. Nowadays, the applications of AHP model has been pervaded throughout numerous fields like economic planning and management, energy allocation, behavior science, military command, transportation, agriculture, education, medical treatment, environment and so on. As a useful tool to help people make decisions in situation where multiple choices are presented, AHP model treats a complex multi-objective decision problem as a sole system and then decomposes the goal of this whole system into several sub-goals. Thereby, in order to realize those sub-goals, we will have several indicators or restrictions accordingly which is followed by the method combined with qualitative index and fuzzy quantization so as to calculate the hierarchical single arrangement (or weight vector) and the total sequencing.

In order to use AHP to solve problem, we need 4 steps. First of all, build AHP model. In other words, it means that we should firstly break the factors which are involved in the decision problem into different layers and use the hierarchical chart to express the relationship between those factors in a clearer way. Normally, there will be three hierarchies like the following figure 2:

(a) Top level, which is the goal of solving the decision problem.

(b) Middle level, which is all kinds of measures that have to be taken in order to realize the goal and we will have to consider different criterions which are derived from those different measures accordingly.

(c) Lowest level, which is the various kinds of solutions that can solve the problem

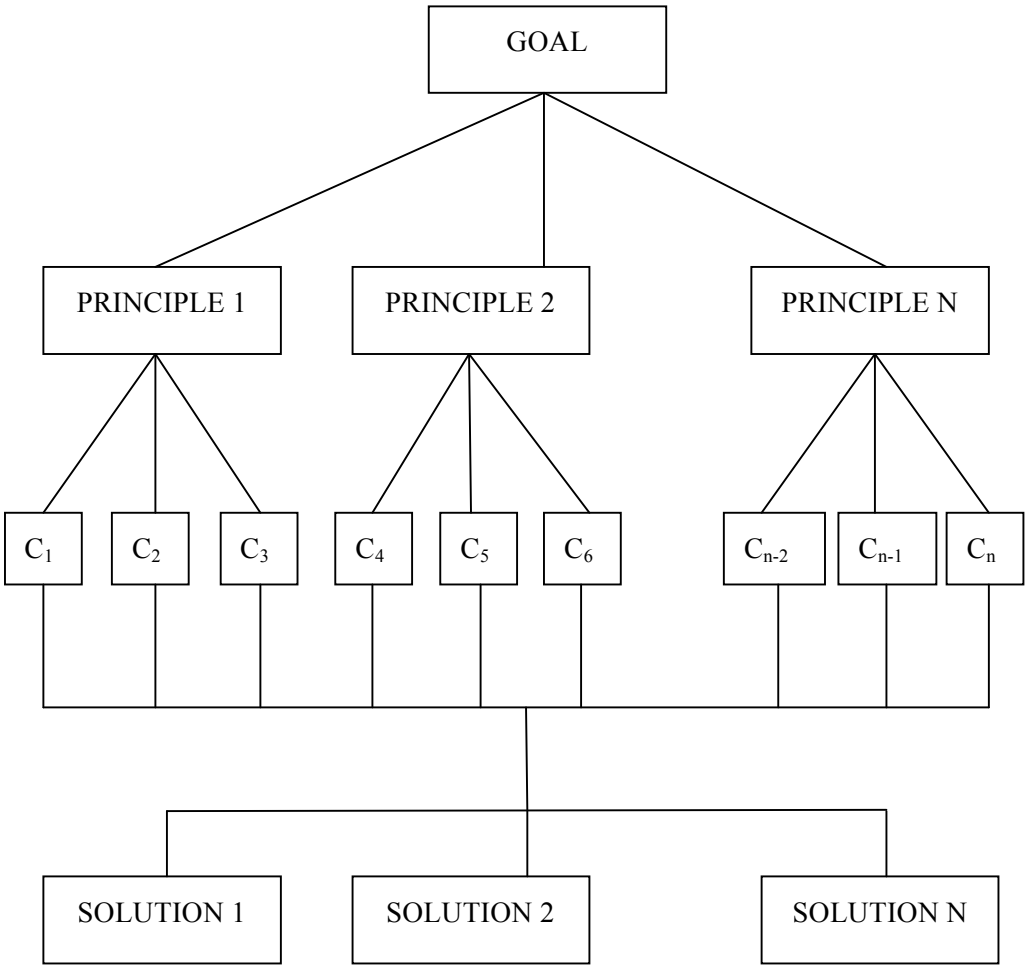

Figure 2: Different Hierarchies of AHP model

Secondly, we are going to use the method of solving judgment matrix vector so as to get the priority weight vector of each element in the principle level. Thirdly, after we calculate the sorting weight vector of C (Criterion) level, we are going to check the consistency of single hierarchical arrangement of this level. Fourthly, [8]the total sequencing weight vector of each level's element to the goal level are built and the

[8]www.ceps.com.tw

consistency check of total sequencing of each level is applied. Last but not least we should sum all the weight vectors of each alternative solution and choose the one which as the biggest weight as the best one.

