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Double-stack container trains railway transport organization research

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Double-stack Container Trains Railway Transport Organization Research (Jing-Hu Line)

By

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For

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DECLARATION

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

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

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ABASTRACT

Title of Dissertation: Double-stack Container Trains Railway Transport Organization Research (Jing-Hu Line)

Degree: Master of Science in International Transport and Logistics

Abstract: The emergence of railway double-stack container transportation (DST) is a revolution in the history of container transportation. It is one of many directions that China's railway cargo transport system is going. DST can reduce operating costs by 25-40% per unit and raise transport capacity by at least 30%. Many transport organization problems still need to be further studied because China's DST is still at an initial stage.

On the basis of summarizing experience of foreign DST and the development reality of domestic DST, this paper not only analyzed the category and development conditions of double-stack container train, but also studied its organization principles and forms, the methods of determining its operating and running plans, and the contents of station organization required by the double-stack container train. By forecasting the OD container volume of the Beijing and Shanghai (Jing-Hu Line) railways, the operation and running plans of the double-stack container trains can be determined.

KEYWORDS: Double-stack container trains; Transport organization; Principle; Transport volume forecast; Operation plan.

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LIST OF ABBREVIATIONS

DST	**Double-stack container train**
Jing-Hu Line	**Beijing-Shanghai Line**
CFS	**Container Freight Station**
CY	**Container Yard**
OD	**Original and Destination**
TEU	**Twenty Foot Equivalent Unit**
FEU	**Forty Foot Equivalent Unit**
APL	**American President Lines Inc**
D&P	**Drop and Pull work**
FCL	**Full Container Load**
LCL	**Less than Container Load**
GDP	**Gross Domestic Product**

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CHAPTER 1 INTRODUCTION

1.1 Research Topic Source and Introduction

Container transport is an advanced, normative way of transportation. Since the 20th century, container transport has been greatly developed to be highly-efficiency, safe and insusceptibility to weather. From the late 1970s to the early 1980s, the world average container flow had increased 12% and the number of containers increased 8%. While the shipping increased 20%, the freight rate decreased by 1/3. The throughput of a container at an American port on the west coast has broken through 2 million TEU and up to 3 million TEU in 1979. Among the 13 ports, whose container throughputs were over 1 million TEU in 1984 all over the world; three ports were in American, two of which were on the west coast. The containers arrived at the west coast ports were almost immediately transported to the mainland and east area[1]. Only if the operation is fast, economic, efficient and superior to land-bridge service, can we attract and evacuate more container flow from Asia.

At the end of 1970, the American Congress passed the bill that relaxed restrictions on vehicle length. From then on, we can see a tractor with two or three semi-trailers, which is a challenge to traditional railway transport. The railway transport must adopt new measures to accommodate transport market variations due to the pressure of air and high way transport. Donald C. Orris, the president of domestic transport branch of American President Lines Inc (APL) first raised the suggestion "to put one container to another"[2]. In 1981, Southern Pacific Railroad Company changed a one-stack into a double-stack container train in order to lower the cost and raise transport capability. At the same time, they developed a special vehicle for the

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[1] Che Dehui(1992): The new development of container transport--Double-decker container train transport. < Railway freight>

[2] Xu sufeng(1996) : The development of double-stack container trains [J]. <Containerize>. Page 17-20, Vol.11 & http://en.wikipedia.org/wiki/Intermodal_freight_transport

double-stack container. In early 1984, this way of transport was proven to be highly beneficial economically and showed strong potential. However, there was no railway company willing to take a risk on expending. There are some concerns in railway transport. Although there are no limits in the west rail, the center and east rail have to be broadened. Though there was sufficient commodity supply (abundant Asia import container) to the eastern area, there is only little to the west because there were more imports than exports between American and Far East. Therefore, the market should be developed domestically. The solution to the connection problem between railway and port included the construction of transshipment station and the arrangement of train and ship's delivery schedule. What the railway company most concerned with was the investment involved. In the past, they invested to develop the highest transport demand route. The consideration whether or not the double-stack container transports can be profitable needs to be determined. In this situation, APL invests over 12 million dollar to buy 4 new double-stack container trains designed by Thral Co. This kind of container train was build of 5 carriages per group, and between each carriage they use an articulated arm joint and a 100t bogie. In both sides of group, they used a standard coupler and a 70t bogie, In addition, they have used a new design the "depressed centre flat wagon" to decrease train height. In the depressed centre, 40ft container can be loaded and the top floor can load one 40ft container or one 45ft container.[3] The fastening device between the top floor and the lower floor container was the same as the fastening device used in sea transport.

Picture 1 Double-stack container train

Source: Picture obtained from internet sources.

[3] Zhang Simei(2005): Development of double-stack container train and how to carry out double-stack container transport[J]. <China railway> Page 44-46

http://img.china.tradeprince.com/723/20081023/c74bb0d4-136f-43f8-b05b-c7d93617d040.jpg

APL made double-stack container train operation a great success. In 1985, APL invested over 8 million dollars to buy 3 double-stack container trains[4] in order to adapt a double-stack container railway transport system in New York and midland. Also American Railway Interest started to transform a Chicago railway station. After APL supplied this double-stack container transport service, many U.S company have also developed this service[5]. Canada and Australia also operated double-stack container train transport service after a few months.

We consider that container transport is a light carrying capacity transport. A double-stack container train increases the fix area transport capacity. It is a revolution of railway container transport.

In the late 1990s, China's container transport was in a highly developing period. Confined by infrastructure build and low management level, however, the transport capability was insufficient to meet the market needs. Double-stack container railway transport is a low cost, high transport speed service which can save 25%-40% in transport fee and raise transport capability by 30%[6]. It would improve China transport supply greatly. In 2001, China started double-stack container train research. In 2004, we started the Beijing-Shanghai double-stack container train. So, China was at the initial stage of using double-stack container train.

In the thesis, I chose the most important part of container train—the Organization of the double-stack container trains transport program, to research.

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[4] APL (1996): The Intermodal Safe Container Transportation Act and Amendments, a Handbook for Shippers.

[5] Those U.S.A companies: Sea-Land company ,American Express company

[6] Wang Zhanguo(2002): China double-stack container train transport[J]. <China railway> Page 42-45, Vol.11

1.2 Literature Review

Railway double-stack container transportation (DST) organization

In 1981, South Pacific Railway Company in the United States has changed container train from single-story to double-shipment to reduce unit operating costs and improve transport capacity by developing a double-stack container shipping special flat car. In early 1984, American President Lines Inc (APL) also designed and manufactured a double-stack container car.

Different countries have different methods of Railway double-stack container transportation organization. Since China is in the initial stages of double-stack container transport, we can only refer to other country's Organization programs, and use these examples to improve.

Railway double-stack container transportation organization research has contained many parts:

(1) Railway double-stack container type and operating condition
(2) Railway double-stack train's weight and speed
(3) Railway double-stack train's driving condition
(4) Railway double-stack train's timetable development
(5) Railway double-stack train's capacity
(6) Railway double-stack train's direction, capacity and development forecasting

Railway double-stack container transportation (DST) organization's development

Richard d coirtis (1992) & Matt Hannes (2004) both give a brief understanding of the United State's double-stack container transport development history as follows: APL was the first company to begin operation of the railway double-stack container train, and from the west coast in Seattle, Los Angeles and Chicago as well as between the east coast cities. APL was also responsible for vehicles and cargos. The railway companies only provide traction power lines and traction together with a mileage fee to APL.

Initially, APL double-stack container train was composed of 20 compartments, with a total length of more than 1,609 m that could ship 200 boxes FEU. From Los Angeles and Seattle to Chicago, the whole journey is about 3,540 km with a running time of 53.5 h, and a maximum train speed of about 113 km/h. In May 1987, the United States had at least 12 railway companies and 11 shipping companies using double-stack container transportation. Bound for the east coast from the west coast, the double-stack container trains have 59 times, the number of containers rise up to 12,000 boxes and accounts for 20-30% of the United States door-to-door combined transport rail. Its characteristics of high transport efficiency and low operating costs can save around 15% -20% of the shipping costs. It can also shorten shipping time by 14 days as compared with shipping via the Panama Canal to the East Coast.

Ata M.Khan (1995): By the end of 1985, Canadian railway operated double-stack container trains in eastern areas. Despite opposition, double-stack container trains have become the main transport method in Canada in less than 10 years.

Railway Ministry study tour report (China, 2006): Austria started double-stack transport in 1980. In 1989, Australia State Railway (AN) began to pilot double-stack standard containers transport, Australia's western railway gauge is not problematic, and double-stack container transport has been very common, accounting for about 50% of all the container transport. Double-stack trains loaded with container transport was enhanced by 20% -30%, thereby reducing the unit operating costs, resulting in a good economic benefits.

In China, the first Double-stack railway transport began between Beijing and Shanghai in 2004. In 2006, China finished railway transformation from Shanghai to Ningbo. So China is still in the initial stages of Railway double-stack container transportation (DST) organization.

Railway double-stack container transportation (DST) organization problem in China

From Ma caiweng's (2006) *China Double-stack container feasibility study*, Double-stack container transport in our country is a new thing, although we can draw on the development of double-deck container transportation in other countries. Because China's railways have different specific characteristics than foreign countries, there are many transport organization issues that require an in-depth study. For example, the need of China's dual - layer of container trains and the application of the types of conditions, train stations and transit operations sent to the organizations, as well as train formation and operation of organizations on issues such as analysis, and propose solutions.

Institute of Economic Planning Ministry of Railways (2006): Railway double-stack container transport channel planning study. It said that the distinct natural geography conditions in China are another problem in China's double-stack container transportation development.

Research result on railway double-stack container transportation organization and prediction method

China Academy of Railway Sciences research result in 2003: Designed 7 basic rules for railway double-stack container transportation organization, including (1) Basic on China railway's actual traffic, (2) Reference to foreign technology, (3) Practical, (4) Efficient, (5) Accurate, (6) Forecasting, and (7) Low costs.

Deng Junlong (1980s): *Grey Theory--Gray prediction method*. Definition: If a system of all information is known, the system is the white system, all information unknown, is the black-box systems, some information is known and some unknown, then the system is the gray box system. Generally, the social system, economic system, ecological systems are gray system. For example, the price system, number of factors leads to increase price, but many factors are not known, so that the price prediction can use the gray prediction method. Zhu Zongbo has developed gray theory for railway transport area. This mathematic theory is consistent of 4 parts: Series prediction, Disaster prediction, System prediction, Topology prediction.

1.3 Research Content of This Dissertation

At present, China railway's main problem is that the transport ability can't accommodate transport development. So the double-stack container train is a very important method of improvement that can effectively address current shortage problems.

The significance of the double-stack container train:

(1) Relief transport ability support shortage problem

In recent years, China's railway container transport capability increased every year, in 2002-48.19 million ton, in 2003-59.02 million ton, 2004-59.52 million ton, 2005-65.32 million ton, 2006 82.58 million ton, 2007 110.21 million ton. The main hubs in China are: Guangzhou, Chengdu, Tianjing, Shanghai, Beijing, Urumchi, Kunming, Chongqing, Harbin and Lanchow. These main railway hubs' total dispatch transport capacity accounts for 30.33% and the delivery capacity account for 35.46% of total transport quantities. Many railway routes transport capacity can't satisfy current container transport demand.[7,8]

Now, most of China's railway use flat wagon and open top container wagons, In the condition of 850 m effective length railroad, the marshalling carriage number is 50, and the traditional train capability is 100TEU. Double-stack container train can reach over 150TEU, and also increase the traction use ratio increase sharply[9,10].

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[7] Jing-Guang, Jing-Hu, Jing-Ha, Longhai route's transport capability shortage

[8] Pan Guoqiang(2003): Domestic railway double-stack container trains's necessity and feasibility[J]. < Railway Survey and Design> Page 5-7, Vol. 6

[9] Ma Caiweng(2006): China's double-stack rail container transport feasibility study[J] <Dalian railway

(2) Increase railway container transport competitive power

Railway is facing a strong competition from other transport methods, increasing the railway transport's market competitive power, and strength and developing market have become urgent problems. Although China's container transport systems have had a great development, it is still only developed on a low level when compared to other transport methods. Since the 1990s, China has operated intermodalism service between sea transport and land transport. Railway delivery port container throughput accounts for just 3% of the total port container throughput. In several main containers distributing methods; Road transportation has absolute advantages over railway transport. Since the railway did not give a full play of itself in long distance transport advantages, it strongly blocked China intermodalism development[11]. We should operate the double-stack container as soon as possible in order to raise railway transport's competitive power.

(3) Speed up railway transport reform

Compared to the passenger train revolution, China's cargo train revolution is far behind it. So we could start from double-stack container train revolution to increase transport ability, raise traffic volume, increase efficiency and decrease unit transport cost. Double-stack container train would be a new point of economic growth.

(4) Save container transport costs, and increase railway company economic benefits

With the same train length and same transport conditions, double-stack train can increase railway carrying capacity. One two-way drive double-stack container train can save nearly 0.5 time running line. On Jing-Hu, Jing-Guang line, double-stack container train can save ￥30 million costs by decreasing circumambulate; Longhai line can save ￥26.70 million.[7] Therefore, on a full transport rate railway, we should operate double-stack container train to increase railway transport capability and transport earning.

University paper>. Page 31-33, No.27, Vol.1

[10] Yan Meifen(2002): Double-stack rail container transport and container A preliminary study on building site. Page 21-25, Vol.4

[11] China Academy of Railway Sciences (2002): The research of double-stack container train between Beijing-Shanghai[R]. Page 54-57, 65-68

Double-stack container transport is still at the initial stage in China. Although we can learn from foreign country's experiences, we still have many organization problems due to China's special circumstances. For example, we should analyze the type of container train, the marshalling of the double-stack container train, container station management, and the operation and organization of container train in order to develop successful solutions and suggestions.

