Cost-Benefit Analysis in the Assessment of LNG Ship Bunkering Station on Inland Waterway Port

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Abstract

According to the development trend of green shipping, liquefied natural gas (LNG), as a marine fuel, has obvious advantages in safety, economy, environmental protection and so on. It has gradually became the first choice of ship power fuel in the future. The planning and construction of Marine LNG filling stations is the basic work for the waterway transportation industry to promote the application of LNG fuel, promote the ship 'oil to gas', and achieve energy conservation and emission reduction. In this paper, a shore-based LNG secondary filling station is assumed to be established in Baguazhou of Nanjing, and economic analysis of operation investment is carried out in terms of LNG filling station construction, infrastructure, and LNG transmission and distribution links, so as to provide reference for enterprises and relevant governments.

Keywords- *LNG ship bunkering station; Baguazhou in Nanjing; Cost-Benefit Analysis*

1. INTRODUCTION

With the development of transportation industry, the shortage of oil resources and the air pollution are becoming more and more serious. Water transportation is an important part of transportation industry. At present, the power fuel of ships is mainly diesel and fuel oil, diesel is mainly used for small and medium-sized ships in inland or offshore areas, with high fuel cost; Fuel oil is mainly used in large and medium-sized ships in the ocean, which usually contains more impurities such as sulfur and ash, and has a lot of pollution. According to the development trend of green shipping energy, LNG, as a ship energy, has obvious advantages in safety, economy and environmental protection, and gradually becomes the first choice of ship power fuel in the future. The planning and construction of LNG filling station is the basic work for the water transportation industry to promote the application of LNG fuel, promote the ship 'oil to gas', and realize energy conservation and emission reduction. Over the years, the Ministry of state attached great importance to the LNG filling market on water, issued a series of documents, participated in many enterprises, but affected by many factors, the whole industry has developed slowly and did not reach the expected progress. Since this year, due to the expansion of oil and gas price difference and the improvement of environmental protection requirements in inland rivers such as the Yangtze River, many state-owned enterprises of petroleum and petrochemical industry and private enterprises of society have been actively involved in the market. The LNG filling of ships with relatively mature green environment protection and technology has ushered in development opportunities.

In view of the reasonable layout planning of inland LNG filling stations, Liu Guoliang [1] and others put forward the ideas and methods for the layout planning of inland LNG filling stations based on the relevant experience of port layout planning and LNG filling station design, and guided by the LNG demand within the planning period, including the determination of filling station scale demand, spatial layout planning and so on. The proposed method can provide reference for the layout planning of inland LNG filling stations in China. Dai Wenqiang [2] and others analyzed the existing ship structure of the Yangtze River trunk line, Beijing Hangzhou canal and Xijiang shipping trunk line, analyzed and predicted the demand for marine LNG filling in the main provinces along the line, and combined with the annual filling capacity of a single LNG filling berth, obtained the overall density layout scheme of LNG filling terminals in the three provinces along the inland river, and analyzed the navigation conditions of inland river LNG powered ships. Based on the analysis of the water and land conditions of each candidate station, this paper proposes the layout and location of inland LNG

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filling station. Hu Yong [3] and others analyzed the prediction method and specific implementation steps of Inland River Marine LNG fuel demand, and studied and proposed the model for determining the scale and quantity of inland river LNG filling stations and the key points of site selection method, as well as adhering to the principles of adaptability, safety and economy, so as to provide reference for the layout planning and construction of inland river LNG filling stations. Liu Zhiren [4] and others pointed out the problems existing in the site selection of LNG filling station on water, and proposed the matters needing attention in site selection, including the determination of main functions of LNG filling station on water, calculation of filling capacity, classification and determination of layout spacing, and then analyzed the constraints and basic requirements of site selection of LNG filling station on water, This paper discusses the improvement and application of site selection method of LNG filling station on water.

In order to better realize the basic work of energy conservation and emission reduction, the application of LNG fuel should be promoted in the water transportation industry, so as to promote the high-quality development of green shipping through the site selection and economic analysis of LNG filling stations.

2. Status quo of LNG bunkering stations for waterway transport

According to the data provided by IHS, at present, 85 ports have or promise to build LNG filling facilities. It is reported that by the end of 2018, there were 60 marine LNG filling points in operation around the world, mainly in Europe, and a few in the Caribbean, Southeast Asia and the Middle East. In addition, 28 filling facilities have been built, and at least 36 filling facilities are in the stage of research and demonstration.