AHP model has many advantages and the most predominant one of them is simple and clear. It can not only be used to solve the problem which is full of uncertainties and subjective information but also enables us to solve the problem logically based on our experience, insight and even intuition. Moreover, according to the simplified hierarchies it helps us to think about how to make decision easier by evaluating the relative importance of different indicators. However, AHP models have disadvantages as well. First of all, it cannot improve our solution or even provide us new solutions but only allow us to choose one solution from the existed ones. Secondly, it is not easy to be convinced because we use more qualitative but fewer quantitative. In order to solve this defect we can simply add more indicators but at the same time by doing so it will lead to the third problem which is when the number of indicator is increasing the difficulty of calculation is increased in proportion.

3.2.2 Significance of Analytic Hierarchy Process model and its usage for improvement of bulk yard management

Compared to container yard management, as the author stated before, the researches or studies about how to improve bulk yard management are far less. Moreover, due to different natures of bulk cargoes and different methods of storing, the management of bulk yard is very difficult to be standardized. Therefore, many decisions of bulk yard are conducted mainly based on the historical experiences and manual operations.

For example, one of the most prevailing problems that cargo owner will face is to decide the proper size of storage yard. Generally speaking, choosing the proper size of storage yard, two elements were under consideration: the first element was either the biggest size of yard in order to avoid congestion; the second was the smallest space so as to avoid high costs. However, these two kinds of decisions are done in accordance to the historical experience which leads to certain deficiencies in the practical application. For example, if we simply choose the biggest size of storage yard, it is possible that the cargo owner may suffer a loss of low yard utilization because of smaller amount of cargo are stored compared to the bigger yard area. Or if we decide to save costs by choosing the smallest size of storage yard, the higher potential of congestion not only happen inside the storage yard, but the waiting trucks will cause the transportation jam outside the storage yard.

In the pragmatic world, from the perspective of cargo owner, the size of storage yard can be dynamic according to different cargo flow. Nevertheless, from the perspective of terminal operator, it is not possible to provide different storage yards from time to time according to the changeable amount of cargo flow. Therefore, AHP model is used to fix the gap between these two sides. The decision of storage yard will be chosen, by cargo owner, among different choices that provided by terminal operator. As a result, the cargo owner can have a proper size of storage yard which will be able to have lowest risk of wasting money or congestion.

Compared to the decisions which are be done based on the historical experiences or [9]the relationship with terminal operator, AHP model turns out to be an reliable and scientific way, by taking multiple criterions into account, building the evaluation

[9] In china, for cargo owners or forwarders or logistics companies, the size or location of storage yard they can get are changeable based on how close relationship they have with terminal operator.

index system, using Analytic Hierarchy Process, to choose an optimal size and location of storage yard from the choices that provided by terminal operator.

3.3 The usage of Analytic Hierarchy Process model in the improvement of storage yard management

3.3.1 Build AHP model

As the author has discussed in the previous chapters the factors which can influence the decision of yard size can be numerous but there are four dominant ones can be summarized up: yard management, transportation environment (location issue in general), customer satisfaction (or in other words, congestion ratio in the storage yard)[10] and handling machines.. So, firstly, we can build the AHP model like the following figure 3:

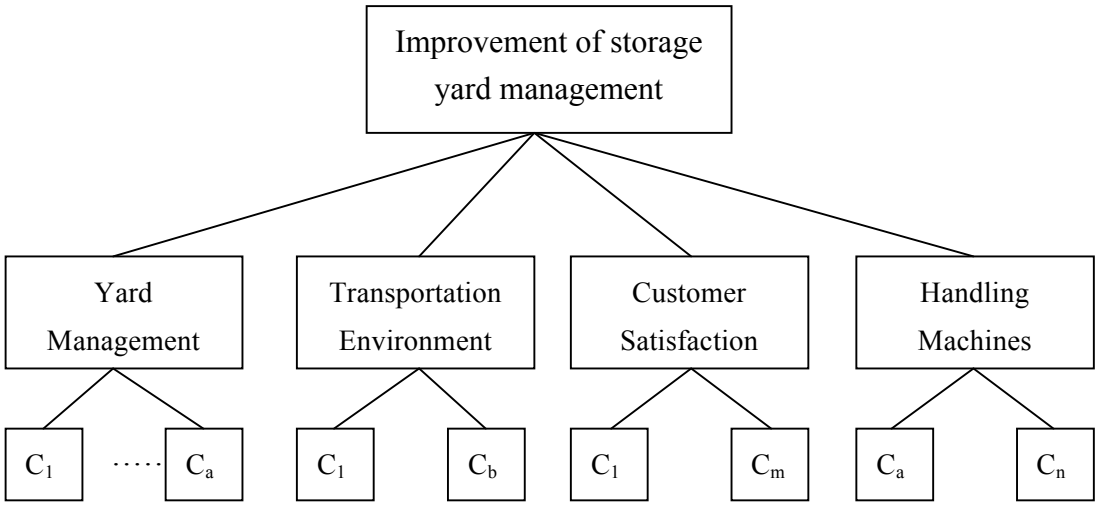

Figure 3: AHP model related with yard operation

[10]Congestion ratio is total amount of cargo over amount of cargo stored. Here, the author means that customer satisfaction is directly related with the congestion ratio of the storage yard. Due to that, if the congestion ratio is very high, it means that the cargo movement rate is correspondingly low, and vice versa. The result of this will lead to the loss of cargo owner's profits.