1.4 Organization & Structure of the Dissertation

Chapter 1 is the introduction of American railway double-stack container train survey and the double-stack container railway's significance in China.

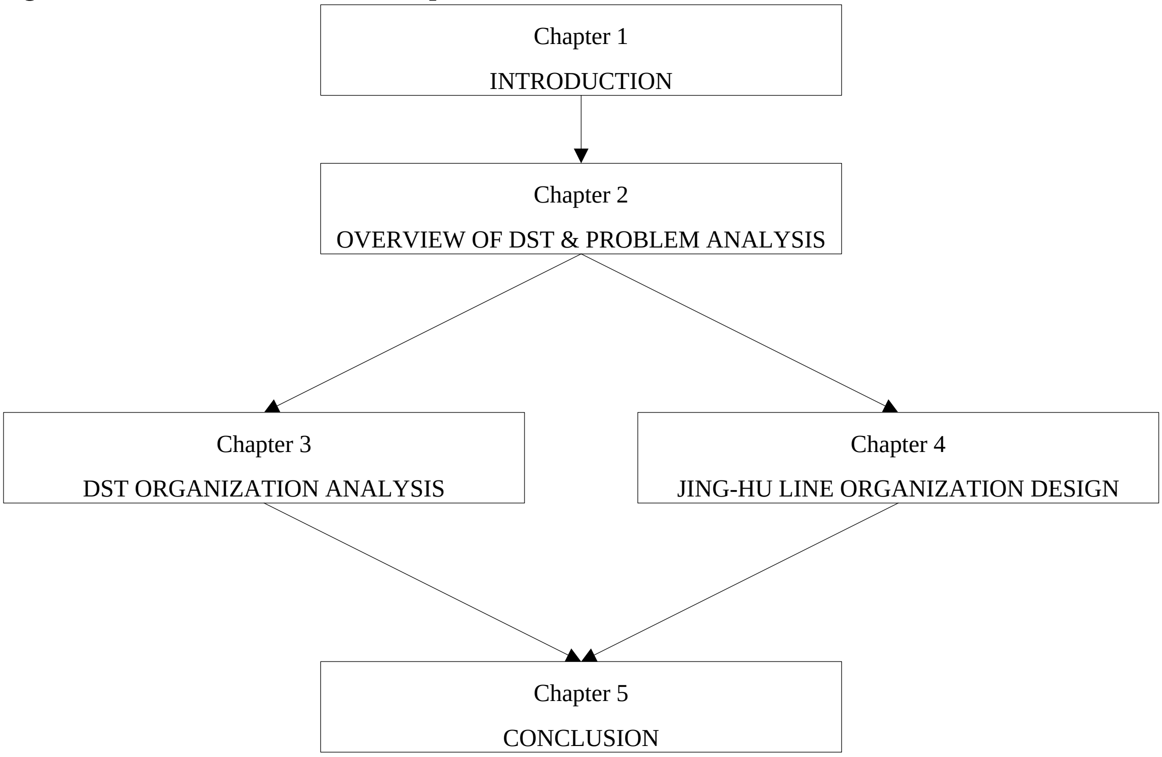
Chapter 2, summing-up China railway's developing problems and give suggestions based on the summary of foreign double-stack container train transport development and the analysis of China's double-stack container train present situation.

Chapter 3 highlights the double-stack container train organization research, it contains the organizing principle, organizing type, the weight of double-stack container train, the running speed, the timetable of double-stack container, the marshalling schedule design, container train wagon number design, and container train work manager on departure station, delivery station and train dispatch.

Chapter 4 is based on chapter 3's research results and double-stack container flow detail research between Beijing-Shanghai. It will give designing the double-stack container's running schedule and marshalling plan which is the main part of the hold organization research.

Finally, chapter 5 gives the conclusions that have been derived from the research. Also, recommendations which the author wishes to recommend to organization design of Beijing-Shanghai Double-stack container train will be present.

Figure 1 Structure of the Research Paper



Source: Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line)

CHAPTER 2 DOUBLE-STACK CONTAINER TRANSPORTATION (DST) ORGANIZATION METHOD

2.1 U.S.A, Canada and Australia's DST organization method

2.1.1 DST organization method in U.S.A

APL is the first company that started to operate double-stack container transportation between Seattle and Los Angle on the west coast, and in Chicago and many East Coast cities. APL is responsible for container train and cargo supply. The railway company supplies railway and traction power (Locomotive). Charges are based on the distance to APL. The initial APL container train has 100 compartments, is 1690 meter long and can transport 200 40ft containers. From Los Angles to Seattle and Chicago, the distance is 3540 km, running time is 53.5 h and the top speed is about 113km/h[12]. By May, 1987, more than 12 railway companies and 11 sea transportation companies have double-stack container transportation service, 59 double-stack container trains serves between the West and East Coast, and container capacity raised over 12000 TEU. The double-stack container transport has the advantages of high efficiency, low operating cost and high speed. In fact, double-stack container transport is faster than the transport by ship from the Panama Canal by14 days[13].

In the United States, the total train capacity increased with the development of railway standards and vehicle manufacturing technology. The new technology appeared, consisting of 5 groups of double-stack container trains which use 125t[14,15]

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12 Richard D Coir(1992): The United States designed double-decker container trains & Mat Hannes(2004): American Intermodal Double-stack Railcars [EB/OL] http://www.trainweb.org/intennodal/

13 Che Dehui(1992): The new development of container transport--Double-decker container train transport < Railway Freight Transport>. Page 22-26, Vol.4.

14 It means every 2 bogie can transport 125t.

15 Yang Qingbo(2004): United States inter-modal summary < Railway Freight Transport>. Page 41, Vol.5

Bogie to connected each group[16,17].

Table 2-1 Category of double-stack container train in USA[18,19]

TYPE	LOADING FORMS	MAX GRAVITY HEIGHT (mm)	MAX SPEED (km/h)
DTTX 5 Group vehicles	Lower: two 20ft container(or one 40ft~48ft container) Upper: one 40ft~53ft container	2535.53	126
DTTX 3 Group vehicles	Lower: two 20ft container(or one 40ft~48ft container) Upper: one 40ft~53ft container	2535.53	126
DTTX Single vehicle	Lower: two 20ft container(or one 40ft~48ft container) Upper: one 40ft~53ft container	2514.22	126

Source: Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line). Summarized from: Research report of China double-stack container train's operating problem [R] Beijing and China railway institute of Science and Technology (2003): Main problem research of double-stack container train operate

In the 1990s, the Unite states had 10000 double-stack container train groups and 200 specialized double-stack container trains operating each week. During this period, there were two grouping ways: 1, each train has 20 units; each unit consisting of 5 double-stack container cars. 2, Transport by 113t one stack container train with a total gross nearly 10 thousand tons. These kinds of specialized container trains use 4 traction engines[17].

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16 APL (1996): The Intermodal Safe Container Transportation Act and Amendments, a Handbook for Shippers.

17 Railway ministry research institute (2003): Main technical matters research of China double-stack container transport. Page 4-5, 68-71.

18 Research report of China double-stack container train's operating problem[R]. Beijing

19 China railway institute of Science and Technology (2003): Main problem research of double-stack container train operate Vol. 4-5th, page 68-71

Now, double-stack container train transport is of great importance in the United States' transportation market. Specialized double-stack container trains run between each main port, big cities and container stations. These container trains were 2~3km's long, had 150~220 Groups, consisted of single vehicle DTTX, 3Group vehicles DTTX or 5 Group vehicles DTTX. It can transport different sizes of containers: 20ft, 40ft 45ft, 48ft and 53ft. Special container trains made transport cost much lower than car transport. Gradually double-stack container train transport would replace car transport. Now, the double-stack container train's capacity comprises 80% of total container train transport in the U.S, and the rail way transport comprises 80% of the total market, Car transport now comprises only20% of total railway transport. 20 years ago, it just the opposite.[20]

The advantage of double-stack container trains in the U.S.A[21]:

(1) Due to High building standard, railways can support 35.7t heavy train, enabling them to use 3 Group and 5 Group vehicles to shorten container train length.
(2) The use of diesel trains allows easy transformation of tunnels, bridges and railways.
(3) The use of highly effective traction engines can transport 3 hundred 40ft container and 2 crews.

[20] Ministry of Railway, Beijing:, International Cooperation Department Ministry of Railways, Investigation trip abroad report. No.377, Page 519-528, 533-534,543-546,562-570

[21] The Second survey and Design Institute China Railway [FSDI] (2003) Chengdu China Development and Cooperation office: railway container station's preliminary work assessment report. Page 1-8, 9-30, 42-46, and 83-93, 107-140, 199-208, 251-258, 367-408.

2.1.2 DST organization method in Canada and Australia

In 1985, Canadian Railway Corporation (CN) operated a double-stack container train in east Canada in order to distribute Atlantic coast port containers. Delta Vancouver port railway container yard, BIT container yard in Toronto CN, and Toronto container yard CP Co have run 4-5pair specialized container trains, most of them double-stacked.[22]

Canadian double-stack container trains are built up by 80~130 Group, over 2 km long with the deadweight between 10000~15000t[23].

Australia's double-stack container transportation started in 1980. The primary design used half height container on the lower floor, and twenty feet equivalent unit on the top floor. In 1989, double-stack container railway transport was first used in Adelaide to Whyalla railway transport by Australia's state-owned railway, Co. Then the practice of double-stack container transportation became successful in Australia.

In east Australia, double-stack trains did not run, because of many tunnels in the railway line and the electricity powered traction engine. The cost of transforming railway system to operate double-stack container trains was too high. In Western Australia, exactly the opposite situation exists. Therefore, the double-stack container railway transport has been widely used. At present, double-stack container railway container transport accounts about 50% of the total Australia railway transport volume.[5]

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[22] TRIMAC (2001): Operating Cost of Trucks in Canada-2000, Final Study Report; & Ata M.Khan. Canada. (1995): Canadian heavy-duty transport technology

[23] "China rail way"(2002): China railway Canada railway investigating group—Canada railway transportation organization and freight yard manage Report Page 44-46, No.6

2.2 China's DST organization method

2.2.1 Present situation of DST organization

The Jing-Hu line is the busiest railway line, via Beijing, Tianjin, Jinan, Xuzhou, Nanjing and Shanghai 6 railway hubs. Between Beijing and Shanghai, there are 5 road network stations: West Fengtai, West Jinan, South Xuzhou, East Nanjing and Nanxian. In 2001, the China Railway Ministry has organized a research, named as the <Research of the feasibility of Beijing-Shanghai double-stack container train Transport>. This study has done a comprehensive survey of the Beijing-Shanghai railroad, including considerations of flat condition, vertical section, track, roadbed, bridges, tunnels and station equipment. The total length is 1452km.The study concluded that the Jing-Hu line is a best railway line to run DST in China.
On April 15, 2004, the China Railway Ministry issued a <China Double-stack container railway transport management scheme>, which is the first Guidance document available to China's double-stack container railway transport. The document ruled that double-stack container transport should use international standards of 20ft, 40ft or 48ft container. Temporary, height restrictions are 2438mm and 2591mm, the full case weight should not exceed 78t, and a full car's gravity height should not exceed 2200mm. The Double-stack container train's running time and running way should be in strict compliance with the China Railway Ministry's organization design, and the speed should not exceed 80km/h[24].

The document also defined the principle of loading programs, station conditions, operating requirements, relaying operation work conditions, and the contents of examinations. The document determined the double-stack container transportation's operation method, the reliability of security management, transportation management organizations and the units responsible for security. The government has modified

[24] China railway's environment condition is different as other countries. At the same time, the nominal tractive capacity is 5000t, which can not support heavier train and high speed.

the <China Railway Traffic Rules> and the <Train Station Work Detail Rules>.

The first operation of the double-stack container specialized train between Beijing-Shanghai was in April 18th, 2004. The two-way train started from East Beijing, traveled through Fengtai, Huangcun, Hengshui, Dezhou, and arrived at Yangpu[25]. Each train can transport 152 TEU, and had a runtime of 38h from Beijing to Shanghai, 46h from Shanghai to Beijing. In the other word, one trip was run every two days. This specialized double-stack container train has improved logistic efficiency and duration, and improved the capacity of rail transport.
At the very beginning, the train ran two times a week from East Beijing station, normally every Tuesday and Friday. From March 8th, 2005, the time table changed to three times a week: every Tuesday, Thursday and Saturday from East Beijing station to Yangpu station, and every Monday, Wednesday and Friday from Yangpu station to East Beijing station.

The Double-stack container train transportation uses contracted management operation method; commodity supply and packing were the responsibility of the contractor. The railway station was only responsible for transport services and relaying operation work.[26,27]

In 2004, the number of runs of freight trains was 160. In 2005, it increased to 292 runs. Also, the total transport quantity went from 13530 TEU to 18941 TEU in this time period. Statistical data of transportation demonstrated that the commodity from Beijing to Shanghai had sufficient supplies. The freight source from Shanghai to

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[25] China railway ministry, 2004: double-stack container railway management method proposed regulation.[S]

[26] “China Railway United Logistics Co., Ltd.”: It have contract for Double-stack container train transport service from Beijing to Shanghai, they have provide commodity transport, light industry product transport, stone material transport and chemical products.

[27] “Hongda Logistics Co., Ltd”: .It have contract for Double stack container train transport service from Shanghai to Beijing, they have provide paper transport services, food transport service, cigarette transport service and electronic product transport service.

Beijing was much lower when compared to the Beijing to Shanghai line. At the same time, by the restriction of container transport prices and vehicle load conditions, cargo owners always use 20ft container. The 48ft container was not as popular because of the low height and long length.