LNG used as marine fuel in foreign countries originated in northern Europe, and has been used for more than 10 years. Its main purpose is to meet the emission requirements of emission control area (ECA). The research and construction of LNG filling station for foreign ships is in its infancy. The TC67 / wg10-LNG marine fuel filling working group of international organization for Standardization (ISO) and IMO IGF working group are carrying out the research work of LNG filling on water at the same time.

The European Commission (EC) adopted the "clean fuel strategy" in January 2013, which proposed the "EU integrated framework action plan for LNG on water". By the end of 2014, EC and the European maritime administration (EMSA) jointly proposed a set of comprehensive norms, standards and guidelines on the supply, filling and use of LNG on water. By January 2020, LNG filling stations will be built in all core ports of ten-t to provide LNG filling services.

In Norway, there are three main LNG filling methods: shore ship filling (TPS), tank car ship filling (TTS) and ship ship filling (STS). Most of the existing filling terminals have LNG / fuel dual fuel filling function. On the northeast side of Bergen, gasnor company, a subsidiary of Shell Group, has its own LNG filling terminal, which mainly supplies LNG for its own offshore oil field. Fjord line terminal LNG filling terminal in Norway is located at risavika port, which is specially used for filling LNG for ferries. LNG is supplied by the LNG terminal of skangass company nearby (one 30000 m^3 offshore natural gas tank has been built).

In the United States, in order to promote LNG powered ships, relevant departments and units are planning to build LNG filling facilities. For example, Waller marine company in Houston plans to build a small ship LNG filling station at the port of Baton Rouge area in Mississippi River Basin, Louisiana.

LNG filling terminals in China are mainly shore ship type (LNG storage tank is located on the land) and pontoon type (LNG storage tank is located on the pontoon). From 2012 to 2013, four LNG filling stations have been planned and constructed in China, which are located in Nanjing port, Wuhan port and Wuhu port. Among them, Nanjing ‘Haigang star 01’ was put into operation in September 2013. In addition, there are many ship LNG filling station projects in the state of approval and planning, such as the ship LNG filling station project of Kunlun energy (Changhang) Natural Gas Co., Ltd. in Wuhu, Maanshan, Anqing, Tongling and other ports, the ship LNG filling station project of Chongqing Gas Group, and the corresponding projects in Zhejiang, Nantong and Yichang.

In September 2014, the general office of the Ministry of transport released the "list of the first batch of pilot demonstration projects for the application of LNG in water transportation industry", including 7 pilot projects, 6 demonstration projects and 3 demonstration area projects, such as Zhejiang Zhoushan international ship LNG filling pilot project, Jiangsu section of the Yangtze River mainstream and Guangxi section of Xijiang trunk line.

As of September 2017, 16 inland river LNG filling terminals have been basically completed, including 9 shore ship terminals and 7 pontoon terminals, which are mainly distributed along the Yangtze River trunk line and the Beijing Hangzhou canal.

In coastal areas, CNOOC, PetroChina and other large oil and gas enterprises have plans to build LNG supply outside the natural gas pipeline based on their coastal LNG terminals; Xinao group, a private enterprise, has built a LNG terminal in Zhoushan, Zhejiang Province. This project is also the first supply base in China that can go to the high seas to fill LNG for international shipping

ships. In addition, ENN has selected Dalian shipyard to build an 8500 cubic meter LNG filling ship to provide LNG filling service for coastal and ocean going ships entering and leaving nearby ports.

3. COST-BENEFIT ANALYSIS ON LNG BUNKERING STATION INVESTMENT

Promoting the use of LNG clean fuel for inland ships is one of the important measures to achieve the goal of energy conservation and emission reduction in China. LNG water filling station is a place that provides LNG fuel filling service for LNG powered ships. Under the principle of ensuring the effective utilization of LNG filling station resources, meeting the needs of users, meeting the shipping development planning and ensuring safety, this paper analyzes the investment and operation of LNG filling station with NPV and IRR methods, so as to provide reference for enterprises and relevant governments.

3.1. Cost-benefit analysis

NPV (Net Present Value) refers to the difference between the present value of future capital (cash) inflow (income) and the present value of future capital (cash) outflow (expenditure). That is, the algebraic sum of the present value of the net cash flow of each year calculated according to the industry benchmark discount rate or other set discount rate during the calculation period of the project. It is an important index to evaluate the feasibility of the project. The calculation formula of NPV is derived from the formula (1) .

$$NPV = \sum_{i=0}^{n} (CI - CO)_t (1 + i_c)^{-t} \quad (1)$$

In the formula

$(CI-CO)_t$ ——Net cash flow in year t ,

i_c ——Benchmark rate of return ,

n——Calculation period of investment plan.