Based on the fact that different storage yards in different terminals will set their own sub-criterions according to the practical situation so here the author only sets the general AHP model to show how we should take different main factors into consideration in the very beginning.

3.3.2 Analysis on the weight value of each index by building the pair-wise comparison matrices

First of all, assuming that each factor in the Principle level[11] is a subset in the evaluation index set P and we set it as $P=\{P_1, P_2, ...,P_n\}$. Meanwhile, every subset in the index set P can be evaluated by its corresponding criterion in the Criterion level[12] and we set the criterion group as the sub-evaluation index set of the set P. Therefore, the set of each criterion in the Criterion level can be shown as $P_i=\{P_{11}, P_{12}..., P_{ij},\ldots,P_{in}\}$. Moreover, based on different practical situations, the number of levels of the index set P can be subdivided even bigger.

Secondly, we can acquire the weight value by determining the relative importance which is derived from the pair-wise comparison of each indicator of the evaluation index set P. And by doing so, we can form a matrix A, which is so called as the pair-wise comparison matrix. The process of the determination is conducted by using the analytic hierarchy process to structure the matrix. In matrix A, we use A_{ij} (row of matrix A is labeled as i and column is labeled as j) to indicate that the relative importance which is obtained from the comparison of objective i to objective j. The scale of importance is measured in integer from 1 to 9 and the meaning of each number is explained in the following table 1.

[11] As the author states in the graph in Chapter 3.2.1
[12] As the author states in the graph in Chapter 3.2.1

Table 1: Scale of pair-wise comparison importance

Value of A_{ij}	Interpretation
1	Objective i is equally important as j
3	Objective i is slightly more important than j
5	Objective i is pretty more important than j
7	Objective i is obviously more important than j
9	Objective i is absolutely more important than j
2,4,6,8	When it is difficult to choose from two adjacent values, we can set it as the compromised value of them.

For instance that if $a_{12}=3$, which means objective 1 is slightly more important than objective 2. On the other hand, if we want to show that objective 1 is slightly less important than objective 2, we can express it like $a_{12}=1/3$. In addition that all the $a_{ii}=1$. Therefore, by doing so, we can have a matrix of the results from the comparison of the entire index, which can be shown as:

$$\mathbf{A}=\begin{bmatrix} 1 & a_{12} & \cdots & a^{1n} \\ a^{21} & 1 & \cdots & a_{2n} \\ \cdots & \cdots & 1 & \cdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix}$$

Thirdly, we can estimate the weight of each objective in matrix A through two steps. Step one is to normalize matrix A so as to get matrix A^* by using formula 1:

$$a_{ij}{}^* = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$$

Step two is to calculate the average the entries in row i of matrix A^* by using formula 2:

$$W_i = \frac{\sum_{j=1}^{n} a_{ij}{}^*}{n}$$

3.3.3 Checking for consistency

It is commonly known that any comparison matrix can face the problem of inconsistency so before we continue WITH the calculation we should check the consistency of the matrices in advance. In the first place we should multiply matrix A with matrix W (which come from the results of W_i) to obtain matrix AW. Then we should[13]find the proportion of each element of matrix AW to the corresponding weight in matrix W and average these ratios, which enables us to get the largest eigenvalue of matrix A, by using the formula 3:

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i}$$

[13]Practical Management Science, Wayne L. Winston, S. Christian Albright

Finally, we can check the Consistency Ratio (CR) of the comparison matrix at the very beginning by using the formula 4:

$$CR = \frac{CI}{RI}$$

In the above formula, CI means Consistency Index which comes from the result of formula 4:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

In addition, "n" means the orders of matrix A. RI means Random Index which is shown in the following table 2. Moreover, only when we get the result that CR<0.1, it can be said that the consistency of the comparison matrix A is successfully proved and the result of the AHP model can be accepted. Otherwise, we have to rebuild the comparison matrix until we are able to compute CR is smaller than 0.01.

Table 2: Random index for checking the consistency of AHP model

n	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

Chapter 4 Analysis on case study based on AHP model

4.1 Introduction of case study

4.1.1 Introduction of Jungong Lu terminal

Jungong Lu terminal belongs to Shanghai International Port (group) Co, Ltd, Jungong road Branch Ltd. Located in western bank, lower reaches of Huangpu River; Jungong Lu terminal is not far away from Wusong terminal as well. Its railroad is connected with Hejiawan Marshalling Yard in the west and its traffic way is closely linked to Yixian Elevated Road and the outer ring road in the north. Meanwhile, it is also the main foreign trade terminal of Shanghai port, which is specialized in handling bulk and break-bulk cargoes. 40 years' professional experience of SIPC bestows the terminal enormous capability of loading/unloading large equipments, steel and bulk cargoes. Apart from these, [14]the principal cargo it handles also includes iron, steel, pulp, vehicles, bulk items and equipment, containers, etc. Jungong Lu terminal owns four 10,000 ton-class berths and the water depth of which is no less than 10.5 meters.