On April 18th 2007(Picture 2), as a sign of China railway "No 6th electrification (Picture 3) and speed development", the double-stack container train between Beijing and Shanghai has changed greatly. The starting place from Beijing to Shanghai has changed to Da Hongmen logistic station in Beijing in order to decrease the effect of the Fengtai railway hub (Picture 4). After this innovation, the train runtime was shortened by 11 hours. In additional, China will run several new double-stack container train lines: Between Huangdao and Zhangzhou, Beihai and Fuquan, Nanchang and Lu Cao port, Tao jiazai and Lian Yungan.

(1) China double-stack container train organization method

The double-stack container train between Beijing and Shanghai was running by the "Five scheduled train"[28] running program.

Picture 2 Jing-Hu line DST First Run

Source from: cnsphoto 4.18th 2007

[28] "Five scheduled train": Scheduled Station (Scheduled loading station and unloading station), Scheduled Time (Cargo delivery time), Scheduled Route (Running route), Scheduled Train (Fix non-stop train number), Scheduled price (Fix transport fee). This is a new promise of China railway, it would be improve China railway's credit and raise up competitive power.

Table 2-2 Time table of Beijing-Shanghai double-stack container train

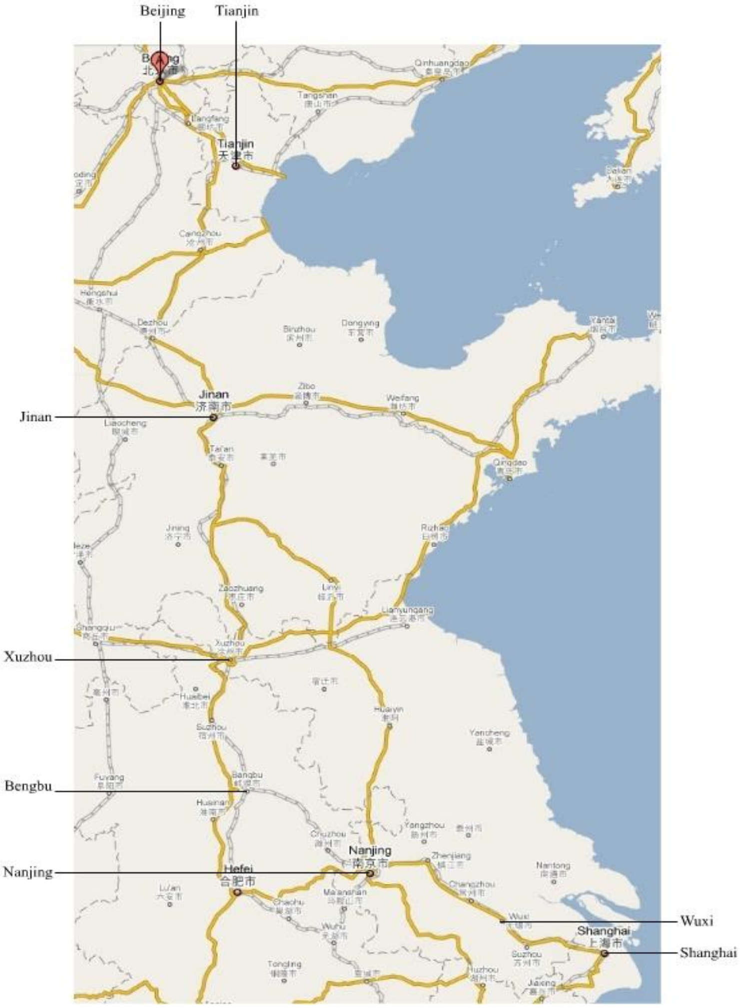
Direction	Train number	Frequency	Depart and arrived time
Beijing-Shanghai (down train)	No.80311	Every Monday, Wednesday and Friday	East Beijing Station:23:59 Yan Pu Station: After 3 days 14:33
Shanghai-Beijing (up train)	No.80734	Every Tuesday, Thursday and Saturday	Yan Pu Station: 0:07 East Beijing Station: After 3 days 0:39

Source:South Shanghai railway station manager office. Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Beijing-Shanghai)

Picture 3 Jing-Hu Line No 6th electrification revolution

Source: From internet, cnsphoto. http://finance.yinsha.com/file/200606/2006060216300567/1.jpg

Picture 4 Beijing-Shanghai line (Jing-Hu line)



Source from: Google map. City name signed by author
http://maps.google.com/maps?hl=en&tab=wl

According to the requirements of the cargo owners, the container train added a carriage drop and pull (D&P) work at south Wu Xi train station in 2005.[29]

(2) China double-stack container trains railway marshalling

At present, the double-stack container train cycle uses 5 depressed centre flat wagons, and is restricted by the min single traction parameter and the effective length along each stop. Under these restrictions the capacity was 38 vehicles and 4000t weight. The double-stack container train's single traction engine parameter was over 4000

[29] "Drop and pull work in Wuxi train station": Train Running from Beijing to Shanghai, drop carriage in south Wuxi train station, the rest train directly drive to Yang Pu station, the dropping carriage have handling work in Wuxi, pull on the end of Shanghai to Beijing train, arrived North Beijing station.

tons, so this specialized double-stack container uses a single traction engine.

What is more, Chong Qin railway ministry was announced that railway between Chong Qin and Cheng Du was finished electrification update to adept double-stack container train operate. After electric locomotive update, it will cut down 200thousand Yuan transport cost per day between Zhengzhou and Xuzhou.

2.2.2 Present problems of China's DST organization

(1) Low speed, time consuming and no obvious competition as car transport
(2) On-schedule rate low[30]
(3) Inadequate supply of 48ft container wasted transport capability because some double-stack container trains were running with only a single floor container.
(4) Double-stack container train stations lack specialized loading equipment[31] (Picture5, Picture 6) have narrow and short loading area and have no capability of handling the entire train. It caused low container loading efficiency, low transport efficiency and long turn-around time.
(5) Double-stack container train's transport capability was imbalanced and inadequately supplied.
(6) Double-stack container train only operated between Beijing and Shanghai, which is a route that is not widely used.
(7) The management of container transport was still under-developed and there is no Container Transport Management Information System.

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[30] The running timetable design that from Beijing to Shanghai would cost 38h, from Shanghai to Beijing would spend 46h. In fact, the better situation is 3h or 4h delay, under normal circumstances should be delayed over 10-20h, sometime even has 100h delay. It has caused very bad effect of double-stack container train transport's market reputation.

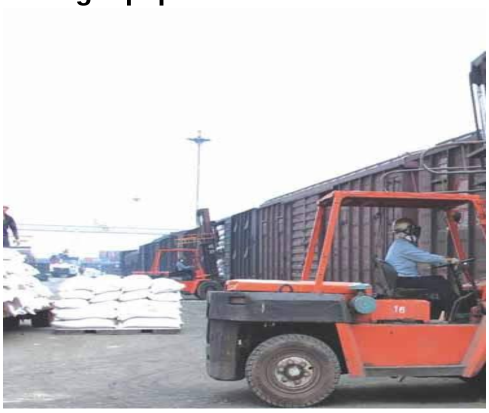
[31] In 2007, east Beijing Station Lake of unloading equipment and Wuxi station lake of 48ft container loading machines.

Picture 5 Traditional handling method

Source: From internet http://www.humanrights-china.org/china/newspic1/200512/zta05122827.jpg

Picture 6 Technological handling equipment

(1)



(2)

Source: Picture 6(1) pictured by author, from Shanghai railway west railway station: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line)

Picture 6(2) from internet http://www.fcport.com/fcpunder/duozhongjying/mutimage/huoche_r1_c1.jpg

2.2.3 China's DST organization Problem Solving analysis

There are 7 problem-solving points:

(1) In train dispatching, raise container train's running level to the passenger train level in order to avoid delay.

(2) Speeding up the train to shorten transport time. Shorter turnaround time will result in timeliness and competitive advantages.

(3) Include Double-stack container train's loading transition plan[32] into objective plan[33] in order to change the inadequate supply problem and the increasing load factor.

(4) Equip professional loading equipment to train stations, expand and rebuild double-stack container train stations. This increase loading and transport efficiency.

(5) By improving service quality, reducing container transport cost and increasing marketing efforts, we can attract commodity supply. To get rid of the inadequate supply problem and the transport capability distribute imbalance, the division of work should be more professional, disperse container should be accepted, load should be concentrated and the allocation of commodity supply should be optimized.

(6) To speed up double-deck container transportation development and build double-stack container transportation nets.

(7) To establish a fully functional container transport management information system to increase the management level of the double-stack container train station.

[32] Lower floor (type 1): two 2591mm height 20ft containers, Top floor: 2438mm height 48ft container

[33] Lower floor (type 2) two2591mm height 20ft containers, Top floor: 2896mm height 40ft container

CHAPTER 3 DOUBLE-STACK CONTAINER RAILWAY TRANSPORTATION ORGANIZATION CONTENTS

3.1 DST railway organization's basic principles and organization forms

3.1.1 DST railway organization's basic principles

China's domestic transport environment and transport policy are very different from U.S.A, Canada and Australia. The Characteristics of the Chinese container trains railway organization's basic principles are as follows:

(1) The train dispatch schedule should be developed based on careful research of actual transport quantity and precise forecasting.

(2) China's organizational design should extract the experience of "Five scheduled train" special train operation and the foreign country's organization projects.

(3) According to China railway's truth and commodity supply distribution condition, China's double-stack container train should be based on the principle of the container freight liner model, assisted by the irregular train schedule.[34]

(4) Upgrading container train's service level as a passenger train.[35]

(5) Complete infrastructure and support facilities for each container train system.[36]

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[34] "Principle of container freight liner, assist by irregular train": Because China's commodity supply distribute condition is so imbalance of different transportation hub. In the main inland hub have steady cargo supply, it drive container freight liner. But in the main ports, it cannot ensure to have a steady supply, should use irregular train in order to avoid waste.

[35] "Upgrading service level": Updating service level as passenger train in order to adapt fast, efficient service demand

[36] First, make sure that container train run every day between 18 center stations before specialize container station build. Second, build specialize container station; Run the trip between center stations and special station.

3.1.2 DST railway organization forms

(1) Non-stop double-stack container train[37]

Running between container services transit stations with sufficient transport capability and commodity supply. The sticking points are that the train cannot be stopped for either loading work or Drop and Pull work.

(2) loading and unloading operated on trip train[38]

Running between container services transit stations with sufficient transport capability and commodity supply. When the container train approaches several double-stack container train service transact stations, it will have sufficient handling resources.

(3) Have Drop and Pull work double-stack container train[39]

Running between container services transit stations that have sufficient transport capability and adequate commodity supply. It will have drop and pull work systems in several container services transit stations.

[37] "Non-stop train services": This kind of train have special routes on the driving map, totally working by passenger's request that it can supply forecast consignee service, booking service, driving on time, planned receiving service, use fix depressed centre flat wagon, recycle use, do not have Drop and Pull work, do not run on the peaking time, do not have throwing work (in distribution zone) and have fixed marshaling. Non-stop train is the fastest running form.

[38] "Handling work on trip train": This kind of train have special routes on the driving map, followed "Five scheduled train" rules, Scheduled place, Scheduled time, Scheduled d route, Scheduled train, Scheduled price, also it have fixed marshaling recycling use depressed centre flat wagon and do not have Drop and Pull work, do not run on the peaking time, do not have throwing work (in distribution zone). It was so convenience to transport container to small train stations, but also have high request for loading equipment.

[39] "Drop and Pull (D&P) work double-stack container train": This kind of train have special routes on the driving map, followed "5 Fix" rules, Scheduled place, Scheduled time, Scheduled d route, Scheduled train, Scheduled price, also it have fixed marshaling recycling use depressed centre flat wagon and do not run on the peaking time, do not have throwing work (in distribution zone). It have D&P work on the trip, drop and pull work carriage always in the end of the train, in order to shorten D&P working time. The special train between Beijing and Shanghai was running on this kind of design.

(4) Irregular double-stack container train[40]

Running between container services transact stations which do not have adequate commodity supplies.

3.2 Double-stack container train's weight and speed decided

The Double-stack container train's weight and running speed are decided by the container train's carriage number and arriving time which have a directly effect on the railway's transport ability, service quantity and equipment service efficiency.

Double-stack container train's weight was determined by the traction engine's parameter[41]

In the trial operation period, container train's top speed is 80km; formal running speed is 120km. There are two elements involved in making a certain carriage quantity:

- traction engine's parameter
- train's available length[42]

Example 1: Give that one double-stack container train's min traction engine's parameter is $Q_{(t)}$, the double-stack container train's weight is $P_{1(t)}$,the average stow weight is $P_{2(t)}$ [43], the train weight is $P_{3(t)}$, So the max carriage number would be m_1[44] as determined by the traction engine parameter equation:

$$m_1 = (Q - P_{3(t)}) / (P_{1(t)} + P_{2(t)}) \quad (3\text{-}1)$$

[40] "Irregular double-stack container train": Do not have fixed depressed centre flat wagon, do not have fixed time, and do not have fixed stop station, marshalling temp and no special routes.

[41] "Traction engine's parameter": In normal the tractor's parameter would over 5000 tons.

[42] "Train's availability length": It means train's length should not be longer than loading area, otherwise workers cannot handle cargo.

[43] Average stow weight would be decided by container quantity, container weight and container average stow weight.

