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Economic analysis of vessel SOx emission reduction measures in the context of China

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Shanghai，China

ECONOMIC ANALYSIS OF VESSEL SOx EMISSION REDUCTION MEASURES IN THE CONTEXT OF CHINA

By

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CHINA

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Declaration

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

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

(Signature): Guan Peng

(Date): 20/06/2020

Supervised by: Zhang Chuan

Supervisor's affiliation: Shanghai Maritime University

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Peng Guan, June 2020 Shanghai, China

Abstract

Title of Research paper: **Economic Analysis of Vessel SOx Emission Reduction Measures in the Context of China**

Degree： **MSc**

With the rapid development of the world trade, the shipping industry is experiencing a rapid increase. Yet, there is an urgent issue deserving much attention. Ships produce substances that cause air pollution. For example, the flue produces NOx, COx, especially SOx. The impact of the massive emissions of these substances to the atmosphere is increasing.

In the context of IMO , the MARPOL Convention was implemented in January 2020. As I know , MARPOL Annex VI lowered the global sulfur emission standard from 3.5% to 0.5%. It focuses on no marine pollution but air pollution not only in China, but also in the world. Normally, there are two measures for controlling SOx emission,one is using low sulphur bunker, another one is Scrubber. This project comprehensively analyzes the current status and problems of ship's air pollution emissions, analyzes the main emission reduction measures to reduce ship's atmospheric emissions, and conducts economic analysis of emission reduction measures. I will apply both Quantitative and Qualitative methods to select which way is much better to control SOx emissions, so as to provide decision supports for the formulation and implementation of emission reduction measures in China.

Key words： Air pollution, MARPOL, Control emission, Reduction measure，Scrubber，Low-sulphur bunker.

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List of Abbreviations

IMO: International Maritime Organization

MEPC: Maritime Environment Protection Committee

MARPOL: Maritime Agreement Regarding Oil Pollution of Liability

NPV: Net Present Value

IRR: Internal Rate of Return

NSD: Norwegian Social Science Data Service

MSD: Middle Speed Diesel

HFO: Heavy Bunker Oil

MGO: Marine Gas Oil

LSFO: Low Sulphur Fuel Oil

SECAWYAD: Ship Emission Control Area in Waters of Yangtze River Delta

ECA: Emission Control Area

TBN: Total Base Number

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Economic Analysis of Vessel SOx Emission Reduction Measures in the Context of China

Chapter 1. Introduction

1.1 Research Topic

A research topic is a broad subject matter addressed by a study. With the development of the world trade, the shipping industry is getting a rise .However, there is an urgent issue deserving much attention. Ships produce substances that cause air pollution(Christer Ågren AirClim 2019). The flue produces Nox, Sox, COx, and volatile organic compounds produced by tankers. The impact of the massive emissions of these substances to the atmosphere is increasing (Kang, H., Wang, G., Bang, H., & Woo, S. 2015).

According to the information provided by Norway to IMO[1], Norwegian ships emit NOx 6.02 million tons per year, which accounts for 7% of the world's total emissions; SOx 6.34 million tons, accounting for 4% of the world's total emissions; COx annual emissions approximately 1.24 million tons, accounting for 2% of the world's total emissions; VOC380,000 tons (Christer Ågren AirClim 2019). The polluted atmosphere can affect the climatic and coastal countries beyond 1000 km away. Among the pollutants, SO2 and SO3 in SOx are the culprit of acid rain.

[1] IMO: International Maritime Organization

The 70th MEPC[2] meeting held in October 2016 lowered the global sulfur emission standard from 3.5% to 0.5%, and the MEPC decided to start implementation of MARPOL[3] on January 1, 2020.

The policy of controlling sulfur emissions in the European Union and North America is also very strict. The EU in advance implemented the sulfur oxide emission standard in MARPOL 73/78 Annex VI before 2020, and gradually expanded the scope of application of the sulfur emission standard. North America has also advanced the implementation time of sulfur emission control standards. From this, it can be seen that the international community is accelerating the legislative process and continuously strengthening the control of ship sulfur emissions in China.

1.2 Research Problem

A research problem is a general issue about topic, concern, or controversy addressed in research that narrows the topic (Creswell, J. W. 2012). Pollution emissions from maritime bunker cause air pollution. After stating the topic in the opening discussion, I then narrow the topic down to a specific research problem or issue， SOx emission from maritime bunker. Recall that a research problem is an shipping industrial issue, concern, or controversy that the researcher investigates.

I am justifying my research problem based on evidence from my study experiences before. So research problem was based on the courses that I once took , which is called Environmental Issues of Maritime Transport (ENV). In the course it has been

[2] MEPC: Maritime Environment Protection Committee
[3] MARPOL: Maritime Agreement Regarding Oil Pollution of Liability

mentioned that the MARPOL will be applied in 2020. At that time, the shipping company will suffer an urgent situation (Moon. J, 1986).

Justifying a research problem means giving out reasons for the importance of studying the problem or concern. As is shown in the following Figure 1, we can justify the importance of this environment issue by citing evidence from:

- Other researchers and experts' suggestion
- Experiences in the workplace
- Personal experiences

These justifications drawn from different sources are used in different types of methodologies , such as quantitative or qualitative ones (Creswell, J. W. 2012).

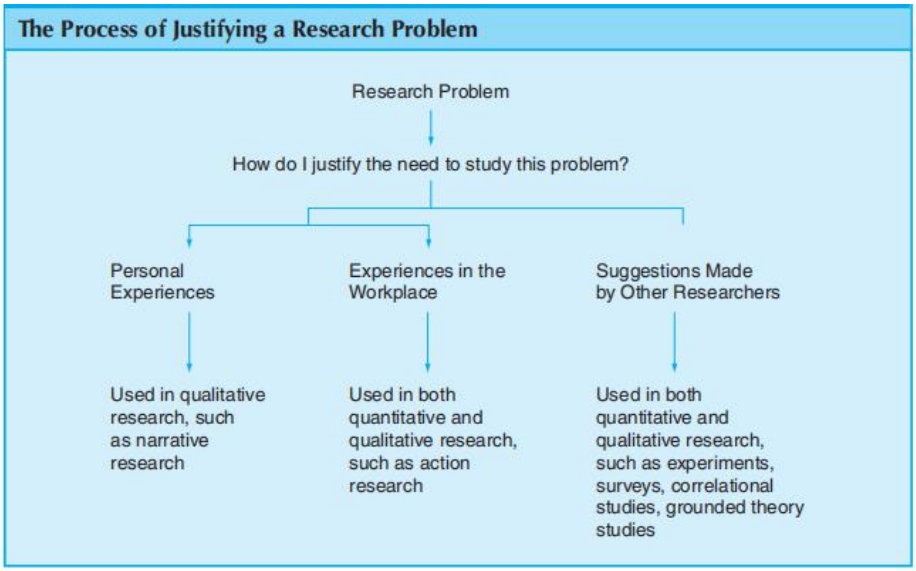


Figure 1. Research problem

A purpose is a major intent or objective of a study used to address a problem (Creswell, J. W. 2012). I will state the purpose of my study as follows: " The purpose of my study is to identify an economical way to control SOx emissions" .