[14] http://210.5.155.56/en/subcompany/jgl.html

Along the 743 meters long coast, the terminal is equipped with advanced machineries, such as bank hoist and obverse hoist. Moreover, it has 430-fathom-deep wharfs, each of which can berth a ship of over 10 thousand tons. Jungong Lu terminal has an operational yard of 251,461 thousand square meters, with a staking floor space of 161,131 square meters. Its multi-layer warehouse is outfitted with the first class storing facilities; with its floor space amounting to 36 thousand square meters in area, this warehouse boasts to be the largest one in Asia. Furthermore, Jungong Lu terminal has more than 100 lifting and leveling machines, including four 40-ton, two 16-ton and four 10-ton shore-type cranes, two 45-ton gantry hoists, one 8-ton counter-balance truck, one 37-ton and one 42-ton forklift truck, fourteen 14-ton hoists and two 50-ton hoists. All of these machines provide Jungong Lu terminal powerful ability to meet even the most demanding requirements of loading/unloading cargoes under all weather conditions.

SIPG Jungong Lu Ltd has 2 sets of Dongfeng railway locomotives, each of which can take up 50 carriages at one time; the maximum traction is 6,000 tons. The special owned railway lines are 6304 meters which directly leading to the forefront of terminal coast and Shanghai Railway Bureau Hejiawan marshalling. Therefore the carriages of cargoes can be distributed to every corner of China through railway, thus making Jungong Lu terminal one of the best terminals in Eastern China with sea, land and railway transportation.

4.1.2 Introduction of storage yard of DHL in Jungong Lu terminal

DHL is a very famous logistics company and is regarded as the global market leader in the logistics industry. It has one corporation project with an Indian company and recently they have a new program which mainly deals with the bulk cargo

transportation between Shanghai and India. Therefore, DHL wants to rent a storage yard in Jungong Lu terminal especially for storing these bulk cargoes which are packaged in different forms, like frame, frame-cooler, pallet, bundle, wooden case, roll, null case, nude, iron case, container, etc. The fact is that the previous decisions of the yards they chose in this terminal were conducted based on several principles. First of all, it is based on historical experience gained from the storage yards in other terminals. Secondly, the size of the storage yard is sometimes influenced by the business relationship between DHL and the terminal operators. It is not easy to have an ideal yard space in most situations. Last but not least, the principle of cost controlling. Normally DHL will rent the smallest space among the options provided by the terminals in order to save costs but this can bring the risk of the relatively high congestion ratio in the storage yard which influences the yard operation efficiency at the same time.

Hence, for this new storage yard, DHL is willing to use a more scientific way to choose the most proper yard in Jungong Lu terminal and the more important point is to use this decision as a reliable pattern. Because with the development of this project with the Indian company, there will be bigger and bigger quantity of bulk cargoes which need to be transported so the number of the storage yards that DHL has to rent in Jungong Lu terminal in the near future will be increased in proportion. Due to this fact, DHL hopes that the decision of choosing the first size of storage yard can provide a regularity so as to simplify the following work in a rational and specific way.

4.2 Application of AHP model according to the storage yard management of DHL in Jungong Lu terminal

As the author states in the previous chapter that the four main principles which can influence the decision of the storage yard space is yard management, transportation environment, customer satisfaction and handling machines. According to the practical situation of DHL, it is essential to analyze the criterions which are derived from these factors separately.

4.2.1 Analyze the criterions of yard management

(a) Operating cost

According to the previous data of the cargo flow, we can see from the following table 3 that it is very dynamic and hard to be forecasted.

Table 3: Historical data of cargoes

[15]Ordinal number of batch	Number of packages	Volume	Gross weight
46	405	4065.05	1840.896
48	1399	15341.24	6898.707
49	726	9695.61	4676.389
50	794	10646.44	4288.562
52	927	13360.24	4716.869

[15] The time interval between two batches is not longer than one month.

55	1503	15209.21	7258.418
58	807	12875.65	4625.464
74	2025	14491.53	6809.539
81	1684	13756.82	5578.107
91	981	8437.13	4607.007
101	602	6039.7	3030.693
121	832	4770.42	2367156
128	90	1639.13	611078
130	34	1364.62	1036270
138	568	4221.91	1953435
148	137	762.55	594232

Moreover, due to the fact that different cargoes are packed in different ways and the height of stack of different cargoes are different as well. Therefore, according to the practical operation experience, they can be divided in table 4:

Table 4: Different cargoes' package types and package factors

Package type	Package factor[16]
Container	3
Frame (cooler)	7
Pallet	2
Bundle	5
Wooden case	2.5
Roll	1
Frame	2.5
Null	1.3
Nude	1.3
Iron case	2

Based on the above data, the historical yard area is normally between 2000 m^2 to 3000 m^2 and per square meter of the storage yard costs 1 RMB and the cost of storage yard is paid monthly. After discussion with the terminal operator, in Jungong Lu terminal, DHL can get 0.9 RMB/m^2 for the yard which is bigger than 3000 m^2 based on the amount of cargo. This difference of cost will be significant when DHL

[16] Package factor is the parameter that shows the stack height of the corresponding package type, which is set by DHL based on the historical storing experience. For example, the package factor of container is 3, which means the maximum stack height is 3 containers to be stacked vertically.

will have several storage yards at the same time with the development of their program with the Indian company.