[44] Yan Haifeng (2004): Node station railway container transportation organizations, theoretical and methodological research

Example 2: Give that the availability loading area from stop place to start place is $L_{1(m)}$ long, the double-stack container's carriage is $L_{2(m)}$ long, the traction engine is $L_{3(m)}$ long, and the safe train stop distance is $L_{4(m)}$ the max carriage number would be m_2[24] which is determined by the availability loading area length equation:

$$m_2 = (L_{1(m)} - L_{3(m)} - L_{4(m)})L_{2(m)} \tag{3-2}$$

We should choose the smaller value between m_1 and m_2 as the max suitable double-stack container train's carriage number.

3.3 The Constitution of the Running Program of DST

To constitute a working program for the double-stack container train system, we should use the exchange data between the container freight stations as the basis. This taken together with the weight and the number of double-stack containers on different track sections, the running sections which contain the origin stop terminal and routes, the classification of the train, and the order of the train will develop a successful working program. The choice of the double-stack container train's railway routes should follow these rules:

(1) To satisfying the rail capacity requirements、axle weights、bounds and operation stations, resulting in the lowest value become the best choice. When there is a lack in the transport capacity of some shortcuts, the double-stack container trains can make a detour to relieve the force caused by it.

(2) The working path of the double-stack container trains should be adjusted in accordance with the development of the train relaying operation tube.

According to the rules of choosing the double-stack container trains railway routes, a comparison is needed between the transport routes of different double-stack container stations. When compared, the following factors should be considered: the distance, time, and the adaptability of districts along the way, carrying capacity of the stations, and the tonnage rating for the districts.

According to the capacity of container flow between the double-stack container stations, - the following double-stack container trains conditions can be considered: nonstop, stevedoring, drop and pull transporting, and non-scheduled.

According to the amount of container flow between double-stack container stations, we can consider the following running time tables as options: ① several runs per day ② onetime per day ③ five runs per week ④ four runs per week ⑤ onetime per every two days ⑥ three runs per week and ⑦ two runs per week.

3.4 The Constitution of the Working Program of DST

After designing the running program of double-stack container trains, the requirements of the design of the double-stack container train routes should be determined by the following criteria: the time parameters of the running design, the technical operation, the drop and pull transport, and the stevedoring of containers necessary for the route. The design of the running program of the double-stack container train routes regulate the time of arrivals, departures, passages, parking of every station and the running speed and time of every district.

There are several rules for developing a working program for double-stack container trains.

(1) To reduce the stops and the parking time of the double-stack container trains, and increasing speed, the train turnaround time is decreased, ensuring that the goods arrive on time.

(2) The time of departure and arrival of double-stack container trains and the arrival-departure time during the stevedoring should be well connected with the time of shipping, loading, unloading and relaying.

(3) We should accelerate the turnover of trains and depressed centre flat wagon and put the trains into better use economically. To make sure of the effective utilization of the depressed centre flat wagon we should rationally connect the time of several different trips to share the same depressed centre flat wagon and

avoid wasting time.

(4) Good coordination should be established among the running routes of double-stack container trains, passenger trains and other freight trains to improve the transport capacity and raise the utilization ratio in a rational fashion.

(5) The working of the double-stack container train should align with the technical operation of the stations.

(6) The relation between the arrival-departure time and train density, the uses of depressed centre flat wagon, locomotive routing, and the closing sections for construction should be optimized.

3.5 The Confirmation of the Needed Number in the Depressed Centre Flat Wagon (or Train)

Due to its particularity, the depressed centre flat wagon usually can be used in the inter-transportation between stations (i.e. one depressed centre flat wagon runs for two trains), or for the inter-transportation among three or more stations (one depressed centre flat wagon runs for three or more trains). The former one is applicable when two stations have the same container flow, while, the latter one can be used when three or more stations have circling container flow. The runs of every week should be the same when we run two or more double-stack container trains per week.

The turnaround time of the depressed centre flat wagon is the time it takes for one round-trip from the allocated station. According to the turnaround time of the depressed centre flat wagon and the running schedule, we can determine how many depressed centre flat wagons we need between one station and another.

For example, if one double-stack container train's depressed centre flat wagon turnaround time is θh and every week K trips are run, two trips a day means that K=14; For one trip a day K=7; For one trip every two days, K=3.5; If 3 trips a week, K=3; If two trips a week K=2 Thus, the container train's depressed centre flat wagon demand number N, can be calculated from the following equation:

$$N = (\theta / 24) * K / 7 \qquad (3\text{-}3)$$

3.6 The Organizational Work of the DST in the Departure Station

3.6.1 The Content and Procedure of Freight Operation at the Originating Station of the Double-stack Container

(1) Shipping and Accepting

Consignor declares the container loading arrangement to the station. The station then verifies the size, number, type, weight and details of the consignee.

(2) Claiming the Empty Container

When the consigner loads the cargo by him selves, they can get empty container by the empty container delivery order.

（3）Loading Cargo

① Cargo loading by consigner: The consigner takes charge of loading cargo and delivering to station.

② Cargo loading at the station: The station should follow the demand of consigner.

（4）Weighing

① All the containers should be weighed. The container weight report should be saved independently for distribution.

② Indicate that the lorry arrived at the specified place.

(5) Check and Seal

The container loaded by consigner must be checked and sealed by an officer and a consigner.

(6) Distributing and Loading of the Double-stack Container

According to the loading demand of the double-stack container, we can distribute and load based on the actual weight. Then two copies of the “double-stack container distribution and loading schedule" are needed for the receiving clerk and the loading and unloading group.

(7) Signing Bill of Lading and Carriage

Account for the freight clerk's shipping document, receive transport fee and stamp data on the shipping document.

(8) Handling

Freight clerk gives stevedore working order through the "Double-stack container distribute schedule" document. The stevedore should observe 6 kinds of checking work.[45]

There are 3 different kinds of loading conditions:

① Direct reloading container[46]

② No special requirement loaded container[47]

③ Special requirement loaded container[48]

(9) Feedback and send order

The cargo survey officer will systemize document and made double-stack container train's loading list. After they check train number, container number and document, officer will fill in the "Double-stack container distribute schedule" and inform the container loading details to the consignee.

---

[45] "6 checking work": First 3 check: Before loading cargo, they should check vehicle condition, check train number and check container number. Second 3 check steps, after finish loading cargos they also should be check vehicle condition, train number and container number, what is more, stevedore should be check container connecting lock was locked up; middle floor's special use lock was locked up. At last, they should fill up "Double-stack container distribute schedule".

[46] "Direct reloading container": This kind of container's arriving time can be perfectly connected with double-stack container train's departure time and it can be directly transferred into double-stack container train without any stop.

[47] "No special requirement loaded container": This kind of container cannot be connected with departure train that it should be stored in container yard.

[48] "Special requirement loaded container": This kind of special requirement needed container should be unloaded to Customs Surveillance Zone or other special use keeping yard, after finish special require work, container will transferred to double-stack container train.

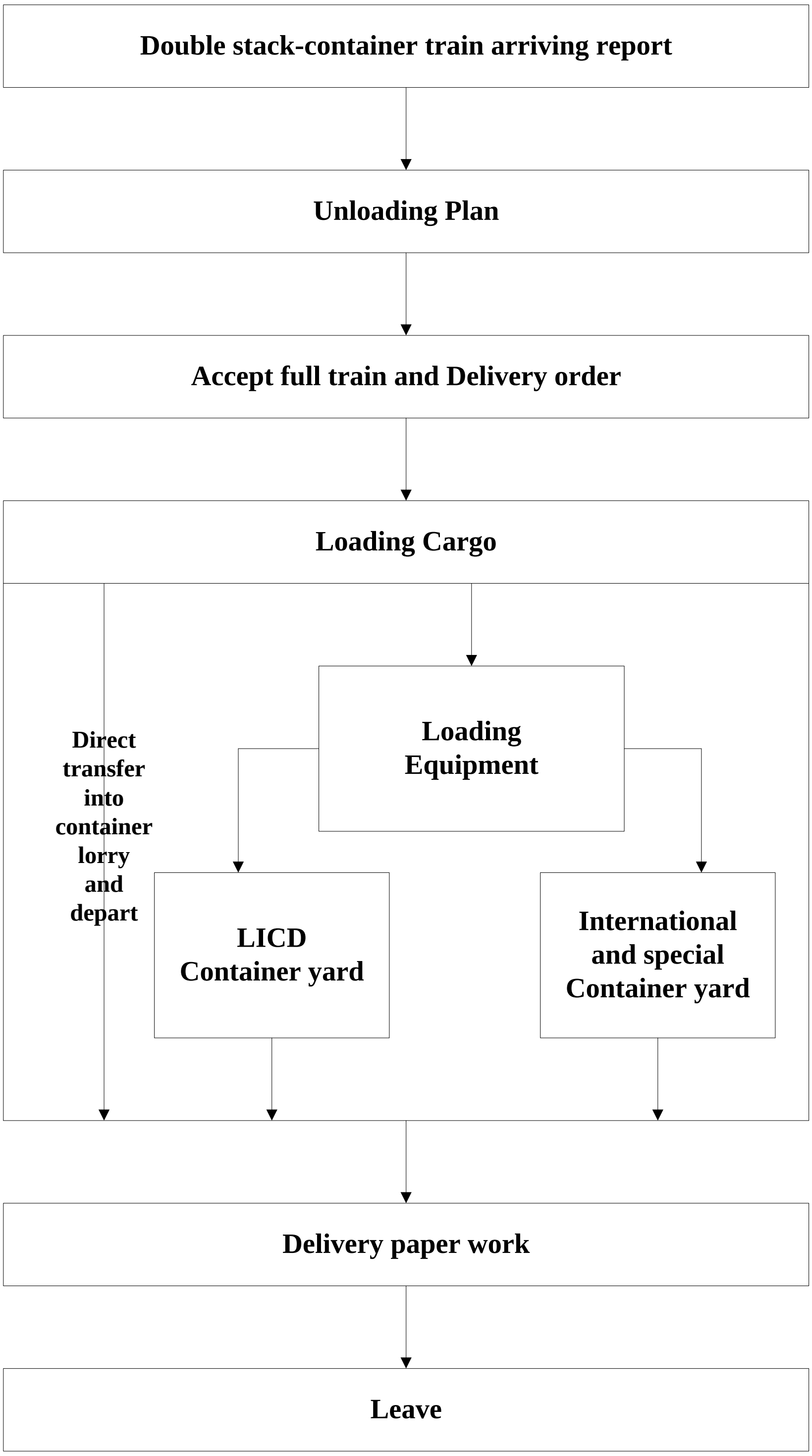

Figure 2 Sending procedure of container flow chart

Source: Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line).

3.6.2 The Operation Stage and Procedure at the Departure Station of the Double-stack Container

When the double-stack container train is loaded, the train can depart from the loading area directly. And after the handover and security check, the traction engine pulls the trailer out to the loading area. The loaded double-stack container train should be handed over and checked. When fully loaded, the double-stack train needs to depart from the forwarding siding, have a security check, a cargo survey, a train number check, a container number check and a relaying delivery order documents. The technical operation of the double-stack container train at the departure station: technical testing, shipment check, pull the carriage, air test and departure. Technical procedure and time standard of double-stack container train at origination (Table 3-1)

Table 3-1Technical procedure and time standard of double-stack container train at origination

Order	Project	Working time (min)									Time standard
		5	10		20		30		40		
1	Carriage inspector, Car accountant and Goods examiner's work										0
2	Technical Inspection (Contain: Change of locomotive and air test)	5	5	5	5	5	5	2			32
3	Cargo Check	5	5	5	5						20
4	Car accountant check car number	5	5	5							15
5	Driver receive bill notes and train	5	5	5	5						20
6	Get ready to depart and start							5	5		10
Total time		5	5	5	5	5	5	5	5		40

Source: Fujian Railway ministry General Office. Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line)

3.7 Work Organization of the DST

According to the specialty of the double-stack container train, the technical work of every stop can be divided into three kinds:

(1) No handling work, drop and pull work and transshipment when the train is on its way. The main technical work: technical testing, shipment check, pull the carriage, air test and depart. (Table 3-2)

Table 3-2 Technical procedure and time standard of double-stack container train at intermediate station (1)

Order	Project	Working time (min)									Time standard
		5 10 20 30 40									
1	Carriage inspector, Car accountant and Goods examiner's work										0
2	Technical Inspection (Contain: Change of locomotive and air test)	5	5	5	5	5					25
3	Cargo Check	5	5	5	5						20
4	Car accountant check car number	5	5	5							15
5	Driver receive bill note and train	5	5								10
6	Hanging Locomotive						5				5
7	Get ready to depart and start						5	5			10
Total time		5	5	5	5	5	5	5			35

Source: Fujian Railway ministry General Office. Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line)

(2) Drop and pull work: technical testing, shipment check, drop double-stack container carriage or pull, drop and pull traction engine, air test and depart (Table 3-3)

Table 3-3 Technical procedure and time standard of double-stack container at intermediate station (2)

Order	Project	Working time (min)										Time standard
		5 10 20 30 40										
1	Carriage inspector, Car accountant and Goods examiner's work											0
2	Technical Inspection (Contain: Change of locomotive and air	5	5	5	5	5						25

	test)											
3	Cargo Check	5	5	5	5							20
4	Car accountant check car number	5	5	5								15
5	Drop or hanging double-stack carriage						5	5	5			15
6	Driver receive bill note and train	5	5									10
7	Hanging Locomotive and air test									5		5
8	Get ready to depart and start									5	5	10
Total time		5	5	5	5	5	5	5	5	5	5	50

Source: Fujian Railway ministry General Office. Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line)

(3) Handling work: technical testing, shipment check, loading and unloading container, drop and pull traction engine, air test and depart. (Table3-4)

Table 3-4 Technical procedure and time standard of double-stack container train at intermediate station (3)

Order	Project	Working time (min)													Time standard
		5	10		20		30		40		50		60		
1	Carriage inspector, Car accountant and Goods examiner’s work														0
2	Technical Inspection (Contain: Change of locomotive and air test)	5	5	5	5	5									25
3	Cargo Check	5	5	5	5										20
4	Car accountant check car number	5	5	5											15
5	Drop or hanging double-stack carriage						5	5	5	5	5	5			30
6	Driver receive bill note and train	5	5												10
7	Hanging Locomotive and air test												5		5
8	Get ready to depart and start												5	5	10
Total time		5	5	5	5	5	5	5	5	5	5	5	5	5	65

Source: Fujian Railway ministry General Office. Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line)

3.8 Work Organization of Double-stack Container Train's Arrival

3.8.1 The Operation Stage and Procedure at the Destination of Double-stack Container

When a container train arrives on the arrival and departure track the following activities need to occur: First, they should have a train examination in both the arrival and departure work area. Second, loading and unloading by the traction engine.[49] Third, survey cargo with the container list and deliver transfer container's document to the cargo survey officer. The main technical work at destination is: technical testing and shipment check.