China is a major country in international trade, and the issue of shipping emissions control is quite important. This article analyzes the current status of air emissions from ships, and analyzes the main measures for controlling ships' SOx emissions, and the economic analysis of emission reduction measures provides decision supports for the formulation and implementation of emission reduction measures for shipping companies in China.

1.3 Research Question

A Research question is usually short, general, so that you would like to answer it in the study(Creswell, J. W. 2012). Obviously, if we want the shipping industry to significantly reduce air pollution, it must take urgent actions. In terms of governmental intervention, the rules and regulations in the form of mandatory emission standards are first used, often referred to as the Command and Control (CAC) method. MARPOL is a kind of method of CAC(Shuoma.2019).

In this research，research questions narrow the purpose down into specific questions that the researcher would like to answer or address in the study. I will ask, "which way is better for control SOx emission in China? --Scrubber？--Low sulphur bunker？

Chapter 2. Literature Review

As far as I know, the basis of this paper is the MARPOL Convention to be implemented in 2020. SOx emission control is becoming increasingly urgent. The

main contents of the MARPOL Convention are as follows (IMO, 2020).

In October 1973 the International Maritime Organization (IMO) held the International Conference on Marine Pollution in London and passed the 1973 International Convention for the Prevention of Pollution from Ships. In February 1978 the International Conference on Tanker Safety and Pollution Prevention passed the Protocol modifying the Convention, which would also be implemented together with the Convention (Djadjev, 2015). They are collectively known as The International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978 (MARPOL73/78). MARPOL is divided into six annexes:

Annex I Prevention of pollution by oil & oily water (compulsory annex), effective October 2, 1983;

Annex II Control of pollution by noxious liquid substances in bulk (compulsory annex), effective April 6, 1987 (Djadjev, 2015);

Annex III Prevention of pollution by harmful substances carried by sea in packaged form (optional annex), effective July 1, 1992;

Annex IV Pollution by sewage from ships (optional annex), effective September 27, 2003;

Annex V Pollution by garbage from ships (optional annex), effective December 31, 1988;

Annex VI Prevention of air pollution from ships (optional annex), established September 26, 1997, effective May 19, 2005.

The international community has long been concerned with air pollution caused by ships, especially the nitrogen oxides (NOx) in exhaust gas. Such concerns can be traced back to the 1970s when MARPOL 73/78 was first adopted. At that time, however, the IMO did not include air pollution in the Convention. Regarding global concerns about environmental pollution, the IMO's Marine Environmental Protection Committee (MEPC) officially started to discuss and review issues relating to preventing air pollution from ships in 1988 (IMO, 2020).

Annex VI of MARPOL73/78 restricts the amount of sulfur oxides (SOx) and nitrogen oxides (NOx) in ship exhausts and prohibits deliberate emission of ozone-depleting substances. The Annex also sets the global cap for sulfur content in fuels and calls the IMO to monitor the average sulfur content in fuels worldwide after MARPOL enters into force. The Annex allows the establishment of special control areas for SOx emission in order to exercise more strict control over sulfur emission (Djadjev, 2015). In the control areas, the sulfur content in fuels used by ships shall not exceed 0.5%; otherwise the ship must install exhaust gas cleaning equipment or use other technical means to limit SOx emissions.

The supply and demand of low-sulfur oil refers to the correlation between supply and demand of low-sulfur oil in market economies in China. The price of low sulphur fuel oils affects the shipping company' choice. If the suppliers of low sulphur fuel oils increase， the price will drop, the shipping companies will prefer to choose low sulphur as the solution to control SOx emission. It also reflects the relationship between suppliers (mainly producers) and buyers of low-sulfur oil in the market ("Marketing Research", 1958). There are three possible supplies and demand models

for low-sulfur oil, just like all other goods: supply is greater than demand, demand is greater than supply, and equilibrium. Assume the price of low-sulfur oil depends on its supply and demand, then the price would rise if demand is greater than supply, and vice versa (Borch, 1968). Therefore, equilibrium is the ideal status and will not result in price change.

Major global oil corporations have all had schemes to produce LSFO: ExxonMobil, Lukoil, Total, Shell, BP, etc, and have successively announced their projects, their production capacity and supplying branches.Sinopec has also listed the production of LSFO for ships in the "13th Five-Year Plan." However, there is still a huge gap between the published production capacity and global market demand. All the above will affect shipping companies' decision (Shuo ma.2020).

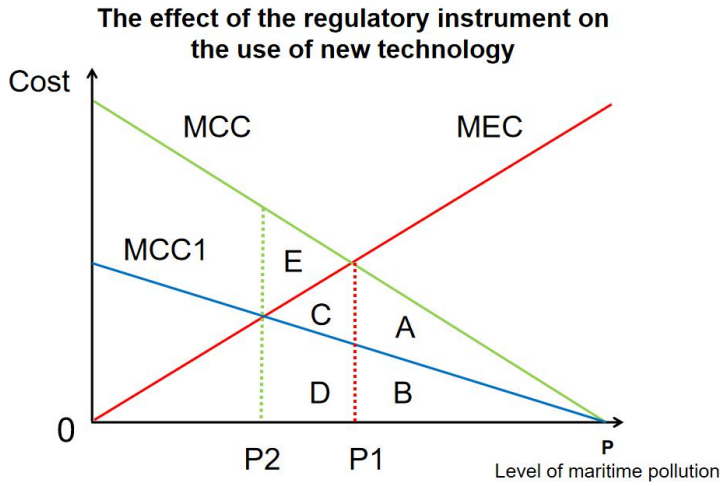


Figure 2. The effect on the use of new technology

As for the ship, if it would keep the emission level at P1, the total emission control cost is the area represented by A + B and the total emission cost payment is C + D +

E. If there is new technology available(Scrubber), applying the Scrubber will enable the ship to reduce its marginal control cost from MCC to MCC1. If the scrubber is employed, the total control cost would be in the area B + D and the tax cost payment would be E. So the net cost savings are the area A + C : the area A is control cost savings and the area C tax cost savings.

If the regulatory instrument with uniform emission standard is applied, the total cost savings would only be area A . Therefore, area C represents an extra incentive for the shipowner to invest in new technology (Shuo ma.2020). It means that using new technology increases big changes in emission cost.

Traditional methods may not be sufficient enough to eliminate air pollution caused by the shipping industry. The IMO is the principle administrative agency of international shipping. Its primary approach is to establish technical standards that are to be implemented by member states. This approach is often referred to as “command-and-control,” which is clear, flexible and executable. However, possible criticism may suggest that this approach may be inefficient because applying universal standards could neglect the difference in the costs of controlling pollution for different polluters. Thus, some endorse an economical approach, a.k.a. market-oriented approach, which is to encourage the adoption of more up-to-date and advanced control technologies by offering economic incentives to polluters with low cost of control. The market-oriented approaches have been successfully applied in many cases, and now it is the best time to adopt the approach within the IMO frameworks as supplementary tools for reducing ship emissions and achieving the overall environmental goals (Shuo ma.2020).

In addition, only voyage charters shall be analyzed in this paper, because the responsibilities of voyage charter parties and time charter parties are clearly different. Voyage charters can be defined as legal contracts – the shipowner allows the lessee to carry specific cargo on a specific ship on a specific voyage for an agreed amount. Voyage charters can be subdivided into one-way voyage charters, round-trip voyage charters and multiple voyage charters (Charter parties, 2020).