(b) Yard utilization

The package factor is not only related with yard cost but also can influence the yard utilization as well. As we can see, if the package factor is bigger which can help to store more cargoes vertically, then we can store more cargoes to avoid congestion in the yard. Under this situation, the coefficient of yard utilization can be increased as well and vice versa.

(c) Storing mode

Because there are many different package types which means there are different storing modes accordingly. So trying to improve the method of storing so as to optimize the storing mode can help to increase the yard utilization in order to save the necessary area and save costs as well.

4.2.2 Analyze the criterions of transportation environment

(a) If the storage yard is close to the berth in the terminal

This criterion will influence the turnover rate in the storage yard and at the same if the yard is far away from the storage yard, DHL will have to consider purchasing

more trucks in order to maintain the cargo loading/unloading rate in an effective level.

(b) If the storage yard is in the railway area

As the author introduces before, Jungong Lu terminal has very well-developed railway system. So even if the storage yard maybe not so close to the quay but if it is surrounded by the railway it can still be ensured that cargoes will be transported in an effective level.

4.2.3 Analyze the criterions of customer satisfaction

(a) Congestion ratio

Congestion ratio is high which leads to a high possibility that the cargoes will not be transported in time and the customer (cargo owners) will suffer a loss. So this is the first factor which has to be controlled and guaranteed.

(b) Coefficient of truck utilization

If there is congestion in the yard, then truck plays a very important role to help to solve the problem so the situation of truck operation is important and has to be considered as well.

4.2.4 Analyze the criterions of handling machines

(a) Maintenance ratio

The importance of maintenance ratio reflects not only the potential maintenance costs but this index also directly influences the congestion ratio as well.

(b) Operation efficiency

Operation efficiency is almost as important as maintenance ratio but works in different ways. For example, this index can be improved by giving more training to the operators of handling machines and it affects the yard utilization in accordingly.

(c) Investment volume

On the one hand this index is quite predominant because it influences both the previous two indexes to a great extent but on the other hand it is the most changeable one among all the indexes which means that the value is not fixed so that the importance can be different based on the real situation.

4.2.5 Build AHP model of the storage yard of DHL in Jungong Lu terminal

In order to increase the objectivity of AHP model, one questionnaire (which can be check in the attached word file) is done by the experts from DHL to score the weight value of all the criterions. Therefore, the scores in the following figures are evaluated not only from the perspective of the author but are done based on the result of questionnaire.

First of all, there are four main principles the author states before, yard management, transportation environment, customer satisfaction and handling machines. So the comparison matrix A, as we can see from table 5 below,(the comparison matrix which describes the relative importance and weight value of four principles compared to the decision of the storage yard that DGL is going to make) is going to be built based on the pair-wise comparison importance (which is shown in table 1).

Table 5: Comparison matrix A of the principle level

Matrix A	yard management	transportation environment	customer satisfaction	handling machines
yard management	1	5	3	2
transportation environment	1/5	1	1/4	1/2
customer satisfaction	1/3	4	1	2
handling machines	1/2	2	1/2	1

By using formula 1 we can normalize matrix A so as to get the result of matrix A^*:

$$\mathbf{A^*}=\begin{bmatrix} 0.4918^{17} & 0.4167 & 0.6316 & 0.3636 \\ 0.0984 & 0.0833 & 0.0526 & 0.0909 \\ 0.1639 & 0.3333 & 0.2105 & 0.3636 \\ 0.2459 & 0.1667 & 0.1053 & 0.1818 \end{bmatrix}$$

And then by using formula 2 we can obtain the matrix of Weight and the sum of all the weight value equals one:

$$\mathbf{W}=\begin{bmatrix} 0.4759^{18} \\ 0.0813 \\ 0.2679 \\ 0.1479 \end{bmatrix}$$

4.3 Check the consistency of AHP model

First of all, we have to calculate matrix AW:

$$\mathbf{AW}=\begin{bmatrix} 0.4918 & 0.4167 & 0.6316 & 0.3636 \\ 0.0984 & 0.0833 & 0.0526 & 0.0909 \\ 0.1639 & 0.3333 & 0.2105 & 0.3636 \\ 0.2459 & 0.1667 & 0.1053 & 0.1818 \end{bmatrix} \begin{bmatrix} 0.4759 \\ 0.0813 \\ 0.2679 \\ 0.1479 \end{bmatrix}$$

Secondly, according to formula 3, we can get $\lambda_{max}=4.1290$ and then we apply λ_{max} and RI, which according to the Random Index table shows when n=4, RI=0.9, into

[17] $A_{11}=1/(1+1/5+1/3+1/2)$
[18] $W_{11}=(0.4918+0.4167+0.6316+0.3636)/4$

formula 4 so as to acquire that CR=0.0478. The calculation process is shown in the following figure 4:

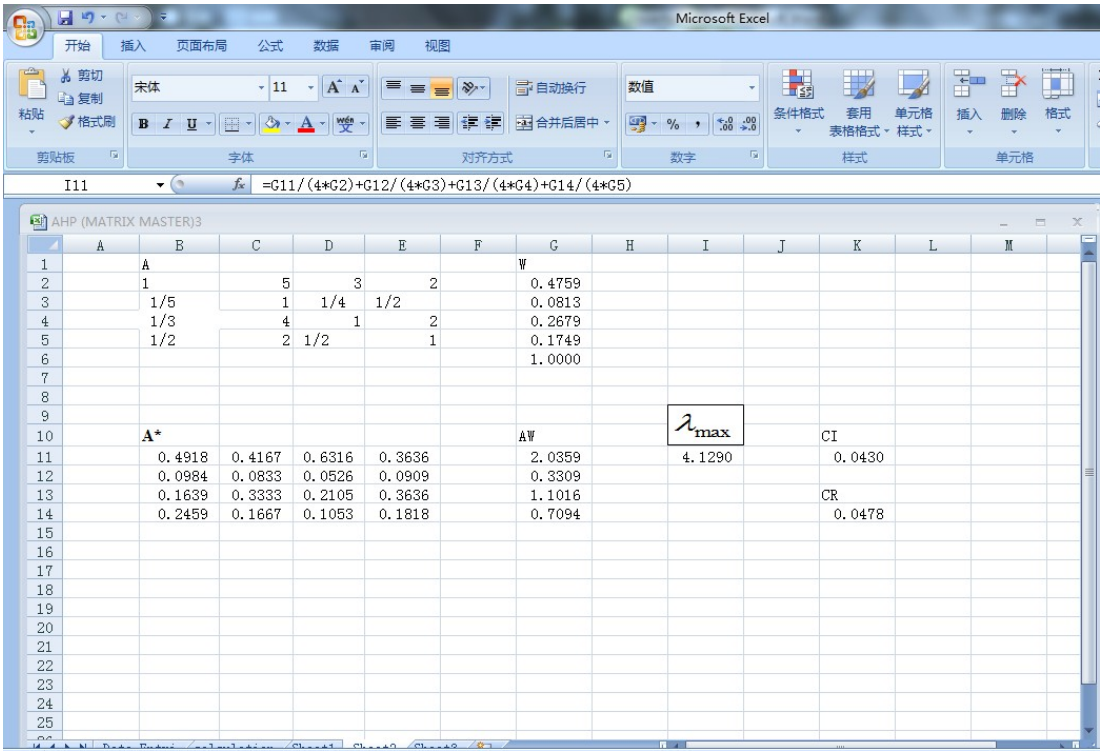

Figure 4: Calculation process of AHP model

Thirdly, since CR=0.0478 which is smaller than 0.1, so the weight value the author set is reasonable and the result of this AHP model can be accepted.

Finally, with the same steps we can check the consistency for the matrices which are derived from the criterion level. Then we can use the same calculation process to set the relative importance and obtain the weight value of the evaluation index set $P_i=\{P_{11}, P_{12}..., P_{ij}, \ldots, P_{in}\}$, (the criterions which are derived from four principles)and check their consistency respectively. For instance, like the following table 6 and the

calculations of all the matrices A_n which are derived from the criterion level are shown in figure 5 and figure 6:

Table 6: Comparison matrix $A_1$of the criterion level

Matrix A_1	Operating cost	Coefficient of yard utilization	Storing mode	$Weight_1$
Operating cost	1	4	3	0.6196
Coefficient of yard utilization	1/4	1	2	0.2243
Storing mode	1/3	1/2	1	0.1560