Table 3-5 Technical procedure and time standard of double-stack container train at destination

Order	Project	Working time (min)									Time standard
		5 10 20 30 40									
1	Carriage inspector, Car accountant and Goods examiner's work										0
2	Technical Inspection (Contain: Change of locomotive and air test)	5	5	5	5	5	5	5			35
3	Cargo Check	5	5	5	5						20
4	Car accountant check car number	5	5	5							15
5	Driver receive bill note and train	5	5	5	5						10
6	Get ready to depart and start						5	5			10
Total time		5	5	5	5	5	5	5	5		35

Source: Fujian Railway ministry General Office. Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line)

[49] When container train can direct drive into handling line, it should be tracking by train locomotive and start handling work after finishing paper work.

3.8.2 Main Content and Procedure of Arrival Operation

(1) The arrival report of the double-stack container train

24hours before its arrival, consignee should fax the relevant information (the arrival order, train number, container number, name, weight, consignee and so on) to the cargo division at the arrival station.

(2) Unloading plan

The cargo division should make three copies of the "Arrived container unloading design map" for: the freight dispatcher, the freight clerk and the loading group.

(3) Accept Full Train and delivery order

After the double-stack container train arrives at the station, the freight clerk should check the train and examine the goods. Then, the freight clerk can handover the full train and delivery order to either the conductor or train crew. The full train can be handed over to the freight office after the full train delivery order is registered.

(4) Unloading

When unloading, the freight clerk should abide by the demand of back office force. After that, the freight clerk should write down where the goods were unloaded. Arriving containers can be divided into three different types:

① Direct relaying container: when it's arriving, the container can have a good succession with transshipment station in the matter of time and without other operation. The goods can be directly unloaded from the double-stack container train by using the handling machinery to lorry.

② Container with no special operation demand: the container must be unloaded at an appointed place for storage until the lorry's arrival because of the discrete-time to connect and there is no special operation.

③ Container with special operation demand: if the container arriving has international packing or some other special demand, it must be unloaded at the packaging area. The container should then be transferred to either the

Customs Surveillance Zone or to another dedicated packaging area. After all these operations, the lorry can begin its packing.

(5) Handover

The station should notify the consignee according to the “sending schedule” (the place, size and number). With the letter of notice, the consignee can attend to the handover at the station with the voucher or a recommendation from the company. After paying the charge and stamping the date, the container can be handed over red. (Figure 3)

(6) Sending

After passing through the handover ring, the consignee can dispatch the container with sending permission. If train relays the container, the consignee takes charge of the opening and sealing of the container. The entire container should be cleaned out and sent back to the station. The station officer should charge an extra fee if the container is not turned back in time.

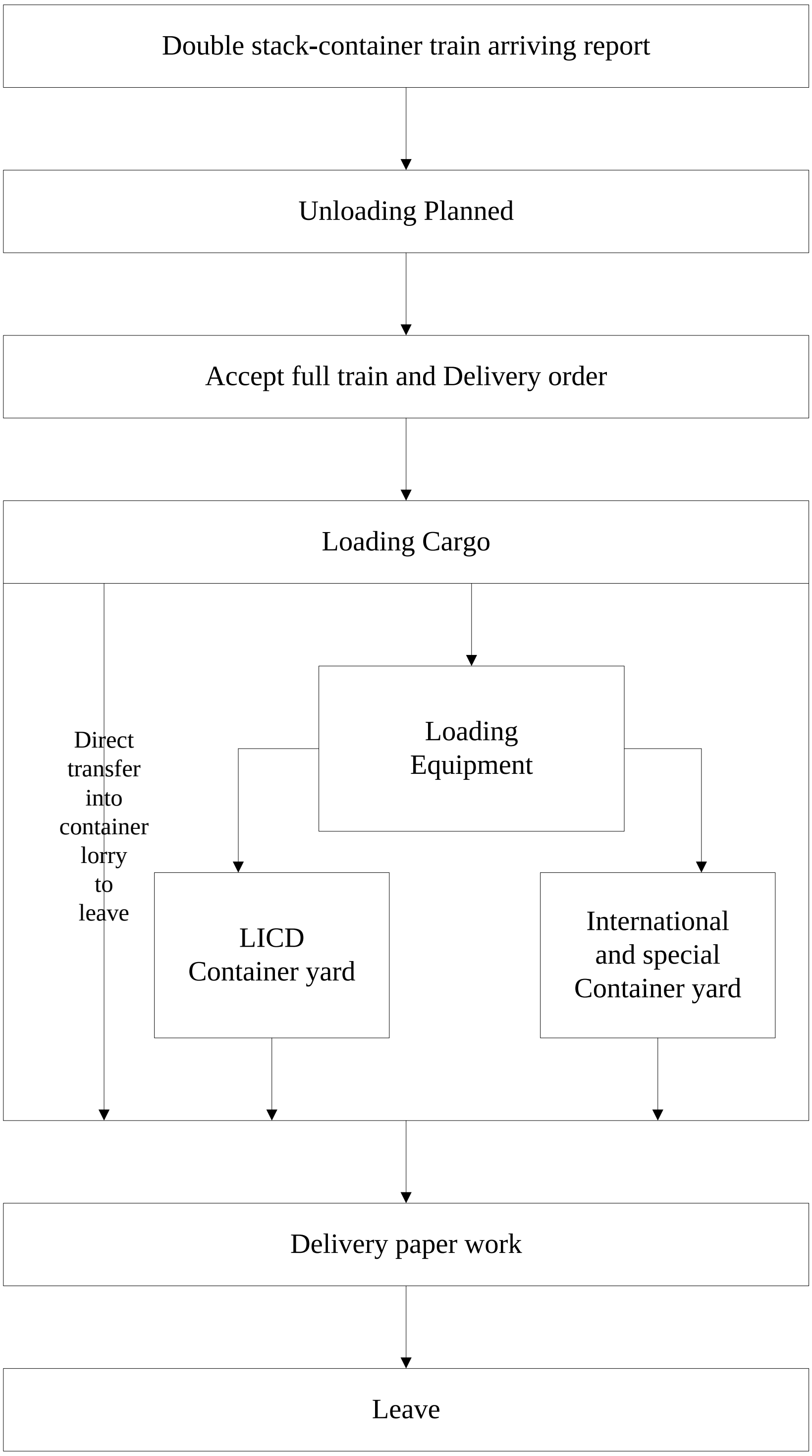

Figure 3 Arriving procedure of container

Source: Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line).

3.9 The Dispatch and Command Operation of the DST

The transportation of the double-stack container train also should abide by the rule of unity of command. The operation dispatching of China railway container transporting LTD should belong to the railway dispatching system. All the dispatching of double-stack containers should be comprehensive, prompt and accurate so as to know the dynamic transport well and finish the double-stack container transporting task.

The dispatching operation of the double-stack container is the most important aspect in the daily work organization of transportation. Its main task is to organize the double-stack container train operation in regard to timetables and continuous transportation operation. Precedence relation should be considered between double-stack container train and passenger train.

One hour after departure, loading railways bureau should report number, time, content, and weight of the double-stack container train to the transport control of Ministry of Railways and telegraph to railway bureau and unloading station. When dropping carriage or reloading occurred, the station should telegraph to departure, arrival station and the superior dispatching office.[50,51]

In the daily transport operation of the double-stack containers, the containers and train flow are not always same. To ensure a smooth operation, daily dispatching work should be enhanced. The dispatching officer should establish a daily dispatching schedule, carry out marketing plan, and organize the run, according to the timetable, marketing plan, the distribution of train flow and empty train.

When a delay occurs, the assessor should carefully examine all available information about the double-stack container train, such as the source and the flow of the goods; analyze the key point that connected to the delay. So, we can find out and result the problems to improve the quality of double-stack container service.

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[50] Railway Ministry (1998): "Five schedule train" transport organization method[S] Beijing.

[51] Railway Ministry (1997): "Five schedule train" freightage temporal method[S] Beijing.

CHAPTER 4 DOUBLE-STACK CONTAINER TRANSPORTATION ORGANIZATION DESIGN (JING-HU LINE)

The double-stack container transportation in foreign countries has been developed greatly. For example, the double-stack train transportation accounted of over 70%[52] of the total transportation in U.S. The geography depth is less deep in the United State than in China. By comparing railway environment between China and the United states, we can deduce that China's double-stack container transport has great space for development. Chinese government planned to construct 18 container station centers in port and center cities in order to build a new transportation network.

In this chapter, I will design a new train timetable and driving program based on container transport quantity forecast (between Jing-Hu lines).

4.1 DST Quantity Forecasting analysis

Transport quantity is affected by many factors, especially influenced by economic situation. "*Chinese economic 2008 Report*" said that Chinese's economic growth will keep on a high level until 2015. As a busiest rail transport line between Beijing and Shanghai, it is important to analyze the factors that may affect the transport quantity.

4.1.1 Factors that Influence traffic volume

(1) Economic factors

Transportation demand caused by community economy directly affects on rail traffic

[52] Richard D Coir (1992): The United States designed double-stack container trains. Page 15-19, Vol.6.<Foreign Rolling Stock>

volume. Therefore, economic factor is a directly affecting element. It has expressed on:

- Distribution of natural resources and productive forces would cause transport demand;
- High-speed economic growth would have a strong requirement of goods transportation;
- Developing imbalance between different countries and different geographical locations may cause transport requirement;
- Differences of industry and product structures in the national economy system will affect on the demand of transport quantity and quality;

In the same area, different economic developing stage may also cause variation of traffic demand.

Above economic factors demonstrated a direct effect on traffic volume[53].

(2) Policy factors

Policy factors consist of the relationship between countries, the internal policy situation, national economic system and economic legislation. There are two kinds of economic system: planned economy[54] and market economy. Different economic systems have different transport demand that greatly affects on traffic volume. In additional, economic legislation functions as standardization and indemnification, which is greatly affect national economic operation. It also will affect on traffic volume.

(3) Technology factor

Technology is a very important factor, which directly affects on transportation ability and cargo quality. As an economic developing power, technology will greatly affect on economic system and economic legislation. The developing speed for transporting high added-value product is faster than for bulk cargo transport.

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[53] Nan Jinglin, Beijing jiaotong University (2002): Railway container traffic prediction Page 9-13, 43-45.

[54] "Planned economy": Before 1978, China has been under planned economy system for a very long time. Its disadvantage: Inefficient resource distribution – surplus and shortage, Cannot determine and prioritize social goods better than the market can, Lack of incentive for innovation, Infringement on individual freedoms, Suppression of economic democracy and self-management and Corruption.

(4) Transport network and transport service level

Allocation of transport network and transport service level would directly influence commodity supply area. Perfect allocation of transport, convenience, faster and high quality transport service will stimulate transport demand[55].

(5) Price factor

The variation of the transportation fee and the commodity price also affect on the transportation demand. Generally, freight price declines while transportation demand rise. When the freight price rises, the transportation demand will be restrained in a short time period. If the price variance of two places has increased, it will stimulate the transportation demand between these two places. In the other hand, when the price variance is decreased, it will restrain the transportation demand. In addition, the variation of fuel price or conveyance also result in changes of transportation fee, which will affect on the transportation demand.[28]

(6) The Competition among different transportation

There are five ways of transportation: railway, road transport, water carriage, air transport and pipeline transport.

- Road transport is flexible, widely used, especially in door-to-door transportation. The advantages of Road transport play a predominant role in short distance delivery, districts, and in limited quantities. With the development of expressway, road transport becomes an arch rivals to railway transport in long distance transportation. Road express transport is applicable to limited quantities, variety kinds, and time-sensitive cargos.
- The advantages of water carriage are mass, low cost, high efficiency, less wasteful energy, less investment. But in other hand, it's slow, multi-step, susceptible to natural condition, not flexible and so on. Water carriage is usually used in bulk cargo of long distance transport which is the main force in trunk line transport. Some commodity is mainly transported by water

[55] "China railway development plan": In next 20 years, China will speed up development of passenger train, new rail line and two-way railway traffic to get rid of transport ability shortage problem in order to running more freight train.

carriage: such as petroleum, coal, mineral sand and break-bulk or general cargo in limited quantities.

- Air transport is fast and effective but it is limited in size, high cost, susceptible to natural condition and low traffic volume. Air transport is only suitable to expensive goods and time-sensitive cargo.
- The advantages of pipe line transport are all-weather, safe, bulk, and fast. But it has its own disadvantages: high cost, limited in liquid, gas and slurry and greatly influenced by geographical position. The large number of oil, natural gas can be transported in this way.

The advantages of railway transport is mass, fast, safe, low cost, less energy, less land, all-weather and environmental friendly. It has an advantage over bulk freight traffic, middle and long distance transport. Railway transport is the main method in goods distribution, especially in inter-regions.