For time charters, the shipowner leases the ship to the lessee for an agreed period. The rent is calculated based on the duration rather than the number of completed voyages. Within the chartered period, the lessee may use the ship to transport cargo or passengers, or sublease the ship for freight income or rent.

However, responsibilities associated with the two charters are different: For time charters, the shipowner is responsible for the ship's operation, but the commercial right of control belongs to the lessee. The shipowner shall bear all costs associated with crew support, maintenance and insurance, but the lessee shall pay for bunkers and port fees(Charter parties, 2020). For voyage charters, the shipowner is responsible for both technical and commercial management of the ship, and should afford not only all expenses associated with crew, maintenance and insurance, but also all other costs, including bunkers and port fees (Ship. Charter-Party, 1911).

The ways to pay rent are also different between time charter and voyage charter. Time charter parties: For time charters, the lessee pays rent every day. Voyage charter parties: For voyage charters, the lessee is obliged to pay for freight costs to the shipowner. Freight costs are calculated, based on the amount of cargo carried or

shipped, or the total costs (regardless the number of ships and whether the rent paid to consigner has reached the prescribed limit). When we analyse the cash-flow, we should pay attention to the difference between time charter and voyage charter. Because these two charter parties have totally different operation cost and capital cost.

Chapter 3. Methodology

In this thesis, I will carry out a quantitative and qualitative analysis through analysis, induction, deduction, interview and survey. The theme of this paper is to explore the economic analysis of whether to install a desulfurization scrubber or use low sulfur oil under the IMO's policy for controlling sulfur emissions in China, and further, I will conduct a qualitative analysis through an interview to discuss why each shipping company chooses the way they do. I will apply quantitative cash-flow analysis the cost efficiency for both methods, after qualitative interview continue using quantitative survey to analysis relationship of each factors in China.

3.1 Quantitative Method

We know that quantitative analysis is an analysis of the quantitative characteristics, quantitative relations and quantitative changes of economic phenomena. In investment analysis, researchers will use mathematical models to analyze the obtained data. Through the analysis, I will evaluate the operation of shipping companies and make investment judgments in China. The subjects of quantitative analysis are mainly data statements, such as Balance Sheet, Income Statement,

Statement of Retained Earnings, etc. We often use these data to reveal and describe a certain phenomenon or development trend. In this project, the Balance Sheet can directly show the capital situations of the shipping companies in each scenario. Survey is a commonly used tool for quantitative analysis (Creswell, J. W. 2012). In this article, I will first use quantitative investigation to analyze whether it is more economical to install desulfurization scrubber or select low-sulfur oil after IMO MARPOL convention is implemented in the future. Quantitative analysis is a method to establish mathematical model based on statistical data, and calculate the indexes and values of the analysis subject with mathematical model. So I will list all kinds of balance sheets and show the results through the final figures. In addition, I will use a simple survey to analyze each shipping company's views on which method to choose in China.

3.1.1 Cash-flow

Cash flow is the blood of an enterprise, and cash flow statement is the blood system of an enterprise. A company without profit is likely to survive, and a company without cash flow is bound to die. However, most bosses regard profit as their business target, but ignore that cash flow is more important than profit. Cash flow = cash inflow - cash outflow (Lewellen & Lewellen, 2010). Cash flow greater than zero is positive cash flow, which means cash flows into the enterprise. Cash flow less than zero is negative cash flow, which means cash flows out of the enterprise. So, the cash flow statement is the blood system of an enterprise. In cash-flow there are many important elements needing to be pay attention，such as NPV or IRR.

NPV: Net Present Value (NPV)[4] is the difference between the value of cash inflow

[4] NPV: Net Present Value

and the value of cash outflow over a period of time. NPV is used to calculate the investment budget and make the investment plan to analyze the expected investment value or the profitability of the project(Arnold & Crack, 2004).

The following formula is used to calculate NPV:

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)^t}$$

where:

R_t = Net cash inflow-outflows during a single period t

i = Discount rate or return that could be earned in alternative investments

t = Number of timer periods

Formula 1. NPV

When the NPV is positive, it means that the estimated benefits from the project investment exceed the expected costs, which shows that when NPV is positive, investment will be profitable, and when NPV is negative, investment will cause losses. In addition to the formula itself, you can also use excel tables, spreadsheets and calculators to calculate the net present value (Arnold & Crack, 2004).

IRR: Internal rate of return (IRR)[5] refers to the discount rate when the accumulated net present value is 0. This IRR means the maximum depreciation rate that the project can bear. The formula for IRR is:

$$IRR=a+[NPVa/(NPVa-NPVb)]*(b-a)$$

Where:

a, b are the discount rate.

Formula 2. IRR

[5] IRR: Internal Rate of Return

IRR depends on the internal part of the project. It can be calculated when the investment amount, construction and operation period, and cash flow is known (Bhattacharyya, 2004). It does not need to determine the external factors in advance, so that it is called internal.

Net Present Value (NPV) refers to how much money we can make in the project cycle considering the time value of money (inflation and devaluation). Internal Rate of Return (IRR) refers to the maximum devaluation rate that we can bear in the project cycle considering the time value of money (inflation and devaluation). More generally, it is assumed that if we take a loan to invest in this project, what is the maximum annual interest rate that we can bear. IRR is the rate of return that takes into account the time value of money. It is a weighted result that considers the amount and time of cash inflow and outflow in each period (Arnold & Crack, 2004).

3.1.2 Survey

Survey is an important method for researcher to collect the quantitative data. In the survey process, a valuable questionnaire can not only correctly reflect the purpose of the surveyor, but also accurately convey the ideas of the respondents. It is an information link connecting both the surveyor and the respondent.

After recovering from the questionnaires, the surveyor analyzes, summarizes and concludes the information in the questionnaires, and then writes the survey report according to the obtained survey results. Therefore, a survey plays an important role in this project. First, it links up the above cash flow to further collecting the macro data of each shipping company in China, judging the industry trend in China, and

then guiding the following interview based qualitative research to determine the judgment of professional practitioners' views on low-sulfur oil and scrubbers. Then the survey can work as a continue research for interview.

The quality of the questionnaire has a direct impact on the survey results and the value of the survey report. The questionnaire plays a central role in the survey process (Creswell, J. W. 2012). The role and process of the questionnaire in the research are shown in the figure below,

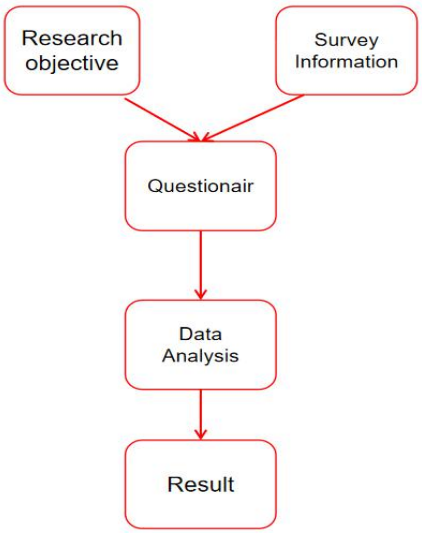


Figure 3. Process of survey

3.1.3 Survey Guide

The first step in questionnaire design is to fully understand the purpose and content of the survey. This step is actually to specify the information needed for the design of the questionnaire. Second, collect the information needed for the survey. According to the needs of the research, determine the contents to be understood and the data to be collected, classify the existing data, and analyze what is the main data and what is

the secondary data. Furthermore, it is necessary to determine the types of survey methods, and different types of survey methods have different formats and requirements for questionnaires (Creswell, J. W. 2012). Finally, determine the content of each question. This step is to determine which questions are specifically included in the questionnaire and what they should ask, and whether they can accurately and effectively reflect upon the information needed for the survey.

