A New Choice for Shanghai Container Distribution – Underground Container Transportation System (UCTS)

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ABSTRACT

It is a new concept of using underground container transportation system to distribute containers in port. Based on the fact that Yangshan Port will contribute 50% of all the containers in all Shanghai Ports, this paper focuses on problems of distributing containers that Yangshan Port will confront, the feasibility and questions need to be solved when developing this new underground container transport system.

1 INTRODUCTION

1.1 Forecast of Container Throughput and Outgoing Trend of Shanghai Port

According to documents provided by Shanghai Port Bureau, the container throughput in Shanghai Port reached to 1.8million in 2005. In 2010, it will be 2.3-2.5 million TEU; in 2020, it will be 3.6-3.8 million TEU, as shown in the Table 1.

Table 1. Forecast of Container Throughput in Shanghai Port (unit: million TEU)

<table>
<thead>
<tr>
<th>Year</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container Throughput in Shanghai Port</td>
<td>2.3-2.5</td>
<td>3.6-3.8</td>
</tr>
</tbody>
</table>

There are three container port areas in Shanghai: SCT (Jungong Road Harbour, Baoshan Harbour, Zhanghuabang Harbour), WCT and Yangshan Deep-water Port (under construction). Based on the forecast that the container throughput will be 38 million TEU in Shanghai in 2020, the distribution of each port will like Fig.1. According to Shanghai Port Plan, Shanghai Port will expand its shipping itineraries to outer area as the new port area after Yangshan Deep-water Port putting into use. And SCT will no longer be regarded as Container Terminal, the main shipping routes in the near ocean will be transferred to the WCT, the main shipping route of far ocean will be mainly in Yangshan Port which throughput will account for more than half of Shanghai. Thus, this paper focuses on analyzing Yangshan Port containers distribution transport.

Fig. 1. Share of ports in 2020.
1.2 Analyzing of Yangshan Port containers distribution transport

According to the "Yangshan Port Traffic Analysis Report", deducting the international transit, coastal transit, and Yangtze River water transfers, etc., we can get Yangshan Harbor Transportation demand for transportation planning and the annual of all transport modals share as shown in Table 2.

Table 2. Forecast of modal shares in Yangshan Port.

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total amount (million TEU)</td>
<td>0.165</td>
<td>0.415</td>
<td>1.035</td>
</tr>
<tr>
<td>Shares</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shipping Distribution</td>
<td>33%</td>
<td>32%</td>
<td>29%</td>
</tr>
<tr>
<td>Road Distribution</td>
<td>60%</td>
<td>63%</td>
<td>65%</td>
</tr>
<tr>
<td>Rail Distribution</td>
<td>7%</td>
<td>5%</td>
<td>6%</td>
</tr>
<tr>
<td>Donghai Bridge Distribution</td>
<td>67%</td>
<td>68%</td>
<td>71%</td>
</tr>
</tbody>
</table>

Since the railway shares less portion, so there will be no railway on the island of Yangshan Harbor in recent year, so the railway shares are sent from Luchao Port City to different regions of the country. Therefore, before the year 2020, Yangshan Port distributing volume of the Donghai Bridge Highway equals to the sum of highway and railway shares. At that time, Yangshan port container throughput demand forecast, as shown in Table 3.

Table 3. Transportation Proportion of Donghai Bridge

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation Proportion</td>
<td>67%</td>
<td>68%</td>
<td>71%</td>
</tr>
</tbody>
</table>

It is indicated that, from now to 2020, Yangshan Port Container transportation will be mainly conducted by Donghai Bridge highways. Based on analysis, normal weather condition, Donghai Bridge design capacity of the first phase can meet the traffic demand of around 2016, and maybe meet the traffic demand of around 2020. But on rainy days, it will be ahead to 2014 and 2018.

Judging from the current situation, the shares forecast of Yangshan Port transportation in the above reports is accurate. According to relevant information, 2006 container "waterway-waterway transfer" increased to 31%, coincidently with the forecast 32-33% for 2005-2010. Currently, the road transport of Donghai Bridge is not under great pressure.

But with the Yangshan Port II putting into use, Yangshan Port Container throughput achieved in 2007 will reach to 2010 - three years ahead of the expected. Donghai Bridge may reach saturation in advance. Furthermore, the above analysis of Yangshan Port based on 2020 throughput which is 13.4 million TEUs, By the latest analysis, Yangshan port container throughput will reach to 2.1 million TEU in 2020, almost twice as much as the forecast. Therefore, the Donghai Bridge will face serious transportation pressure.