4.1.2 Analytical Approach of Forecasting Container Flow between Jing-Hu Line

In recent years, many forecasting techniques have been developed. The subjective approaches mainly include survey method, consensus, brain-storming, Delphi method, scenario analysis method, analogical method, subjective probability method, relational tree method, and so on.

Quantitative approach consists of time sequence forecasting method, causal forecasting method and combined forecasting method.

- Time sequence forecasting method involves simple average forecasting method, moving average forecasting method, exponential smoothing forecasting method, time regression forecasting method, quadratic curve forecasting method, Markov forecasting method, gray forecasting method, and artificial neural network forecasting method.
- Causal forecasting method includes simple liner regression forecasting

method, multiple linear regressions forecasting method, auto regression forecasting method, nonlinear regression forecasting method, elasticity coefficient forecasting method, system dynamics forecasting method, input-output forecasting method.

According to the specialty of forecasting container flow between Jing-Hu and the material collected after survey, gray forecasting method, gravity forecasting method, and combined forecasting method are chosen to forecast the container flow between Jing-Hu.

（1） Grey model forecasting method[56]

Grey model forecasting method uses time-series data and forecasts through GM(1,1) model[57].

The feature of Grey forecasting model:[58,59]

① Do not require many samples

② High forecasting accuracy

③ Accumulating build differential fitting equation which conform to energy

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[56] Reasons of use Grey forecasting method: Through little and imperfection message build a Grey forecasting model to get a fuzziness long time forecasting of development law. It is a forecasting system between "White System" and "Black System". "White System" means a system's internal features and system message was known. "Black System" means that a system's internal message was unknown; we can just analysis from its connection with outside. So we can know that grey system internal message some parts is known, some parts unknown. Between internal system messages, there are many uncertain relationships. It always used in social system forecasting, economic system forecasting and biological system forecasting. Grey forecast have 6 kinds of method, Series forecasting, Disaster Prediction, season Disaster Prediction, Topology forecasting, system composite forecasts and prediction model.

In this traffic volume forecast, we have got the train's length, weight, routes distances and speed data, but there also have many uncertain details (Economic factors, Policy factor, Technology factor, and Transport network and transport service level, Price Factor, The Competition among different Transportation). And the relationship between them was uncertain. So I use grey forecasting system to forecast traffic volume of Jing-Hu Line.

[57] "GM(1,1) model": It means Grey Model which is the basic mathematic model of Gray forecasting theory. The first 1 in (1,1) means differential equations times, the second 1 means variate number. It basic on the area which is build by time series X(t)'s continuous curve or approach time base curve on the time data XY Plane. This model is build by differential coefficient fitting method.

[58] Zhu Zongbo, Transportation and Computer science, (2001): Gray forecasting model GM (1.1) using in Container traffic prediction.[J] Page 46-48, Vol. 19 No.3

[59] Deng Julong,Huazhong University of Science & Technology (1992): Gray forecasting educate.

system change law

④ Can be used for long-term forecasting

Forecast steps of GM (1, 1) forecasting model:

① After first time accumulation of original time sequence data <$X^{(0)}$(t), t=1,2,…,n> we got a new sequence will be $X^{(t)}$(t), t=1,2,…,n

$$X^{(t)}(t)=\sum_{t=1}^{t} X^{(0)}(t) \tag{4-1}$$

② Use one time added differential fitting equation:

$$\frac{d\mathrm{X}(1)}{dt}+aX(1)=\mathrm{u} \tag{4-2}$$

We can calculate parameter “a” and “u” as following:

$$\begin{bmatrix} a \\ u \end{bmatrix} = (B^{(T)}B)^{-1}B^{T}X \tag{4-3}$$

B and X comes from matrix below:

$$B=\begin{bmatrix} -1/2(X_1^{(1)}+X_2^{(1)})\ldots 1 \\ -1/2(X_2^{(1)}+X_3^{(1)})\ldots 1 \\ \ldots\ldots \\ -1/2(X_{n-1}^{(1)}+X_n^{(1)})\ldots 1 \end{bmatrix} \tag{4-4}$$

$$X=\begin{bmatrix} X_2^{(0)} \\ X_3^{(0)} \\ \ldots \\ X_n^{(0)} \end{bmatrix} \tag{4-5}$$

B^T is B’s transposed matrix, $(B^{(T)}B)^{-1}$ is (B^T B)’s inverse matrix, n is the original sequence quantity

③ Solve this differential equation, the time response function will be:

$$X^{(1)}(t+1)=[X^{(0)}(1)-u/a]\times e^{-at}+u/a \tag{4-6}$$

④ Accounting on derivation of the time response function, a forecasting equation will be:

$$X^{(0)}(t+1)=-a[X^{(0)}(1)-u/a]e^{-at} \tag{4-7}$$

⑤ Use history data to test forecasting model accuracy: by comparing forecasting value with the actual value, we can calculate absolute error AE (Absolute Error), and relative errors for every forecasting step. Through relative error, we can calculate the actual development tendency from differential fitting equation. This forecasting model is used if the relative error is small.

⑥ Forecast through forecasting equation, apply forecast value "t" into the forecasting equation to calculate the forecasting result.

(2) Gravity model[60]

In general, cargo volume means economic parameters (GDP) between two places:

$$Y = a * GDP_1^{a_1} * GDP_2^{a_2} / d^{a_3} \quad (4\text{-}8)$$

In formula, Y means cargo volume between O-D (two Stations);

GDP_1——Departure's GDP

GDP_2——Destination's GDP

d——Distance between departure and destination

a, a_1, a_2, a_3——Parameter item

Based on formula above, container transport volume forecasting formula between O-D can be established as follow:

$$Y = Y_0 * (GDP_1^1 / GDP_1^0)^{a_1} * (GDP_2^1 / GDP_2^0)^{a_2} \quad (4\text{-}9)$$

In the formula, Y—Forecast one year's railway container volume;

Y_0—Present year's container volume;

60 Gravity model: Basic traffic problem forecasting method, after analysis of history economic data we can draw a relationship formula with traffic volume. The GDP parameter is a most elements of traffic volume. So we can find the relationship between GDP, transportation volume and transport distances. It is a basic use of gravity model. 4 different Gravity models: basic model, $T_{ij} = KP_i^{\alpha} A_j^{\beta} f(C_{ij})$; BPR model, $T_{ij} = P_i \frac{A_j f(C_{ij})}{\sum_{j=1}^{n} A_j f(C_{ij}) K_{ij}} \bullet k_{ij}$; Modify model, $T_{ij} = P_i \frac{A_j f(C_{ij})}{\sum_{j=1}^{n} A_j f(C_{ij})}$; Double constraint model, $T_{ij} = \frac{P_i A_j}{K_i K_j'} \bullet f(C_{ij})$, $k_i = [\sum_j K_j' A_j f(C_{ij})]^{-1}$, $K_j' = [\sum_i K_i P_i f(C_{ij})]^{-1}$; In formula P_i, A_j is area i's production and area j's attraction. $f(C_{ij})$ is impedance function; other parameter is correction factor.

GDP_1^1 —forecasting year original place's GDP;

GDP_1^0 —Present year original place's GDP;

GDP_2^1 —forecasting year destination place's GDP;

GDP_2^0 —Present year destination place's GDP;

$(GDP_1^1 / GDP_1^0)^{a_1} * (GDP_2^1 / GDP_2^0)^{a_2}$ means container volume's multiplying factor between original places and destination.

(3) Combination Forecasting

Combination forecasting method is a weighting method among several forecasting results, from which we can choose the optimize one[61]. The main combination forecasting methods are: Equally Weighted Moving Average Method, Variation and Covariance Method. In this paper, by comparing forecasting results of Variation and Covariance Method with the results of Gravity forecast Model, the weighting method is used to evaluate the final forecasting result. Weighted average method should be used to evaluate more accurate result[62].

Suppose the Best Liner Unbiased Predictors from different forecasting methods are f_1, $f_2,\ldots,f_k$, and variances of individual forecast error are $б_{11}, б_{22},\ldots, б_{kk}$. In general, there is no connection between forecast errors from different forecasting methods. The combination forecasting value *k* from different forecasting methods is:

$$f_c = \sum_{i=1}^{k} w_i f_i \,, \quad \sum_{i=1}^{k} w_i = 1 \tag{4-10}$$

[61] "Combination Forecasting": This forecasting method is built basic on the max utilization rate. It has contained many single model messages. What is more it will make a optimize combination. In general, the combination forecast's objective is improve forecasting result.

[62] How to choose weight value is the main problem of combination forecasting method. Variation and Covariance Method is the general method to choose the weighting value, it have contain fix weighting value method and variety weighting value method.

In formula

$$w_i = \left(\sum_{t=1}^{n} e_{it}^2 \right)^{-1} \left[\sum_{j=1}^{k} \left(\sum_{i=1}^{n} e_{jt}^2 \right)^{-1} \right]^{-1} \quad (4\text{-}11)$$

The e_{it} is forecasting error of sample *t* of *i* forecasting methods:

$$e_{it} = y_t - \acute{y}_{it} \quad (4\text{-}12)$$

The y_t is actual value of sample *t*, The $\acute{y}_{it}$ results from the calculation of the forecast value of sample *t* of *i* forecasting methods, *n* is sample capacity.

4.1.3 Forecasting result of container transport traffic volume (Jing-Hu Line)

Based on the data of railway container transport traffic volume from 2000 to 2007, we can calculate railway transportation volume between Beijing, Tianjin, Jinan, Xuzhou, Nanjing, Wuxi and Shanghai. The results are used to build a Grey forecasting model, and forecast the value of the transportation volume between Beijing, Tianjin, Jinan, Xuzhou, Nanjing, Wuxi and Shanghai in 2010 and 2015.

Based on the GDP and the programming GDP, and the railway transportation volume data from these cities, a Gravity Model is established to forecast the transport traffic volume among these cities in 2010 and 2015.

By analyzing the Grey forecast transport volume result, Gravity forecast result, different Gravity model result and the results from combination method of Tianjin, Jinan, Xuzhou, Nanjing, Wuxi and Shanghai we will get the final forecasting results of transport volume for 2010 and 2015.[63]

---

[63] Here I will show the container volume in 2007, 2010 and 2015 in order to have a objective compare and more accurate result. Because, in 2008 global economic have suffered economic crisis, the GDP decreased sharply in second half year, but double-stack container volum was still increased. It's a abnormal phenomenon. So, I did not put 2008's data into my forecasting research, I have average 2006-2007 increase rate and 2007-2008 increase rate, and figure out a reference decrease rate, forecasting with this rate I calculate container volume in 2010 and 2015.

Table 4-1 OD container volume between main stations of Jing-Hu Double-stack container channel in 2007 (TEU/year)

O \ D	Beijing	Tianjin	Jinan	Xuzhou	Nanjing	Wuxi	Shanghai
Beijing	0	3600.00	2674.29	1337.14	1954.29	5862.86	25714.29
Tianjin	3188.57	0	822.86	411.43	2160.00	1337.14	13577.14
Jinan	617.14	411.43	0	514.29	925.71	1337.14	8228.57
Xuzhou	1131.43	514.29	411.43	0	617.14	1337.14	7920.00
Nanjing	2517.43	3908.57	617.14	514.29	0	617.14	11828.57
Wuxi	4011.43	3085.71	1337.14	617.14	720.00	0	3291.43
Shanghai	24788.57	12548.57	4628.57	2982.86	10697.14	3085.71	0

Source: From Lu Cao port. Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line)

Table 4-2 OD container volume between main stations of Jing-Hu Double-stack container channel in 2010 (TEU/year)

O \ D	Beijing	Tianjin	Jinan	Xuzhou	Nanjing	Wuxi	Shanghai
Beijing	0	3985.71	3365.71	2214.29	5225.71	6554.29	33834.29
Tianjin	2391.43	0	797.14	797.14	3188.57	1682.86	27014.29
Jinan	1249.00	708.57	0	531.43	797.14	1594.29	18865.71
Xuzhou	1594.29	442.86	354.29	0	708.57	1328.57	15234.29
Nanjing	3365.71	5137.14	797.14	265.71	0	354.29	8502.86
Wuxi	4162.86	3365.71	1328.57	708.57	265.71	0	3542.86
Shanghai	29937.14	15854.29	6642.86	4162.86	15942.86	3720.00	0

Source: From Lu Cao port. Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line)

Table 4-3 OD container volume between main stations of Jing-Hu Double-stack container channel in 2015 (TEU/year)

O \ D	Beijing	Tianjin	Jinan	Xuzhou	Nanjing	Wuxi	Shanghai
Beijing	0	6975.00	5890.00	3875.00	9145.00	11470.00	59210.00
Tianjin	3826.29	0	1275.43	1275.43	5101.71	2692.57	43222.86
Jinan	2046.00	1169.14	0	876.86	1315.29	2630.57	311288.43
Xuzhou	2710.29	752.86	602.29	0	1133.71	2125.71	24374.86
Nanjing	5721.71	873314	1355.14	451.71	0	602.29	14454.86
Wuxi	7076.86	5721.71	2258.57	1204.57	451.71	0	6022.86
Shanghai	5880.57	30123.14	11957.14	7493.14	28697.14	6696.00	0

Source: From Lu Cao port. Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line)

4.2 Determination of double-stack container train types (Jing-Hu Line)

As I mentioned above, there are 4 double-stack container train organization methods: Non-stop double-stack container train, handling work on trip double-stack container train, drop and pull work on trip double-stack container train and Irregular train.

According to the special condition of the double-stack container train between Beijing and Shanghai, we could plan to run following driving plan:

- Non-stop double-stack container train;[64]
- Double-stack container train with handling work on trip;
- Double-stack container train with drop and pull work on trip.