For example, the survey consists of 150 people, including all levels of employees from shipping companies in China, including sailors and seamen who are still working on the ship, or in shipping companies, who are randomly selected to participate in the survey. The survey was conducted by way of questionnaire survey and later translated into Chinese. The Survey consists of 12 questions about whether or not shipping company in China still using a measure. Calculate the data to find the percentage of each question and analyze the cause of the change.

3.1.4 Regression Analysis

Regression analysis originated from the research of biology. The famous biologist Darwin discovered a very interesting phenomenon at the end of the 19th century that a father was tall, his son was taller, his father was shorter, and his son was shorter. in conclusion, there is a close relationship between the height of the father and the height of the son (Walker & Smith, 2016). In a large number of data analysis, it is also found that there is a tendency for height to return to average height. This phenomenon of average height tendency is called regression.

Regression analysis is a method of analyzing the relationship between the dependent

variable and the independent variable. During the analysis establishing a function equation that approximates the quantitative relationship between dependent variable and the independent variable, and then we ca applying the regression equation to predict the change of the dependent variable(Kilic, 2015).

For surveys, I use dichotomous variables for analysis. Dichotomous variables are just the simplest of categorical variables. For example, gender is the most common form of categorical variables. You only need to encode gender as: 1 = male, 0 = female. The form in which a class variable is coded as 0 or 1 is called a dummy variable. In actual research, the objects to be processed can be divided into three, four or even more.Then, determine the factors that affect Y (the dependent variable). For example, what are the factors that influence men and women to choose a job ? (Walker & Smith, 2016)

Next is to set the model, which is regression analysis, and use software to complete the analysis. I will choose Spass. In fact, the independent and dependent variables are determined, the estimation method is also determined, and the model is basically determined. Finally, do the analysis of data analysis results. We should take the object wanted to analyze as the dependent variable. For example, I want to analyze whether the shipping company wants to choose to install a desulfurization tower or prefer to use low sulfur oil. Independent variable selection is the main influencing factor that affects the choice of the scheme. Based on data analysis, it could find a linear correlation or uncorrelation between these independent and dependent variables.

This paper adopts regression analysis method to explore the weight of influence of each factor, so as to analyze the factors that affect the installation of desulfurization tower. However, as a dependent variable, the willingness to install desulfurization tower is a binary nominal variable, and as an independent variable, each variable is an equal interval variable and a ratio variable, so that the Logistic regression model can be adopted. The basic logic analysis is as follows:

If P represents the probability of an event occurring, 1-P represents the probability that an event will not occur, and then the probability of an event occurring and the probability that it will not occur (polynomial correlation) are as follows (Walker & Smith, 2016):

The function of the probability of an event occurring is: $p = \frac{e^{f(x)}}{1+e^{f(x)}}$

The function of the probability that an event will not occur is: $1-p = \frac{1}{1+e^{f(x)}}$

Then, $odds = \frac{p}{1-p} = \frac{\frac{e^{f(x)}}{1+e^{f(x)}}}{\frac{1}{1+e^{f(x)}}} = e^{f(x)}$

Since odds is not a linear model, regression analysis cannot be directly conducted. Therefore, the natural logarithm of odds is taken, and odds is transformed into a linear equation:

$$\ln\left[\frac{p}{1-p}\right] = \ln\left[e^{f(x)}\right] = f(x) = B_0 + B_1X_1 + \ldots + B_kX_k$$

Formula 3. Liner equation

Based on the practical research problems, this paper adopts the binary Logistic regression model (Walker & Smith, 2016). Before carrying out the binary analysis,

since there are multiple variables involved in this study, in order to make the model more accurate and reasonable, this study first adopts Cross Chi-square analysis to screen variables, and then carries out binary Logistic regression for the variables after screening.

3.2 Qualitative Method

What is qualitative analysis? Qualitative analysis is the analysis of the nature of the research subject. Specifically, we use the methods of induction and deduction, analysis and synthesis, and abstraction and generalization to process all kinds of data materials (Creswell, J. W. 2012). There are two different levels of qualitative research. One is that there is no or lack of qualitative research of quantitative analysis, and the conclusions tend to be general and more subjective; the other is higher-level qualitative research based on quantitative analysis of the cash-flow. Therefore, after the previous quantitative analysis results, I will use qualitative analysis to further analyze the reasons that cause the company to choose which way to respond to IMO implementation of MARPOL (MARPOL 73/78, 2020). Qualitative analysis focuses on the description and interpretation of the doer, emphasizing the influence of behavioral background factors. Most of its data collection methods are reliable research and in-depth interviews to obtain the textual descriptions.

Therefore, I will select some people work in shipping industry in China and collect data through interviews. My research questions and research steps lead to the following use of qualitative analysis method, because it is semi-open, and helps to discover and develop new ideas, but also has a certain structure, so that the interviewees will not wonder off the topic. In this thesis, the understanding of the

phenomenon is variable, and the real data has been developing. For example, the oil price has been fluctuating. I believe that semi-structured interviews are an appropriate and effective solution to this research, as more information about the helper's values, attitudes and views, especially how they express their thoughts and opinions, and their attitudes towards the current situation can be obtained.

3.2.1 Interview Introduction

There are many methods of qualitative analysis and data collection, such as interviewing method and observation method, etc. But interviewing method can obtain more and more valuable information about the research subject's psychological activities and psychological characteristics, and it is more complex and difficult to grasp than observation method (Creswell, J. W. 2012). Compared with observation, interviews can understand the thoughts and emotional reactions of the interviewees. Compared with a questionnaire survey, an interview has more flexibility and space to explain the meaning. Compared with a physical analysis, an interview has more flexibility, immediacy and meaning interpretation functions.

An interviewing method is a methodology for researchers to collect research data through purposeful conversations with research subjects. More formal interviews were conducted, according to uniform design requirements and structured questionnaires. Semi-structured interviews have only a rough basic requirement on the condition of interviewees and the questions to be asked, and the interviewees can adjust flexibly according to the actual situation during the interview. As for the way and sequence of questions, the way interviewees answer questions, the way of interview records, and the time and place of interview, there are no uniform

provisions and requirements, and the interviewers can flexibly deal with them according to specific situations. The use of semi-structure is beneficial to the initiative and creativity of interviewers and interviewees("QUANTITATIVE AND QUALITATIVE METHOD IN SOCIOLOGICAL RESEARCH", 1942). It is beneficial to expand and deepen the research of the question; and beneficial to deal with new situations and questions that were not considered in the original interview design.

For example, in this interview, I will randomly select 20 people who working in shipping industry in China for this interview. Then, I will conduct in-depth analysis according to the interview contents to find out why the shipping enterprises will have the current choices under the premise of IMO's implementation of MARPOL convention.