1.3 Alternative choices

There are two choices under this condition; one is pursuing Donghai Bridge II, or a new container distribution system. According to the "Shanghai Daily" reported that the cost for the construction of about 20 miles of Donghai Bridge is around 14.2 billion RMB. The construction of Donghai Bridge II,
will definitely exceed this cost, and will face the low efficiency of the highway and over-reliance on road transport mode etc. problems. Even use rail-road intermodal in Donghai Bridge II, may not be competitive with the highways and waterways. As economic reasonable distance of the road transport is around 300-500 km, and 90% container transport from now to 2020 is concentrated in Shanghai, Jiangsu and Zhejiang province, as shown in Fig. 2. While the Yangtze River Delta, Shanghai-Hangzhou and Shanghai-Nanjing railway line at 303km and 201km while the region of exceed 500km from Shanghai, will be covered by other ports service. Under such circumstances, the building of underground container transport system is undoubtedly one of the options to replace the Donghai Bridge II. Therefore, since 2006, the Shanghai Municipal Engineering Design Institute began to explore the use of underground container system. This paper introduces the results of the research.

2 STATE-OF-THE-ART UCTS AND QUESTION TO BE STUDIED FOR SHANGHAI

Underground Container Transport system, in general, is an independent pipeline, in whole or partly underground with high efficiency, low-cost, environmental friendly as the principle of sustainable development. At present, the United States, Belgium, Germany and other countries are exploring the feasibility of underground container transport system. This paper mainly introduces the results of representative research – Professor Stein, Germany and Professor Henry Liu (US), and they separately developed research on CargoCap and PCP.

2.1 German Study on UCTS

Highway in Germany is currently facing a shortage of fund for the expansion and maintenance, and estimated that each year 2.5 billion euros is shorted. In addition, the highway expansion is also facing the pressure from the environment and ecology. Therefore, Germany is seeking a new transport system. Ruhr University Bochum is now pursuing the "underground transport and supply system" research. The research will be defined as CargoCap, the fifth of Germany's transport system in the future.

Professor Stein began to study on using the CargoCap to transport Container, swap bodies, semi-trailers between ports and inland to, in 2005. Its transport vehicles are still using CargoCap but a different parameters, such as size; and container transport is automatic, four shafts, with maximum speed of 80km/h can be achieved, as shown in figure 3. Each bundle includes 34 vehicles, with a total length of 750 meters. For the main line, a bundle every 30 minutes, each has a double-line island every 18 km, which is 2.7 km long. The track maximum inclination is 1.25%, the minimum turning radius is 1,000 meters. Single square tunnel is 5.31m X 6.99m, double-line square tunnel is 10.08m × 7.36m, and circular tunnel is 8.10m diameter.

2.2 Study on Feasibility of using PCP Container Distribution System in New York Port

Prof. Henry Liu (USA) studied feasibility of using PCP system distributing containers of New York Port and New Jersey Port systematically and concluded this system should use large diameter tunnels or conduit based on his study. Near the New York Port or New York City, especially when passing Hudson River, a round tunnel at the depth 100 to 150 ft below the water level is necessarily needed. When tunnel outstretching to suburb, opening and covering method can be used, 5 ft underground, square tunnel.
According to standard size, a circular tunnel of approximately 15 ft diameter (4.57 meters) is needed. As for square conduit, 9 ft wide by 11 ft high is needed. For each capsule, 8.5 ft wide, 10 ft high, 42 ft long, so that can conduct a 40-foot container, or 2 TEU (twenty-foot Equivalent Unit).

Using blower pump, the system can dispatch 756000 capsules (1.5 million TEU) considering 350 work day every year. If Linear Induction Machine (LIMs) instead of blower, it will be 5 times higher in efficiency, 7.6 million TEU every year. In 2003, NY Port and New Jersey distribute 4.1 million TEU. It indicates that PCP system with LIM can meet the need of container transport in both New York and New Jersey Port.

In the study of feasibility, Prof. Henry Liu assumed PCP system in NY City needed four 16 miles long minor pipeline, 5 miles long main pipeline, totally 21 miles tunnel, 15 miles square conduit, double direction, double pipeline constructed.