NPV greater than 0 indicates that the return on investment is greater than the cost of capital, so the investment operation plan can be adopted; When NPV is equal to 0, the return on investment is equal to the cost of capital, so it is unnecessary to adopt the investment operation scheme. When NPV is less than 0, the return on investment is less than the cost of capital, so the investment operation scheme can be abandoned.

IRR(Internal rate of return)refers to the discount rate that can make the present value of future cash inflow equal to the present value of cash outflow, or make the net present value of investment project zero. If the IRR is greater than the cost of capital, it should be adopted; On the contrary, the investment plan is not adopted.

3.2. Case study of Baguazhou in Nanjing

3.2.1. Cost analysis

Located in the northwest of Qixia District, Nanjing Baguazhou, together with Liuhe District and Pukou District, forms the Jiangbei area of Nanjing, with an area of 55.62 square kilometers. It is the third largest island in the Yangtze River. It is in line with the principle of port and waterway planning, and far away from crowded areas and dangerous areas. Therefore, this paper assumes to build a shore based secondary LNG filling station in Nanjing Baguazhou, and analyzes its investment and operation.

①Initial investment cost F

Initial investment cost F is divided into infrastructure cost F_0 and construction cost F_1 two modules.

The shore based LNG filling station is divided into storage area, air defense area, water supply area, land unloading area, filling area and production auxiliary area. The facilities required for each area of the filling station are shown in Table 1.

TABLE 1. FACILITIES IN EACH AREA OF FILLING STATION

Area	Facilities
storage area	storage tank, supercharger, low temperature pump, bog recovery device, EAG heater, etc
air defense zone	centralized discharge pipe
water supply berth area	supply berth, supply hose or unloading arm, trestle, etc
land unloading area	unloading position, unloading hose or unloading arm
filling area	filling facilities, filling berth, trestle, etc
auxiliary production area	station building, staff dormitory and living room

The cost of infrastructure for the operation of shore based secondary filling station F_0 is priced at RMB 3003000.

The construction period of the LNG filling station is set as one year, and the construction cost is F_1 divided into land cost F_s and land construction cost F_t . According to the bidding price, the land construction cost of LNG filling station is RMB 120.3186 million, the industrial land price in Nanjing is RMB 229 thousand per mu, and the secondary LNG filling station covers an area of about 8.4 mu.

$$F_s = L_P * S \quad (2)$$

In the formula

L_P ——The price of industrial land in Nanjing

S ——Area of LNG filling station, mu;

The land cost of the secondary LNG filling station in Baguazhou, Nanjing is RMB 1,923,600 .The construction cost of the shore-based secondary LNG filling station F_1 is RMB 122.2422 million.

②LNG transportation and distribution cost F_2

LNG is transported to China from abroad and transported to the coastal terminal by large LNG ships, and then unloaded to the storage tank of the coastal terminal by the coastal unloading dock; Finally, after gasification at the coastal terminal, it is transported to the inland river Reserve Station by LNG tanker. The LNG terminal invested and operated is Rudong LNG terminal.The transportation process of LNG after landing,as shown in Figure 1.

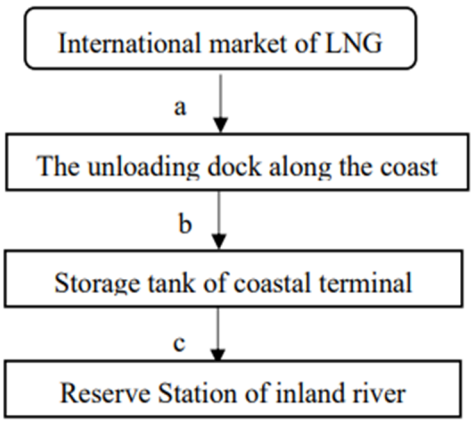

FIG. 1 The transportation process of LNG after landing

The cost of LNG delivery and distribution after landing is divided into three modules. The cost corresponding to the cost code is shown in Table 2.

TABLE 2. THE FEE CODE CORRESPONDS TO THE FEE NAME

Cost code	Definition of the fee
a	The receiving cost
b	The cost of storage
c	The cost of transport by tanker

(1) Fees received F_a and The cost of storage F_b

According to the cooperation experience between a gas enterprise in a city in Guangdong and a coastal LNG receiving station, customs, piloage and other costs are uniformly classified as receiving costs, accounting for about 15% of the total operating and processing costs F_m of the coastal LNG receiving station, and storage costs account for 50% of the total operating and processing costs [5].

$$F_a = 0.15F_m \quad (3)$$

$$F_b = 0.5F_m \quad (4)$$

In the formula

F_m ——The total operation and processing cost of the coastal LNG receiving station is RMB 0.3 per cubic meter, which is converted to RMB 408 per ton;

The receiving cost is RMB 61.2 per ton, and the storage cost is RMB 204 per ton.