3.2.2 Interview Guide

First of all, the interview outline needs to be developed when the interview is conducted. Prepare detailed interview outlines and questions, and master various knowledge related to the interview content. During the interview, we must have a clear understanding and grasp of the questionnaire contents. For example, the main purpose of the interview is to collect those information.

Secondly, for the time and place of interview, the only requirement is that it is convenient for the interviewee be there. As long as the interviewees can tell their full story, we still need to limit the time to less than one and a half hours. The exploration stage is extremely important. The main purpose of the interview is to let the

interviewees express their ideas as freely as possible. The interviewee decides what is important to him, so as to let them talk about the question as much as possible. That is to say, we should not strictly control the interview process, but should try to give the largest narrative space. You should also make sure not to interrupt his / her conversation.

In a certain sense, interview technique is the technique of asking questions. For example, consider the nature and characteristics of the questions. More acute, complex, sensitive and threatening issues should be raised in a cautious and circuitous manner.

3.3 Ethnics

All procedures in this study followed the general procedure of ethics. First of all, I confirmed the project with the Norwegian social science data service (NSD)[6]. I can assure you that I will not use any personal information in the paper, and that I will secure the data and delete the research records after completing the project. In my notification letter, I informed participants that personal information would be anonymized. The copied interview information is saved on my personal laptop which can be accessed only by password.

Secondly, in practice, researchers have a moral obligation to research participants, that is, to interact with them in a humane, non-oppressive, non-coercive way, and pay attention to their role as researchers. At the beginning of the interview and questionnaire, I will introduce the purpose of the study in details to the interview and

[6] NSD: Norwegian social science data service

survey recipients to ensure that the interviewees understand the content and significance of the project. For example, 'I am a postgraduate at the World Maritime University. The purpose of my research is to explore how shipping companies choose their own way to solve the problem of sulfur emission control when IMO is about to implement MARPOL.'

In addition, I will explain the main contents of the informed consent (for example, confidentiality and anonymity, the interviewee's right to withdraw and delete data). In addition, it is necessary to explain the recording needs and obtain the consent of the interviewees. If the interviewee is unable to read and write, the consent of the interviewee shall be obtained to start recording, the contents of the letter of commitment shall be read aloud, and explanations shall be provided if necessary, and then the oral consent of the interviewee shall be obtained to ensure that the whole process is recorded (Creswell, J. W. 2012).

I am grateful to my respondents for being open about their good and bad experiences and for sharing them with me. I know that I should not put pressure on my subjects in any way, especially when they are trying to avoid certain sensitive topics. If I find that the subject of my survey shows any discomfort during the interview, I shall not continue to inquire about the subject. Sometimes, they do admit that they have not thought about a question, and I give them time to stop and think. If they really have nothing to say about a topic, I will skip the question and move on to the next topic. In interviews, I constantly remind myself to be professional and ask questions as a researcher, not as an old friend or acquaintance.

I can survey and interview respondents in mandarin, but I have to transcribe it into English, which may be biased, but I will try to keep the data accurate. Moreover, for me and most of my respondents, English is not our first language, and at some point it may be difficult for us to express ourselves. Of course, when I am working on my thesis, new ideas may appear. Data analysis is a time-consuming and detailed process. Over and over again, I read the recordings of the interviews and kept referring to the concepts I discussed in the literature review. I will try my best to combine the data with my literature theory to get an objective conclusion.

Chapter 4. Quantitative Cash-flow and Analysis

4.1 Bunker Oil Price and Trend Analysis

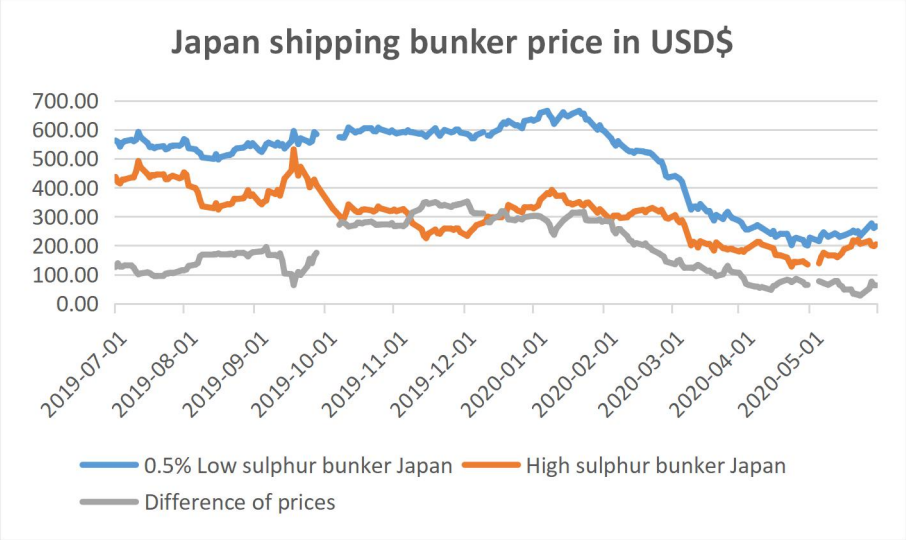


Figure 4. Japan shipping bunker oil price

The line graph illustrates fluctuations in the price change of 0.5% low sulphur fuel oil and high sulphur bunker in a Japan over the years from 2019 to 2020, which collected from Winter Database. And from APPENDIX:VI, you could find the detailed data. As has been observed from this graph, it is clearly that in 2019 the price of both two kind of bunkers was stable.

But in 2020, these two kind bunkers' price declined to different extents. In the January 2020, 0.5 % low sulphur fuel oil had the highest price. In the following years, however, low sulphur continued to lose its price, and in the last year its global sales arrived at roughly 200 dollars per tone in Japan.This trend is very representative in Asia area. The price trend of low-sulfur bunker and high-sulfur bunker is roughly the same. However, the decline in bunker prices in 2019, the impact of COVID-19, and the halt in global import and export trade led to a decline in oil prices, which is also an important reason.

After the implementation of the MARPOL convention in 2020, due to highly demand and rising prices, the price will gradually decrease with the balance of supply and demand. The price of high-sulfur bunker will drop sharply after 2019 when demand suddenly drops, but as there are still companies using the number of scrubber, the market will maintain at a relatively stable price. According to market supply and demand analysis, both high-sulfur bunker and low-sulfur bunker oil will hover around a relatively stable price, and the price gap will gradually narrow down.