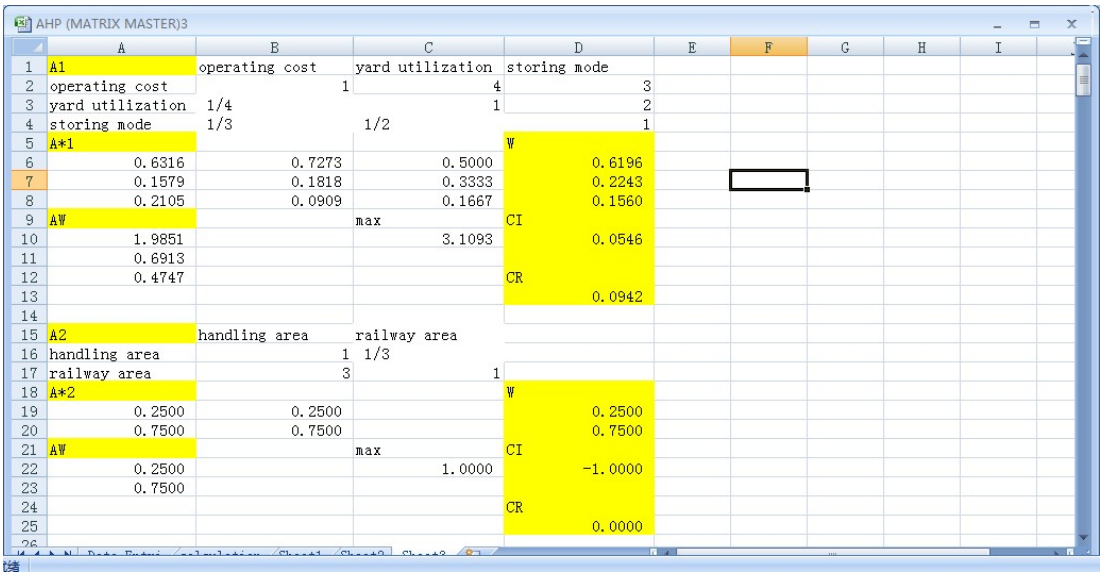

Figure 5: Calculation process of weight value derived from Criterion one and two

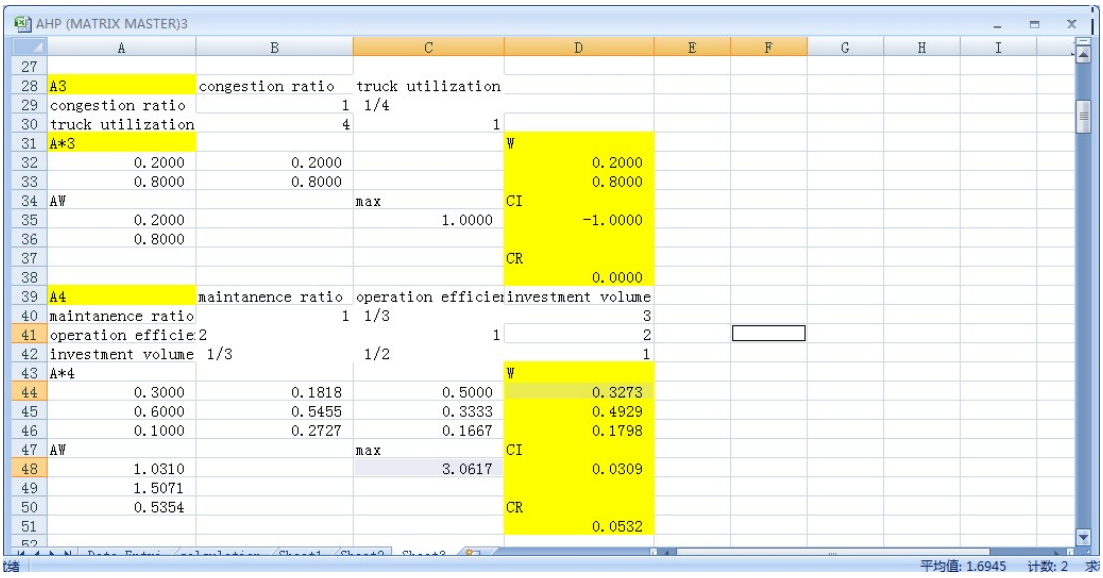

Figure 6: Calculation process of weight value derived from Criterion three and four

After the same steps as before, we can get CI=0.0546 and CR=0.0924, which is less than 0.1. Moreover, we can get the weight for the left criterions which are 0.2500, 0.7500, 0.2000, 0.8000, 0.3273, 0.4929 and 0.1798 in turn. By doing so we can get the matrix W_c[19]= (0.6196, 0.2243, 0.1560, 0.2500, 0.7500, 0.2000, 0.8000, 0.3273, 0.4929, 0.1798)^T. And all the CRs of the left three comparison matrices of criterion level are proved less than 0.1.

4.4 Evaluation of the AHP model

There are three solutions, according to the principles and the criterions which are derived from the corresponding principles, are provided by DHL.

[19] Here means weight value of criterions.

First of all is to choose the smallest one to save cost because this will not be the only one storage yard that DHL have to pay. With the development of the program with the Indian company, DHL may have to rent 4 to 5 storage yards in Jungong Lu terminal, therefore to control the cost is one of the most important concerns.. Moreover, with the smaller size of storage yard, the efficiency of handling machines can be increased as well.

The second solution is to choose the one which is close to the berth but it will be more expensive. Nevertheless, it can help to reduce the purchase of the trucks in order to maintain the turnover rate of the cargoes going in and out of the storage yard.

The third one is to choose the biggest one which is not close to the berth but has the railways surrounding it. According to the negotiations between DHL and the terminal operator, DHL can get 10% discount in the rental expenses if the storage is more than 3000 m^2, plus if the storage yard is far away from the berth the price will be even cheaper. And with the cargo flow which is presented in table 3, the amount of cargoes can sometimes be tremendous. Therefore, to have a big scale of storage yard can ensure the lowest congestion ratio so as to raise the customer satisfaction simultaneously.

By doing so, it is good for DHL to seek for long term benefits. Based on the previous criterions, these three solutions have to be scored in the following table 7 and usually the scores can be given from 0 to 5.

Table 7: Determine the scores of each solution according to each criterion

	Solution 1	Solution 2	Solution 3
Operating cost	5	2	1
Yard utilization	3	2	2
Storing mode	2	2	2
Close to berth	1	5	0
Close to railway	1	0	5
Congestion ratio	1	2	5
Truck utilization	3	4	3
Maintenance ratio	3	3	2
Operation efficiency	2	3	2
Investment volume	0	1	3

The best alternative will be obtained from the calculation, which deals with the weight for all the criterions: W_c[20]= (0.6196, 0.2243, 0.1560, 0.2500, 0.7500, 0.2000, 0.8000, 0.3273, 0.4929, 0.1798)^T , for the all scores for each criterion. For instance:

[20] Here means weight value of criterions.