(2) The cost of transport by tanker F_c

According to the international gas network, in the last ten days of December 2018, the transportation cost of LNG tanker in Eastern China is shown in Table 3, and the transportation cost of LNG tanker is shown in formula (5).

TABLE 3. TRANSPORTATION COST OF LNG TANKER IN EASTERN CHINA

Distance of transportation/km	Floor price (yuan·t^{-1}·km^{-1})	Ceiling price(yuan·t^{-1}·km^{-1})
Within 100 km	1.2	1.5
101-200	1	1.2
201-300	0.8	1
301-500	0.7	0.8
501-700	0.65	0.7
701-1000	0.6	0.65
1001-1500	0.5	0.6

$$F_c = \frac{d * T}{\partial} \quad (5)$$

In the formula

d——Distance of transportation, The distance from Rudong receiving station to Nanjing Baguazhou filling station is 273.6km.

T——The price of tanker transportation

∂——The value of LNG gasification rate is 1400m^3/t.

It is concluded that the transportation cost of LNG tanker F_c is RMB 239.2 per ton. In the whole LNG transportation and distribution process, the transportation and distribution cost F_2 is RMB 2504.4 per ton.

Daily expenses F_3

The daily expenses F_3 is divided into four modules: depreciation cost, labor cost, electricity cost and maintenance cost.It costs RMB9800 every day.

3.2.2. NPV and IRR analysis of the LNG filling station

According to the website of clakson sin, the CIF import price of LNG is RMB 3549 per ton, which is regarded as the import price of LNG. According to the international gas network, the price of marine fuel in the Chinese market is RMB 4337.5 per ton, which is regarded as the sale price of LNG. It is estimated that 307 ships will pass through Baguazhou every day, assuming 50 LNG ships, The target ship type of the LNG filling station on the Yangtze River trunk line is 3 000-5 000 t ships. These ships are usually equipped with 20 m^3 LNG tanks. Considering 75% of the LNG tank capacity, the average filling capacity of each ship is 15 m^3 LNG, that is, 6.75 t for each ship. Under ideal conditions, the probability of filling at the filling station is 50%, and the total demand is 168.75 tons every day, The daily expenses include staff wages, facility maintenance expenses, electricity expenses, etc., and daily transmission and distribution expenses. Without any sudden extreme external factors, the net income of each year after investment and operation is RMB 13921784, and the net present value is RMB 6577134.53 in the 13th year. It can be concluded that the cost of the investment and operation scheme can be recovered in the 13th year, The IRR of investment in the LNG filling station is 9%. The investment in the operation scheme of the shore based secondary LNG filling station is large in the early stage and takes a long time to recover the cost, but on the whole, it can be invested and achieve certain economic benefits.

3.2.3. Sensitivity analysis

①Sensitivity analysis of LNG selling price and LNG filling volume

Assuming that the CIF import price of LNG is RMB3549 per ton and other influencing factors remain unchanged, when the LNG selling price is lower than RMB 4337.5 per ton, the NPV will be lower with the increase of LNG filling amount; When the LNG selling price is more than or equal to RMB 4337.5 per ton ,the higher the filling volume is, the higher the selling price is, the higher the net present value is, and the better the economy is. The NPV of the LNG filling station at different LNG selling prices and LNG filling volume is shown in Table 4.

TABLE 4. THE NPV OF THE LNG FILLING STATION AT DIFFERENT LNG SELLING PRICES AND LNG FILLING VOLUME

Daily LNG filling volume /t	NPV of LNG at different selling prices / RMB 10 million			
	RMB2337.5/t	RMB 3337.5/t	RMB 4337.5/t	RMB 5337.5/t
33.75	-34.68	-23.41	-12.15	-0.88
67.5	-54.02	-31.48	-8.95	13.59
135	-92.69	-47.62	-2.54	42.53
168.75	-112.03	-55.68	0.66	57.00

②Sensitivity analysis of LNG selling price and LNG import price

Assuming that the daily LNG filling capacity is 168.75t and other factors remain unchanged, the larger the difference between the LNG export price and the LNG CIF import price, the greater the net present value, and the better the economy of the LNG filling station. At present, the selling price of LNG is about RMB4337.5 per ton, the import price of LNG is about RMB 3800 per ton, and the net present value is negative, so the investment in inland river LNG filling station is not economical. The NPV of the filling station under different LNG selling prices and LNG CIF import prices is shown in Table 5.