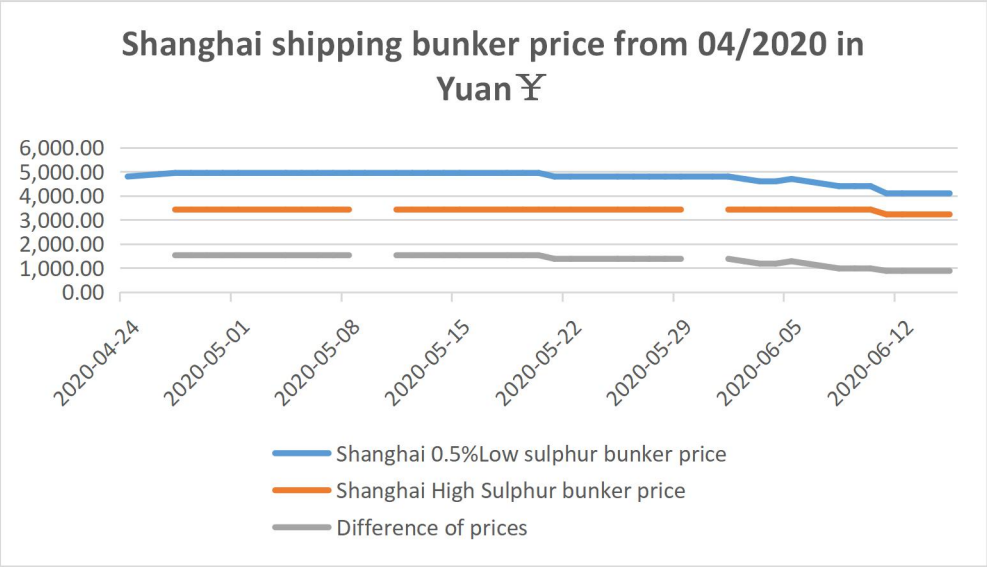


Figure 5. Shanghai shipping bunker price short period

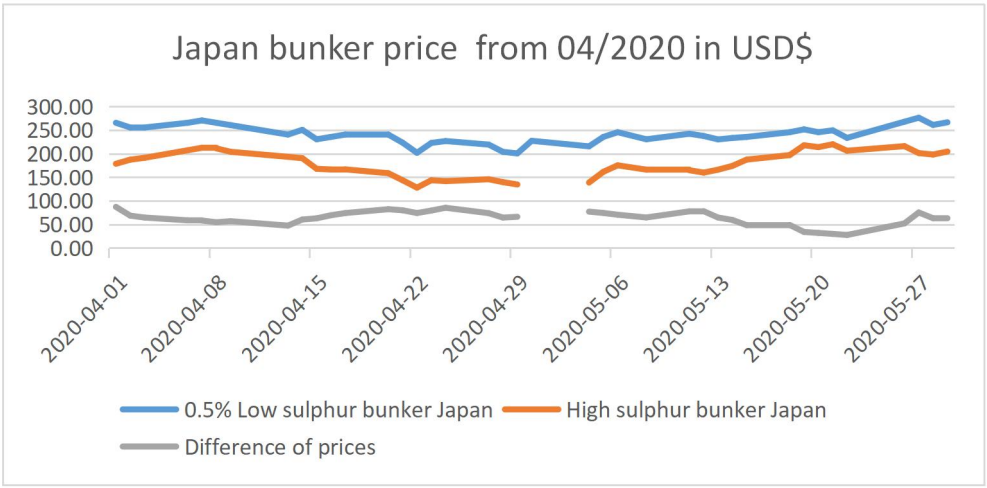


Figure 6. Japan shipping bunker oil price short period

The two graph illustrates the data of changes in the price of shipping bunker in a Japan and shanghai in a short period in 2020, which collected from Clarkson. And from APPENDIX:VII, you could find the detailed data. It can be seen from the figure that the shipping bunker prices in Japan and Shanghai have been relatively stable in recent times. But the difference is that shipping bunker prices in Japan are constantly fluctuating. But China's shipping bunker prices have been less volatile.

The reason is in China the bunker oil prices do not float freely according to market conditions, but are determined by the National Development and Reform Commission. This approach is characteristic of the state-owned economy. Several major domestic commercial oil companies, such as PetroChina and Sinopec, have monopolized and competed against domestic commodity oil transactions, and the import of oil products is regulated by the government. From above analysis could give us an image in our mind about bunker price trend in China.

4.2 Case Background Data Collection

First in first, I would like to use a case study to analyse the IRR, NPV and the profitability of the different way of the changing. The case data come from a shipping company in China in Xiamen. And bunker price I will use collected from above.

In this case the subject of study is a container ship operating between ports of Mainland China and Taiwan. The basic information, including information about engine, bunkers and shifts is provided by the shipping company (Table 1). The ship uses Tier II middle speed diesel engine (MSD).

Ship information:			
Type	TEU	**Main power（KW）**	7980
Speed (knot)	18	**Host speed (r / min)**	148
Year of manufacture	2014	**Engine type**	MSD
The maximum load (ton)	12613	**Engine standard**	TierI
Capability（TEU）	831	**Engine fuel type**	HFO
Length(m)	144.83	**High sulphur fuel sulfur**	2.2
Maximum draft(m)	8.2	**Low sulfur oil fuel type**	MGO
Auxiliary power(KW)	1680	**Diesel sulfur content%**	0.118

Table 1. Case ship information

Note: MSD[7] (Middle Speed Diesel) means medium-speed diesel engine; HFO[8] means heavy bunker oil; MGO[9] means marine gas oil; Tier I, II and III represents engines manufactured in 2000-2010, 2011-2015 and after 2016, respectively. Tier III engines are mainly used in nitrogen emission control zones in the United States.

The time frame of this study is September 6 – 13, 2019. The ship carries out approximately 44 voyages a year; each lasts 8 days and thus the total days in service is 352 days. I will comprehensively consider the ship's current status of emission and how installing a scrubber and using LSFO[10] would affect energy consumption and emission.

The figure below shows the docking and operating conditions of the ship based on the provided data. It departed from the port of Ningbo on September 6, 2019 and sailed to Shanghai, Kaohsiung, Taichung and Keelung before returning to Ningbo on September 13, 2019. The total mileage is approximately 2, 455 km, of which approximately 904 km was in the SECAWYRD[11]. In addition, considering the new policy, 220 km of the shipping route from Ningbo to Taiwan, 380 km of the shipping route from Shanghai to Taiwan and the entire shipping route from Ningbo to Shanghai are included in the SECAWYRD. 34% of the Shanghai-Kaohsiung route is also in the area.

[7] MSD: Middle Speed Diesel
[8] HFO: Heavy Fuel Oil
[9] MGO: Marine Gas Oil
[10] LSFO: Low Sulphur Fuel Oil
[11] SECAWYAD: Ship Emission Control Area in Waters of Yangtze River Delta