Score of the solution one =5*0.6196+3*0.2243+2*

0.1560+1*0.2500+1*0.7500+1*0.2000+3*0.8000 +3*0.3273+2*0.4929+0*0.1798

Similarly, the scores of solution two and solution three can be acquired according to the same formula (which can be checked in the attached excel file) and among these three we will find that the solution three is proved to get the highest score. The process of calculation is shown in the following figure 7:

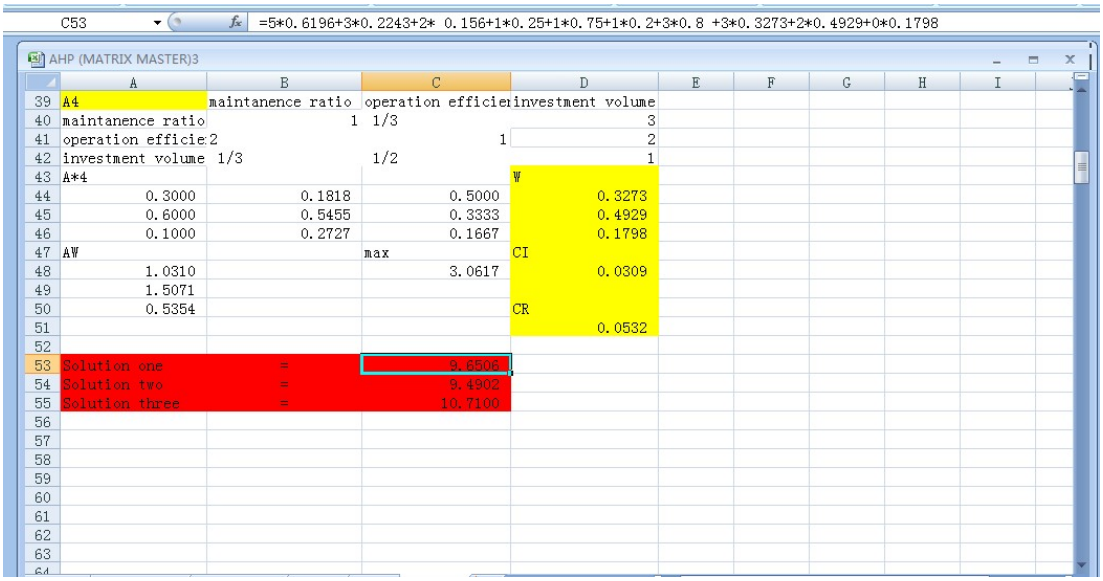

Figure 7: Calculation process of the highest scores

In a word, if DHL wants to rent a storage yard in Jungong Lu port, solution three is the most scientific and rational.

Chapter 5 Conclusion

5.1 Conclusion

From this real case study the author reached the conclusion that for DHL, although the cost for renting the storage yard maybe high but the congestion ratio will be the lowest correspondingly. This result coincides with the long-term development and benefits of DHL as well. However, due to the fact that there is much data which is private and confidential, the paper tried to maintain the scientific level as high as possible. The author believes that if it is possible to get more core data from DHL, this AHP model can be built combined with Fuzzy Comprehensive Evaluation so as to get a more realistic and tangible result and can be serve as a fixed pattern to solve similar problems in the future. The author is looking forward to cooperate with DHL further to realize this model and during this process the author can surely be benefited from more meaningful knowledge.

This paper mainly discusses how to improve the storage yard from many perspectives like yard management, yard operation, yard space, and so on. After a brief look of the background is taken, the author starts the analysis of different storage yards in different terminals. Then from a general point of view, the author

states some commonly used solution which help to improve the storage yard comprehensively. Finally, there is a real case based on the AHP model is conducted to give the suggestion to DHL for one of their storage yard decision in Jungong Lu Terminal.

The importance of storage yard already is a commonly known issue and this paper tries to help to solve the related problems in a different perspective through the combination of the location choice problem and the improvement of storage yard management within the same model. At the same time, the real case study brings more practical meanings to this paper.

5.2 Outlook

Due to the fact that the bulk yard management problem is very complex and it becomes even more complicated after the research is related with the practicalsituation. The author faced some challenges and bottlenecks which led to certain restriction or shortage existed in this dissertation:

(a) Theauthor wants to collect more data of cargoes and communicate more with the port authorities in order to make up the insufficient in objectivity, which is derived from the methodology.

(b) The criterions in the AHP model are the most common and basic ones that we can find in the yard management. According to different requirements from different cargo owners or logistics companies, evaluation index system in the AHP model can be built in a more detailed and personalized way. At the same time, the amount of people, who will be invited to do the questionnaire, can be increased so as to get a more comprehensive and objective result.

(c) The methodology that the author used in the dissertation is a little bit subjective, hence, the result of dissertation can not reflect the improvement of storage yard management in a very accurate way.

All the shortages which are mentioned above need much more time to communicate with more professional experts, more visits to the port and more surveys. At the same time they point the author to the directions that should be done in the near future.

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