TABLE 5. THE NPV OF THE FILLING STATION UNDER DIFFERENT LNG SELLING PRICES AND LNG CIF IMPORT PRICES

CIF price of LNG (RMB/t)	NPV of LNG at different selling prices / RMB 10 million			
	2337.5 RMB/t	3337.5 RMB/t	4337.5 RMB/t	5337.5 RMB/t
2800	-69.83	-13.48	42.86	99.20
3300	-98.00	-41.66	14.69	71.03
3800	-126.17	-69.83	-13.48	42.86
4100	-143.07	-86.73	-30.39	25.96

4. MAIN PROBLEMS OF LNG BUNKERING STATION

Although the state strongly supports the development

of LNG filling station construction in terms of policy, there are still several problems in the specific operation.

① The initial investment is large, and the enterprises lack confidence in large-scale investment. The initial investment in building LNG filling stations and LNG fuel ships is large, and it will take time for the LNG filling market to be fully standardized and perfected. Many enterprises invested in the early stage have lost ground. In the current market outlook is not clear, enterprises are cautious. ②The procedure of examination and approval is complex, and the procedure is difficult to handle. Although after more than ten years of promotion and publicity, many administrative approval departments still lack a unified understanding of LNG water filling station, resulting in unclear approval process and complicated procedures. At present, the construction declaration process of LNG water filling station involves many regulatory departments, such as the construction and planning need to be approved or filed by the Energy Bureau, the LNG qualification of enterprises needs to be approved by the gas office, the use of wharf shoreline needs to be approved by the port and shipping administration, the water area needs to be approved by the maritime administration, and the waterway related issues need to be approved by the waterway administration. It is very difficult for the enterprises planning to build the LNG filling station to get a clear idea when applying for the project, which directly affects the propulsion speed of the LNG water filling station. At the same time, because the state does not clearly define the shoreline attribute and wharf attribute of LNG filling station, the management department has no basis to follow in the approval of LNG filling terminal, which makes it difficult for the construction project of water filling station to be approved. At present, most of the filling stations that have been basically completed do not have complete procedures. Some filling stations have not completed the navigation impact demonstration and flood control impact assessment, and the fire department also thinks that there is a lack of relevant standard basis, so it is unable to carry out fire control review, resulting in the failure to put into operation. ③ In addition to its own safety factors, the development of LNG filling station in inland river is restricted by such factors as no water gas source, site selection and shoreline utilization, port planning, impact on surrounding wharf operation, construction cost and operation cost.

5. Conclusion

Based on the results and discussions presented above, there are some suggestions on the development of LNG bunkering station.

5.1. Implementing government pricing to improve business environment

At present, there is no unified price management mechanism for LNG filling stations. The government pricing of ‘oil and gas linkage’for LNG filling stations can improve the situation of downstream price confusion and create a good living environment for LNG filling stations. This is conducive to more enterprises to invest in the LNG filling station industry, and the loss situation of the filling station may be reduced, which will bring the expected effect to the operation environment of the filling station.

5.2. Simplifying the examination and approval procedures and promoting the construction of LNG filling station

Although it has been publicized and promoted for a long time, the cognition of relevant departments is still insufficient. Government departments at all levels should further simplify the approval procedures and approval contents according to the actual situation, especially give strong support in the construction land (leased land) and planning and site selection, comprehensively promote the approval speed of gas filling stations, and actively promote the construction of filling stations.

5.3. Achieving government policy and financial support

After the national implementation of energy conservation and emission reduction policies, we should give certain subsidies to the operators of filling stations. We can study the impact of the existing incentive policies, oil quality improvement, emission restriction areas and other environmental protection policies on the cost of ship owners, and introduce relevant policies according to local conditions, such as subsidies for changing ships, priority to pass the lock, and restrictions on fuel ships in some waters. This is helpful to encourage a large number of enterprises to invest in LNG filling stations and promote the development of LNG filling stations.

5.4. Promoting technological progress, strengthening exchanges and cooperation between industries

We should study the standards of LNG ship transformation and natural gas engine technology, because there are many factors affecting the development of the aquatic market, involving many industries such as ship transformation, water transportation, refueling equipment and engines. It is necessary for shipping enterprises, engine manufacturers, shipyards, refueling equipment manufacturers and other industries to jointly promote the development of the shipping industry. It is necessary to give full play to the ability of the

government and industry associations to integrate resources, and to promote the development of the shipping industry by coordinating policies, technologies and funds.

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