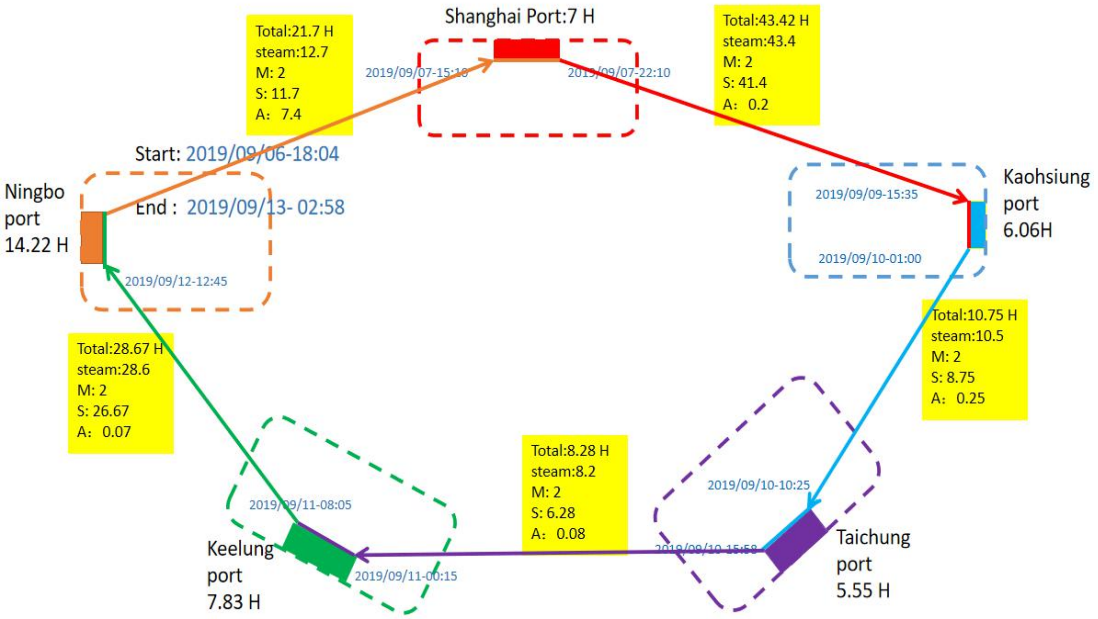


Figure 7. Ship route information 1

Figure 8. Ship route information 2

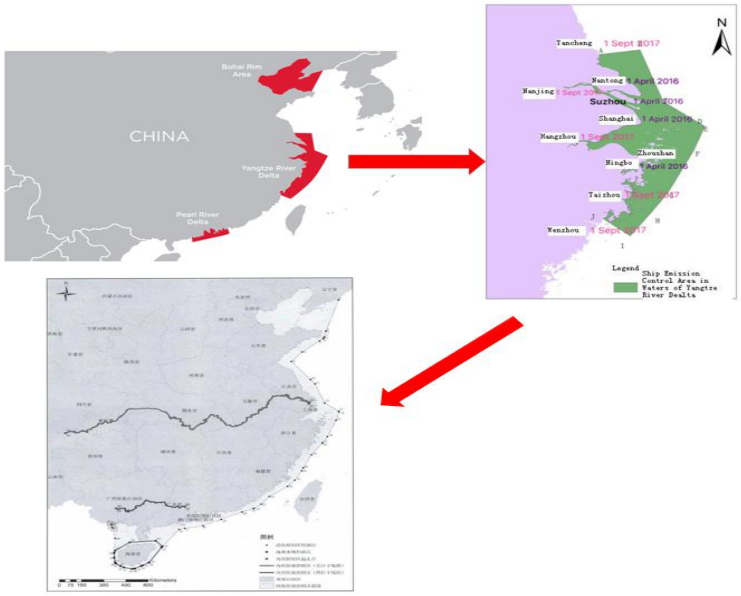


Figure 9. China ECA emission control area

Starting from October 1, 2018, ships bound for the port of Ningbo-Zhoushan that have entered the Ship Emission Control Area in Waters of Yangtze River Delta (SECAWYRD) shall use LSFO with sulfur content ≤ 0.5% m/m.

Maritime Zone Boundary: The area within the following ten points – A, B, C, D, E, F, G, H, I and J.

A: the intersection of the baselines of Nantong and Yancheng;

B: 12 nautical miles from Waikejiao Island;

C: 12 nautical miles from Sheshan Island;

D: 12 nautical miles from the reef; E: 12 nautical miles from the southeast reef;

F : 12 nautical miles from Two Brother Island;

G: 12 nautical miles from Yushan Archipelago;

H: 12 nautical miles from Taizhou (Zhejiang) Archipelago (2);

I: 12 nautical miles from the intersection of the baselines of Taizhou (Zhejiang) and Wenzhou; J: the intersection of the baselines of Taizhou (Zhejiang) and Wenzhou.

The core harbor area includes ports of Shanghai, Ningbo-Zhoushan, Suzhou and Nantong (Chen, Yip & Mou, 2018). The internal waters area includes navigable waters within the 16 administrative areas: Nanjing, Zhenjiang, Yangzhou, Taizhou (Jiangsu), Nantong, Changzhou, Wuxi, Suzhou, Shanghai, Jiaxing, Huzhou, Hangzhou, Shaoxing, Ningbo, Zhoushan, and Taizhou (Zhejiang).

On November 30, 2018, on the basis of existing ship emission control zones, the geographical scope of control was further expanded. The coastal discharge control zone is planned to be expanded from the previous three waters to 12 nautical miles along the coast of the country and Hainan waters area. Inland rivers include navigable waters along the Yangtze River route and the Xijiang route.

The 2015 version of China ECA[12] emission control requirements (Chen, Yip & Mou, 2018):

1) Since January 1, 2016, ships shall strictly implement the SOx emission control requirements of the current international conventions and domestic laws and regulations, and the use of bunker with sulfur content ≤0.5% during docking in the emission control area .

2) Since January 1, 2017, ships should use bunker oil with a sulfur content of ≤0.5% while docking in the core port area of the emission control zone.

3) Starting from January 1, 2018, ships should use bunker oil with sulfur content ≤0.5% while docking at all ports in the emission control zone.

[12] ECA: Emission Control Area

4) Starting from January 1, 2019, ships entering the emission control area should use bunker oil with sulfur ≤0.5% .

Ships may adopt alternative measures equivalent to the above emission control requirements such as connection to shore power, use of clean energy, and exhaust gas clean installation.

4.3 Cash-flow for 3 Plans

There are three options below to analyze the different scenarios of using low sulfur fuel and scrubber. Through comparing them, we could find out which way is more cost-effective.

1.	High-sulfur oil	No emission reduction measures and use the high sulphur bunker
2.	0.5%+0.5%(sulphur emission control area)	0.5% diesel elsewhere (global and SECAWYRD standard)
3.	Exhaust gas processing device	HFO for main and auxiliary engines and reach 0.5%

Table 2. Case emission control plan

The first scheme is the current status of the ship – that is, no emission reduction measures have been applied. The ship now uses diesel only at berths in the SECAWYRD (emission control zone of the Yangtze River Delta), while in other

places 2.2% high sulphur bunker (HFO) is allowed. According to survey data, HFO contains 2.2% of sulfur while diesel contains only 0.1%.

The second scheme is that the ship uses low sulphur bunker with 0.5% sulfur content (hereinafter 0.5% low sulphur fuel oil) in and outside the SCARWYRD. This scheme would be executed if in 2020 0.5% Low sulphur fuel oil and above is allowed in non-emission-control areas worldwide, and in the SECAWYRD 0.5% low sulphur fuel oils is allowed.

The third scheme assumes that a closed-loop exhaust gas processing device is applied. Both main and auxiliary engines still use 2.2% HFO, and thus the device shall process sulfides to meet the 0.1% cap in the SECAWYRD and the 0.5% standard worldwide.

Next, I will analyze the costs of each scenario. In this case, a container ship mainly serving the offshore routes is chosen to evaluate the two emission reduction measures: Using LSFO and installing an exhaust gas desulfurization Tower. Reference schemes include:

The first part is No emission measures applied (status quo) and second part is Using 0.1% diesel at berths and 2.2% high sulphur bunker HFO elsewhere (that is, 2.2% + 0.1%). The comparative schemes for using LSFO include：Using 0.5% low sulphur fuel oil elsewhere and a little bit MGO at berths (that is, 0.5% + MGO (control area)); The last part is comparative schemes for installing exhaust gas processing device is based on the reference schemes (i.e., 2.2% + 0.1% + exhaust gas

processing device).