[64] Personal attitude: Analyzing from double-stack container's service level and transport speed, non-stop container train is the highest level organization form. In the condition of satisfying container flow, we should use non-stop container organization form as possible as we can, it can shorten transport hour per container and increasing transport's time effective.

4.3 Double-stack container train's weight and speed design (Jing-Hu Line)

The weight of the double-stack container is determined by the nominal tractive capacity of the double-stack container.[65] Before the No.6 speed revolution, the maximum speed between Beijing and Shanghai is 80km/h, which is 120km/h now. After the railway electrification rebuild, China's double-stack container normally uses the SS4 type of locomotive. The minimum nominal tractive capacity, Q=5000t[66], empty train's weight P_{empty} =22t; loaded cargo weight P_{loaded} =78t[5]; locomotive's weight $P_{locomotive}$ =91t[67], putting these data in to (3-1) in chapter 3, we can get the number of the maximum container carriage m_1:

$$
\begin{aligned}
m_1 &= (Q - P_{locomotive})/(P_{empty} + P_{loaded}) \\
&= (5000 - 91)/(22 + 78) \\
&= 49
\end{aligned}
$$

Suppose $L_{availability}$ =850m (Availability length), L_{train} =19.50m[5] (Train length), $L_{locomotive}$ =16.5m[31] (Locomotive's length), L_{save} =10m (safe distance), we can get the maximum number of container trains m_2 with formula (3-2). The m_2 is also determined by the length of platform:

$$
\begin{aligned}
m_2 &= (L_{availability} - L_{locomotive} - L_{save})/L_{train} \\
&= (850 - 16.5 - 10)/19.5 \\
&= 42
\end{aligned}
$$

We choose the small one ($m_2=42$) between m_1 and m_2 as container train's carriage number.

65 "Nominal tractive capacity": Generally, nominal tractive capacity is higher than 5000t.

66 After "No.6 railway speed revolution" the nominal tractive capacity in Jing-Hu line will change into 6000t

67 Railway Ministry(2004): Rail wagon statistics rules[S] Beijing <China railway>

4.4 Analysis of DST dispatch qualification

4.4.1 Analysis of the assembly time of the Double-stack container

The double-stack container train's accumulation process equals to the process of container assembly.

(1) The probability distribution of container arriving interval time

If we did not restrict FCL's maximum container number and the container arriving time is totally random[68], the degree of container flow complies with "Pisson distribution"[69]within a time of resignation. We can use Binomial distribution to derivate the probability of *n* containers arriving in *t* hour is:

$$P_n(t) = (\lambda t)^n e^{-\lambda t} / n! \qquad (4\text{-}13)$$

In formula, λ is average arrived strength.

When obeying the "Pisson distribution", the arriving interval time also obeys the "negative exponential distribution". Suppose *T* is the arriving interval time between two trips, then probability density function of the "*T*" $f_y(t)$ is:

$$f_T(t) = F'(t) = d(1 - e^{-\lambda t}) / dt = \lambda e^{-\lambda t} \qquad (4\text{-}14)$$

(2) The probability distribution of container arriving number

Suppose the sending container number *m* is fixed. If the sending container number *m* is fixed, the arriving container number is m_1, the m_1 satisfying $1 \le m_1 < m$ ($m_1 \in N$). Suppose the delivered container quantity is *n*, the probability is P_n, and then arrived container quantity at the i^{th} time is:

$$m_i = \sum_{n=1}^{m-1} n \cdot p_n \qquad (4\text{-}15)$$

The daily container quantity from one direction assembly is N, and it consists of two

---

[68] Actually, we use Lorry to transport containers to arrived double-stack container station.

[69] Teng Chuanlin (1986): Management of operations research. Page 345-353.

M at Hannes (2004): American Intermodal Double-stack Railcars [EB/OL].

http://www.trainweb.org/intennodal/

parts: the container quantity from original station N_0 and other containers (relaying containers) N_T:

$$N = N_0 + N_T = \sum m_i = \sum (\sum_{n=1}^{m-1} nP_n) \tag{4-16}$$

(3) Container inter-arrival time

Suppose the number i-1 times and number i times arriving container inter-arrival time is t_1:

$$\bar{t} = t_t = \int_{\wedge}^{T\max} tf_T(t)dt \tag{4-17}$$

Then in T hours (double-stack container train's assembly time period) arriving times is:

$n_d = T/t$ *and:*

$$\lim_{\Delta \to 0} \bar{t} = 1/\lambda \tag{4-18}$$

(4) Arrived container quantity

Under the condition of the fixed quantity probability distribution, suppose arrived container number is m_i, then:

$$\overline{m} = m_i = \sum nP_n \tag{4-19}$$

The expected arriving time in T hours will be:

$$Nd = N / \overline{m} \tag{4-20}$$

Then the expression for average arriving frequency λ is:

$$\lambda = N / T\overline{m} \tag{4-21}$$

If container quantity grouping number in T time period is N, and the trains carriage number is m_0, the N should not actually be m_0's integral multiple, however in theory we can consider that N is m_0's integral multiple k=N/ m_0 ($k \in Z$). The total container centralization time T_f' will be:

$$T_f' = \sum_{i=1}^{n_d} m_i[T - (i-1)t_i] - \sum_{i=1}^{k} m_i T_i (i-1)$$

$$= \sum_{i=1}^{n_d} \overline{m}[T - (i-1)\bar{t}] - \sum_{i=1}^{k} \overline{m} T_i (i-1) \tag{4-22}$$

Take $n_d = T/\bar{t}$, $t = N/\overline{m}$; $k = N/m_0$; $T_i = m_o \bar{t} / \overline{m}$ into (4-22):

$$T_f' = \frac{Tm_0}{2} - \frac{T\overline{m}}{2} = \frac{T}{2}(m_0 - \overline{m}) \tag{4-23}$$

So we can get the working hours in FCL[70].

① Expend time per container in each day and night:

$$T_f = 12(m_0 - \overline{m}) \tag{4-24}$$

② Expend time per container of each container train:

$$t_f = \frac{Tm_0}{2N}(m_0 - \overline{m}) \tag{4-25}$$

From (4-24) and (4-25) we can have the inference that the average expend time per train has a relation with container design number and arrived container quantity in a time period. In the other hand, the random distribution of probability is a very important element.

③ Each container sending time(t_c):

$$t_c = \frac{t_f}{m_0} = \frac{T}{2N}(m_0 - \overline{m}) \tag{4-26}$$

4.4.2 Analysis of time saving of the double-stack container in relaying station

Normally, double-stack container is recognized by non-stop transport, which means no transfer work in FCL. If we do not use non-stop transport service to drive it, the cost in time will be much greater than in non-stop service. Suppose the time saving from non-stop service is t_s, the stay time of the non-stop service is t_{non}, the stay time of the relaying operation is t_{trans}, when station A does not supply non-stop double-stack container train, the N_1 will be transferred to station B. Then the container flow from B to C is $N_1 + N_3$; the average concentrate per container (t_c) will be:

---

[70] "FCL": Full container load(container yard)

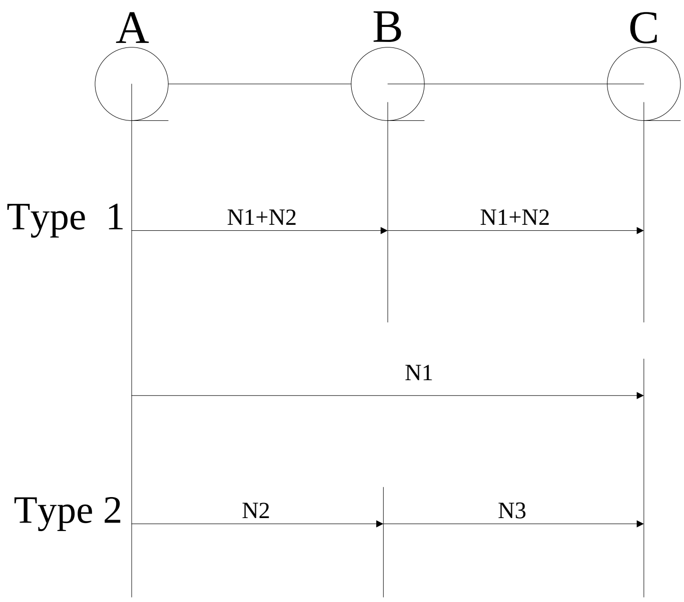

Figure 4 Sketch map of container transportation mode

For example, there is A, B, C 3 FCL stations on the way from A to C. In this direction, there are 3 container concentrate route: N_1 (From A to C), N_2 (From A to B), *and* N_3 (From B to C).

Source: Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Beijing-Shanghai Line)

$$t_c = \frac{T}{2(N_1 + N_3)}(m_0 - \overline{m}) \tag{4-27}$$

When station A supplies N_1 non-stop transport service, then the average concentrates per container (t'_c) will be:

$$t_c' = \frac{T}{2(N_3)}(m_0 - \overline{m}) \tag{4-28}$$

After station A sends N_1, the average concentrate per container time in station B will be increased to ($N_1 t_c / N_3$) hours, the lost time will be N_1 t_c hours.

When N_1 container flow transported by non-stop train, the saving time in station B is:

$$N_1(t_{trans} - t_{non}) - N_1 t_c = N_1(t_{trans} - t_{non} - t_c) \tag{4-29}$$

With non-stop transport, the time saving for each container (t_{save}) is:

$$t_{sav} = t_{trans} - t_{non} - t_{as} \tag{4-30}$$

In the formula:

t_{sav} ——Average saving time per container;

t_{tran} ——Average stay time of the regulated relaying container;

t_{non} ——Average stay time of the non-regulated relaying container;

t_{as} ——Average container assembly time.

By analyzing double-stack contain train relaying operation in Chapter 4; put the data into (3-30):

(1) The handling works of an on-trip container train in harbors are mainly from the train arrival-departure technical operation and the container handling work, we can determine the average container time saving as following:

$$t_{sav} = t_{loading} + t_{unloading} + t_{depart} + t_{arrived} - t_{non} \quad (4\text{-}31)$$

$t_{loading}$ —— average container loading time;

$t_{unloading}$ —— average container unloading time;

$t_{arrived}$ ——average technical operation time when container arrives;

t_{depart} ——average technical operation time when container departs.

(2) The Drop and Pull operation works of an on-trip double-stack container train in harbors are mainly from train arrival-departure technical operation and carriage Drop and Pull work, we can determine the average container time saving as following:

$$t_{save} = t_{Drop(Pull)} + t_{depart} + t_{arrive} - t_{non} \quad (4\text{-}32)$$

$t_{Drop(Pull)}$ is the demanded time for dropping or pulling one container.

$t_{arrived}$, $t_{unloading}$, $t_{loading}$, t_{depart} and $t_{Drop(Pull)}$ can get from statistical analysis and search standards, $t_{contianer}$ can get from above calculation. It is reasonable to predict that the time saving of container transit work in “FCL” is not mainly decided by handling work or Drop and Pull works. Additionally, container transit work in “FCL” can’t save container dwell time, lorry’s dwell time and container transfer fee.

4.4.3 The Running Qualification of the Non-stop double-stack container train

By analyzing the time parameter of a double-stack container train, the departing qualifications of a non-stop train are:

(1) When sub-line container does not have a drop and pull operation or handling work, and the saved time per container was greater than the time required to assembly this container in the departing station, this sub-line train must have non-stop container train services. We said it is the first condition of the running qualification:

$$Nt_{container_i} \geq T_{container_i} \tag{4-33}$$

If sub-line container flow satisfies this condition for any one of the stations, it would be satisfy the absolute condition for all stations. It means that this container flow must be run as a non-stop double-stack container train. Similarly, if the container flows of the same route are combined, the condition is satisfies any one station that it can run non-stop container train.

(2) If the single container flow was combined with many container flows, they transport by a non-stop DST, and if the time saving of a short trip train in the run is more than that in departing station. We call it second satisfy condition of running non-stop container train. This container flow should have non-stop double-stack container train service:

$$N_{far} \sum t_{No.}^{over} \geq T_{assembly} \quad \text{or} \quad \sum N_{far} \sum t_{No.}^{over} \geq T_{assembly} \tag{4-34}$$

(3) When combined container flow without container transfer work saves more time than it consumed in departing station, we can plan to run non-stop double-stack container train. This is the third condition to run a non-stop container train:

$$N_{non-stop} \sum t_{save} \geq T_{assembly} \quad \text{or} \quad \sum N_{non-stop} \sum t_{save} \geq T_{assembly} \tag{4-35}$$

4.4.4 Running requirement of DST with D&P operation or loading and unloading operation on a trip

After establishing the running project of non-stop double-stack container train, some stations maybe hindered by descending container flow. At the moment, the non-stop double-stack container train may be workable. Considering the far side sections, the double-stack container handling station throughout the journey may have a container flow with the same route and direction, which can supply the decreasing container flow from the long distance. Then, the supplied container flow must satisfy the condition of that the drop and pull or load and unload operation should be in the same direction. The unloaded container flow throughout the journey should be less than the available container flow in the same direction:

$$N_{ij_{trains}}^{K} \leq N_{ij_{trailer}}^{K} \quad (4\text{-}36)$$

In formula,

$N_{ij_{trains}}^{K}$ means a double-stack container train with drop-pull operation and load-unload operation on the way runs from one station to station J and the container flow need to be unloaded at station K.

$N_{ij_{trailer}}^{K}$ means a double-stack container train with drop-pull operation and load-unload operation on the way runs from station I to station J and load containers of same direction at station K.

4.5 The Confirmation of the DST Running Project between Jing-Hu Line

4.5.1 The steps of determining the running project of DST

At the double-stack container handling station, with adequate traffic volume and container flow, we can run non-stop train to shorten the turnaround time and increase efficiency of container and double-stack container and reduce the investment. The increased traveling speed, the shortened time on the way and the saved capital all reflect the speed and efficiency of double-stack container transport.