As calculated, the cost of system is 2.001 billion U.S. dollars, the annual operation and maintenance cost will be 312 million U.S. dollars. System life by 30 years (the most conservative estimate), the cost of transportation is 17.2 U.S. dollars per TEU. Consider freight trucks charges 30 U.S. dollars per TEU, in accordance with the largest transport capacity, it will have an annual income of 286 million U.S. dollars (eliminate the annual cost). Consider transport for half of its maximum capacity, there are still 60 million U.S. dollars annual net income (dropping the annual cost).

According to the estimation, 50% of its designed capacity, it can reduce 264 million vehicle kilometres of New York truck operation, and reduction of HC, CO, NOX and PM emissions will be 425,3720,921 and 103 tons. This study did not calculate the environmental and social benefits, like a quicker and more secure transport to prevent terrorist attacks, reduce the traffic jams caused by the trucking, and shorten the transportation time and so on.

2.3 Evaluation of the current UCTS technology

**Technologies Area:** underground container transport systems are based on available technologies. But they are still in the conceptual design stage. Still not a finished design prototype or model.

**Application Area:** underground container transport system is generally from one to another terminal, point-to-point. This system is considered as part of multi-modal port transportation, and suitable for long-distance inland container transport. Professor Stein proposed to construct 400 km underground container transport system between Bochum and Hamburg and Duisburg.

**Economic Feasibility:** According to German Professor Stein’s calculation, if the transport system is a point-to-point transport container, not networks, it is very difficult to obtain economic feasibility. Recommend program is built its network and the transport a variety of freight. According to Professor Henry Liu, PCP use of a point-to-point transport, access and economic feasibility.

**Problem Faced:** The construction of this system, is costly and full of risks, and needs complexity and difficulty planning process. But the return on investment will only start after the entire circuit operation which will take a long time. This is the biggest obstacle to the operating system.

2.4 Future Research

As mentioned above, developing the underground container transportation system offers Shanghai a new choice for freight transport. Whether in terms of efficiency, environmental impact, or land conservation, this system has great advantages, even in cost they are approximately equal compared to the traditional method. According to Professor Henry Liu, New York 21 miles of underground tunnels and PCP container distribution delivery system of 2.001 billion U.S. dollars construction cost, considering the exchange rate of dollar / RMB=7.8, equivalent to about 462 million RMB per kilometer. Donghai Bridge cost 441 million RMB per kilometer, which is almost the same amount of money.

However, construction of such a new costly system fraught with risks, involved transportation engineering, civil engineering, mechanical, electronic information, materials, economic, environmental and knowledge of other fields, we need to consider the distribution of cities, transport planning, logistics management, construction, transportation safety, information transmission and auto
control, technical and economic analysis, environmental impact assessment and so on. Shanghai should focus on the following issues at present:

- Comparing the various forms of underground container transport system, construction and development models and feasibility; Considering Shanghai features and choosing feasible means of transmission underground container transport system, and comparing with traditional container transport system.
- Analysis of the role and impact to improve the quality of urban life by using underground container transportation logistics, sustainable development, improvement of the urban environment.
- Analysis of the technology condition to complete underground container transport system, mainly including constructions (such as pipe diameter, planning), the means of transmission (such as automatic guided vehicles, magnetic levitation technology) and information transmission (such as bar code recognition, sensor, etc.), and proposing and analyzing of the key technical problems of underground container transport system.
- Economic Analysis of underground container transport system, mainly cost-benefit analysis. In the cost analysis, analysis of investment, the cost, the investment return and benefits after the completion, including indirect benefits such as social benefits and environmental benefits.
- Establishing underground container transportation network planning and distribution model; Pointing out the medium-term, long-term development goals, and studying development model of Shanghai underground container transport system
- Recommendations of starting point, the corresponding technology policy and planning for Shanghai underground container transportation system.

3. CONCLUSIONS

Railway, waterway, road etc transport are important to a port. Most ports have been worried by severed traffic jam problems at least in one modal, and commonly all modal. As aforementioned, we draw conclusions that:

(1) Shanghai Port Underground Container Transport system offers new ideas to solve the problem of distributing containers, and it has great potential

(2) Coastal port cities in China, especially in Shanghai and other large cities, should study underground container port logistics for necessary technical reserves. Underground space planning needs take containers transport system into consider, and give full consideration to the possibility of application for the necessary underground space reserved.

(3) Shanghai underground container transportation system involves many aspects and its detail design to be further studied

REFERENCES