Therefore, when determining the running project of double-stack container train, we should first run non-stop double-stack container train in the condition of certain container flow[71].

The steps of running double-stack container train:

(1) To determine the container flow between two double-stack container stations.

(2) To determine number of the operation stations on the way.

(3) To determine the number of cars in a train and the container capacity.

(4) To determine the container assemble every day and night.

(5) To check the container flows between two stations whether satisfy the condition of non-stop double-stack container train. If it is meet the need, we can run the train.

(6) To those stations which don't satisfy the container flow of running a nonstop double-stack container train, we should compare the container flows and the distance factors:

- If it is possible, the nonstop double-stack container train can be combined with the train of previous station.
- Combining with themselves
- After combining, trains should have drop and pull operate or handling work

[71] The condition is $N^{K}_{ij_{trains}} \leq N^{K}_{ij_{trailer}}$

along the journey.

(7) Considering the influence between two double-stack container trains, we should establish a backup plan of the non-stop double-stack container train at handling station.

4.5.2 The Running Project of DST between Jing-Hu Line

In order to simplify the design of organization plan, in this chapter, I change double-stack container quantity forecast result in chapter one from TEU/YEAR into TEU/DAY: (Table 4-4, Table 4-5, and Table 4-6)

Table 4-4 OD container volume between main stations of Jing-Hu double-stack container channel in 2007

O \ D	Beijing	Tianjin	Jinan	Xuzhou	Nanjing	Wuxi	Shanghai
Beijing	0	9.86	7.33	3.66	5.35	16.06	70.45
Tianjin	8.74	0	2.25	1.13	5.92	3.66	37.20
Jinan	1.69	1.13	0	1.41	2.54	3.66	22.54
Xuzhou	3.10	1.41	1.13	0	1.69	3.66	21.70
Nanjing	7.05	10.71	1.69	1.41	0	1.69	32.41
Wuxi	10.99	8.45	3.66	1.69	1.97	0	9.02
Shanghai	67.91	34.38	12.68	8.17	29.31	8.45	0

Source: Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line).

Table 4-5 OD container volume between main stations of Jing-Hu double-stack container channel in 2010

O \ D	Beijing	Tianjin	Jinan	Xuzhou	Nanjing	Wuxi	Shanghai
Beijing	0	10.92	9.22	6.07	14.32	17.96	92.70
Tianjin	6.55	0	2.18	2.18	8.74	4.61	74.01
Jinan	3.40	1.94	0	1.46	2.18	4.37	51.69
Xuzhou	4.37	1.21	0.97	0	1.94	3.64	41.74
Nanjing	9.22	14.07	2.18	0.73	0	0.97	23.30
Wuxi	11.41	9.22	3.64	1.94	0.73	0	9.71
Shanghai	82.02	43.44	18.20	11.41	43.68	10.19	0

Source: Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line).

Table 4-6 OD container volume between main stations of Jing-Hu double-stack container channel in 2015

O \ D	Beijing	Tianjin	Jinan	Xuzhou	Nanjing	Wuxi	Shanghai
Beijing	0	19.11	16.14	10.62	25.05	31.42	162.22
Tianjin	10.48	0	3.49	3.49	13.98	7.38	118.42
Jinan	5.61	3.20	0	2.40	3.60	7.21	85.28
Xuzhou	7.43	2.06	1.65	0	3.11	5.82	66.78
Nanjing	15.68	23.93	3.71	1.24	0	1.65	39.60
Wuxi	19.39	15.68	6.19	3.30	1.24	0	16.50
Shanghai	155.84	82.53	32.76	20.53	78.62	18.35	0

Source: Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line).

According to container quantity flow, container capacity and driving condition, I have drawn running plans for the double-stack container train of 2010 and 2015, (Table 4-7, 4-8), the 2007 train schedule is shown in. Table 4-9.[72]

Table 4-7 Operating plan of double-stack container train on Jing-Hu railway in 2010

No.	Direction	Schedule	Stop stations	Organization form
1	Beijing-Shanghai	1/day	Tianjing	③
2	Shanghai-Beijing	1/day	Tianjing	③
3	Beijing-Shanghai	1/2days	Jinan,Xuzhou,Wuxi	②or③
4	Shanghai-Beijing	1/2days	Jinan,Xuzhou,Wuxi	②or③

Source: Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line).

Table 4-8 Operating plan of double-stack container train on Jing-Hu railway in 2015

No.	Direction	Schedule	Stops	Organization form
1	Beijing-Shanghai	1/day	Tianjing	③
2	Shanghai-Beijing	1/day	Tianjing	③
3	Beijing-Shanghai	1/2days	Xuzhou,Nanjing	②or③
4	Shanghai-Beijing	1/2days	Xuzhou,Nanjing	②or③

[72] In table 4-7 4-8 4-9: ①means non-stop DST organization form. ②means handling work on trip organization form. ③means drop and pull work on trip organization form

5	Beijing-Shanghai	1/2days	Jinan,Wuxi	②or③
6	Shanghai-Beijing	1/2days	Jinan,Wuxi	②or③

Source: Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line).

Table 4-9 Operating plan of double-stack container train on Jing-Hu railway in 2007

No.	Direction	Schedule	Stop stations	Organization form
1	Beijing-Shanghai	1/day	Tianjing,Wuxi	②
2	Shanghai-Beijing	1/day	Tianjing,Wuxi	②

Source: Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line).

4.6 The Establishment of DST Running Project between Jing-Hu

In this section, the 2010 working project of double-stack container train is mainly determined according to the container flow and running project between Jing-Hu in 2007. At first, the traction train should be long routing, fewer changes of locomotive, shorter stopping time. According to the odometer of Jing-Hu railway with the speed of 120km/h[73] and 80km/h[74], the times needed from one station to the other of double-stack container train are listed table 4-10.

Table 4-10 Running time of double-stack container train between stations

No.	Running section	Distance (Km)	Runtime	
			120km/h(speed)	80km/h(speed)
1	Beijing-Tianjing	133	66.5	99.75
2	Tianjing-Jinan	346	173	259.5
3	Jinan-Xuzhou	335	167.5	251.25
4	Xuzhou-Bengbu	165	82.5	123.75
5	Bengbu-Nanjing	187	93.5	140.25
6	Nanjing-Wuxi	171	85.5	128.25
7	Wuxi-Shanghai	126	63	94.5
Total		1463	731.5	1097.25
			12.19(h)	18.29(h)

Source: Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line).

[73] Top speed after "No.6 time railway speed revolution" finished

[74] Top speed now(2008)

The operating timetable of the double-stack container train between Jing-Hu:

(1) Double-stack container train from Beijing to Shanghai[75]:

Main work in North Tianjing station: 50 minutes to hang 5 carriages in the end of double-stack container train.[76] (Table 2-3)

(2) Double-stack container train from Shanghai to Beijing[77]:

Main work in North Tianjing station: 50 minutes to drop 5 container carriages which destination is North Tianjing station.[78] (Table 2-3)

(3) Double-stack container train from Beijing to Shanghai[79]:

Main work in West Jinan station: 65 minutes to unload containers which comes from Beijing.[80] (Table 2-4).

Main work in North Xuzhou station: 65 minutes to unload containers which comes from Beijing.[81] (Table 2-4)

Main work in South Wuxi station: 50 minutes to drop 10 container carriages which destination is North South Wuxi station.[82] (Table 2-3)

(4) Double-stack container train from Shanghai to Beijing[83]:

Main work in South Wuxi station: 50 minutes to hang 10 carriages in the end of double-stack container train.[84](Table 2-3)

Main work in North Xuzhou station: 65 minutes to unload containers which comes from Beijing.[85](Table 2-4)

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[75] Shanghai $_{(1)}$

[76] This 5 carriage destination is Wuxi or Shanghai. They can be 5 loaded carriages in waiting line or 5 loaded carriages in team track area which can directly have hanging work.

[77] Shanghai $_{(2)}$

[78] The normal working method in China is: with for shorten runtime, we will direct have drop carriage work when train arrived; After carriage drop work, train will continue run. The dropped carriage will hang to loading and unloading line by crane.

[79] Shanghai $_{(3)}$

[80] With for shorten handling time, train directly arrive loading and unloading line to have handling work.

[81] Same as explanation 66

[82] This 10 carriage's operate method is the same as explanation 2

[83] Shanghai $_{(4)}$

[84] This 5 carriage destination is Xuzhou or Jinan or Beijing. They can be 10 loaded carriages in waiting line or 10 loaded carriages in team track area which can directly have hanging work.

[85] With for shorten handling time, train directly arrive loading and unloading line to have handling work.

Main work in West Jinan station: 65 minutes to unload containers which comes from Beijing.[86] (Table 2-4)

In 2010, the container center will be completely updated, and be able directly to carry out the container handling work. The container carriages will no need sent to handling area. The handling time per container will be shortened to 5min. Therefore, the dwell time in my plan will be not longer than 1h.

Based on above analysis, we can forecast the runtime of double-stack container train from Beijing to Shanghai $_{(1)}$ as following:

<1> Station-to-station time, 12h

<2> Technical operation time in station 6h

<3> Welg, wait and other time about 5-7h

Total runtime is 23h.

Runtime from Shanghai $_{(2)}$ to Beijing is 27h.[87]

Runtime from Beijing to Shanghai $_{(3)}$ is 26h:

<1> Station-to-station time, 12h

<2> Technical operation time in station 9h

<3> Welg, wait and other time about 5-7h

Runtime from Shanghai $_{(4)}$ to Beijing is 30h.[88]

---

[86] Same as explanation 70

[87] Because the running direction from Shanghai to Beijing is from south to north the running speed would be a little slow than Beijing to Shanghai, so the Station-to-Station time would be about 3 hour longer than from Beijing to Shanghai.

[88] Although the direction for all 4 situations is the same, but they have different work on the trip, they have the different stop time in stations. So the runtime for these 4 situations would be different.

4.7 Double-stack container train's depressed centre flat wagon groups demand design (Jing-Hu Line 2010)

Based on above calculation, addition 4 hours of head back time and change locomotive and exchange of wagon groups' time should be added into the total runtime. Through forecasting train running plan, if the drive frequency K=7, the turnaround time θ of one container train is:

$$\theta = 23 + 27 + 4 = 54h \tag{4-37}$$

Put θ=54h into formulae (3-3). We can get the double-stack container wagon demand N_1 as following:

$$\begin{aligned} N_1 &= (\theta / 24) * (K / 7) \\ &= (54 / 24) * (7 / 7) \\ &= 3 \end{aligned} \tag{4-38}$$

if the drive frequency K=3, the turnaround time θ of one container train is:

$$\theta = 26 + 30 + 4 = 60h \tag{4-39}$$

Put θ=60h into formulae (3-3). We can get the double-stack container wagon demand N_2 as following:

$$\begin{aligned} N_2 &= (\theta / 24) * (K / 7) \\ &= (60 / 24) * (3 / 7) \\ &= 2 \end{aligned} \tag{4-40}$$

CHAPTER 5 CONCLUTION

In 2010, double-stack container trains between Beijing and Shanghai would need 5-“(4-38)+(4-40)” depressed centre flat wagon groups. 42 carriages (Chapter 4.3 $m_2=42$) for one depressed centre flat wagon group. Running schedule is shown in Table 4-7.

Table 4-7 Operating plan of double-stack container train on Jing-Hu railway in 2010

No.	Direction	Schedule	Stop stations	Organization form
1	Beijing-Shanghai	1/day	Tianjing	③
2	Shanghai-Beijing	1/day	Tianjing	③
3	Beijing-Shanghai	1/2days	Jinan,Xuzhou,Wuxi	②or③
4	Shanghai-Beijing	1/2days	Jinan,Xuzhou,Wuxi	②or③

Source: Drawn by author: ©Copyright WU XUHUI, WMU-ITL Shanghai, (2009) by Double-stack container trains Railway Transport Organization Research (Jing-Hu Line).

This Dissertation “Double-stack container trains Railway Transport Organization (Jing-Hu Line)” studies the organization design and transport volume forecasting,

(1) In chapter 1 and chapter 2, the backgrounds of double-stack container transportation in China and foreign countries are introduced. Based on the summarization of foreign countries transport methods and China railway’s current situation, the types of China’s double-stack container railway organization are recommended.

(2) In chapter 3, the double-stack container railway transportation organization’s contents, determination of double-stack container weight, speed, and wagon number per train are discussed. The running plans and operation rules of the double-stack container train are introduced. In addition, the container train operation content, container flow, and runtime standards are studied in this chapter.

(3) In Chapter 4, with Chapter 3 forecasting method’s (Grey forecasting method, Gravity model forecasting method, Combination Forecasting method) and traffic

volume forecasting result, the numbers of the double-stack container train are determined (Jing-Hu Line). According to the results, the running program and operation plan for the double-stack container train are established and discussed in detail. Finally, by using the wagon number accounting formula in Chapter 2, the wagon demand quantity of double-stack container train is resolved.

In this research paper, when I design the container traffic volume forecasting, I have ignored transfer containers form car transport and potential container quantity[89].However, it has little influence on the conclusions of my thesis. I will update detail research in the future.

In China the double-stack container train was still in the initial stage. With the restriction of geological condition and technical experience, the tunnel height, the distance spread, the curve railway and the investment, there was only one special DST line (Jing-Hu Line) right now. The thesis has proved that Double-stack container train transport can rising up transport efficiency and save many transport costs. In future, China will run many new DST lines and the DST industry development will come into a brand new stage.

[89] Double-stack container railway transport between Beijing and Shanghai, it would be a great attraction of container transport demand. So, this kind of container quantity would be potential container.

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