I will choose one-day data from the Shanghai to calculate IRR and NPV in each plan. The data I would like to choose is 25/06/2020. The high sulphur bunker price is 3225 ￥; 0.5 low sulphur fuel oil is 4100￥. The following is the total cost of the bunker in each plan.

		Number of fuel	Cost	Total cost			
High sulphur+MGO	High sulphur+0.1%	2534.40	1166551.06	1271163.80	$	8906409.198	RMB
	MGO	165.27	104612.75				
0.5%+MGO(sulphur emission control area)	0.5% low sulfur fuel	2374.40	1389429.82	1486138.09	$	10412626.500	RMB
	MGO	165.27	96708.27				
Desulfurization tower	High sulphur+0.1%	2787.84	1283206.17	1321912.88	$	9261982.603	RMB
	MGO	61.15	38706.72				

Table 3. Each plan bunker demand

4.3.1 Using Normal High Sulphur Bunker

Data collection:				1	variable cost	15897409.2	RMB						
	Total start-up fund	412,538	USD	1.1	Fuel	8906409.198	RMB						
	Loan percent	0.8		1.2	Light oil	621000	RMB						
	Loan amount	330,030	USD	1.3	Engine oil	108000	RMB						
	Ballon payment	-	USD	1.4	Maintenance cost	3100000	RMB						
	Libor	1.92%		1.5	Port fee	660000	RMB						
	Margin	2.68%		1.6	Marketing fee	693000	RMB						
	Operating Days	352	days	1.7	administration fee	270000	RMB						
	Facility term	5	years	1.8	crew wage	1539000	RMB						
	Daily OPEX	6875.63	USD	2	Fixed cost	6036150	RMB						
	Annual increase	2.0%		2.1	Manager wage	342000	RMB						
	T/C rates	8863.64	USD	2.2	Depreciation	4350000	RMB						
	Interest	4.601%		2.3	Insurance	1344150	RMB						
	Install tower time	0	days	3	Account fee	2458381	RMB						
	Voyage income	78000	$	4	Total cost	24391940.2	RMB						
	Desulfurization tower	0	RMB	5	Operating cost	17585559.2	RMB						
		0	$	6	Year OPEX handy	2509606.679	$						
	Exchange rate	7.0065		7	Operation cost/day	6875.634738	RMB						
	Fuel Consume	7.2	tone/day			0	$						
	Total fuel	2534.4	tone	8	Total cost	6875.634738	$						
Financial cost and Operating cost	YEAR	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
		HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2
	Loan at the beginning	330,030	297,027	264,024	231,021	198,018	165,015	132,012	99,009	66,006	33,003	-	(33,003)
	Interest	7,592	6,833	6,074	5,315	4,555	3,796	3,037	2,278	1,518	759	-	(759)
	Capital	33,003	33,003	33,003	33,003	33,003	33,003	33,003	33,003	33,003	33,003	33,003	33,003
	Total instalment(C+I)	40,595	39,836	39,077	38,318	37,558	36,799	36,040	35,281	34,522	33,762	33,003	32,244
	Loan amount remain after the half year	297,027	264,024	231,021	198,018	165,015	132,012	99,009	66,006	33,003	-	(33,003)	(66,006)
	Number of Operating days	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00
	financial break even per day	231	226	222	218	213	209	205	200	196	192	188	183
	Balloon Payment										-		
	Operating Expenses												
	Daily Expenses	6,876	6,876	7,013	7,013	7,013	7,013	7,013	7,013	7,013	7,013	7,013	7,013
	Number of Days (Operating Expenses)	182.50	182.50	182.50	182.50	182.50	182.50	182.50	182.50	182.50	182.50	182.50	182.50
	Total OPEX per half year	1,254,803	1,254,803	1,279,899	1,279,899	1,279,899	1,279,899	1,279,899	1,279,899	1,279,899	1,279,899	1,279,899	1,279,899
	Equivalent OPEX per day (350days of employment)	7,130	7,130	7,272	7,272	7,272	7,272	7,272	7,272	7,272	7,272	7,272	7,272
	Toral Expenses (CAPEX + OPEX) per equivalent earning days	7,363	7,354	7,494	7,486	7,486	7,481	7,477	7,473	7,468	7,464	7,460	7,455
Capital process:	YEAR	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
	half year	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2
	Operating days	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00
	Daily T/C rates	8,864	8,864	8,864	8,864	8,864	8,864	8,864	8,864	8,864	8,864	8,864	8,864
	Operating revenue	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000
	Operating Expenses	(1,254,803)	(1,254,803)	(1,279,899)	(1,279,899)	(1,279,899)	(1,279,899)	(1,279,899)	(1,279,899)	(1,279,899)	(1,279,899)	(1,279,899)	(1,279,899)
	Gross Revenue	305,197	305,197	280,101	280,101	280,101	280,101	280,101	280,101	280,101	280,101	280,101	280,101
	Capital Payment	(33,003)	(33,003)	(33,003)	(33,003)	(33,003)	(33,003)	(33,003)	(33,003)	(33,003)	(33,003)	(33,003)	(33,003)
	Interest Payment	(7,592)	(6,833)	(6,074)	(5,315)	(4,555)	(3,796)	(3,037)	(2,278)	(1,518)	(759)	-	759
	Net Cash Flow	264,601	265,360	241,024	241,783	242,542	243,301	244,061	244,820	245,579	246,338	247,098	247,857
	Accmmulated Cash Flow	264,601	529,962	770,985	1,012,768	1,255,310	1,498,612	1,742,672	1,987,492	2,233,071	2,479,410	2,726,507	2,974,364
	Balloon Payment										-		
	Estimated Sale of the vessel										-		
	Total Net Cash Flow	264,601	265,360	241,024	241,783	242,542	243,301	244,061	244,820	245,579	246,338	247,098	247,857
	YEAR	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
	half year	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2
	Tower Projection FMV	371,284	330,030	288,777	247,523	206,269	165,015	123,761	82,508	41,254	(0)	(41,254)	(82,508)
	Loan FACILITY ENDING BALANCE	297,027	264,024	231,021	198,018	165,015	132,012	99,009	66,006	33,003	-	(33,003)	(66,006)
	Security Cover	125.00%	125.00%	125.00%	125%	125%	125%	125%	125%	125%	#DIV/0!	125%	125%
IRR CACULATION:													
Year	YEAR 0	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
half year	YEAR 0	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2
Total Net Cash Flow	-82507.61685	264,601	265,360	241,024	241,783	242,542	243,301	244,061	244,820	245,579	246,338	247,098	247,857
Total a year	-82507.61685	529961.7006		482806.5074		485843.5077		488880.4481		491917.3885		494954.3288	
IRR	635%												
NPV	2518782.81												
Total profit	2,479,410												

Table 4. Normal high sulphur bunker cash-flow

This provided cash-flow illustrates the process of calculation of the IRR and total profit of investment of using high sulphur bunker without any solution for emission. This cash flow includes operation cost calculation stage and capital cost calculation with the interest calculation in the earlier stages, which allows improvements and modifications throughout the process. At this scene , the ship needs not to pay for the cost of the desulfurization tower. In addition , due to the change of type of bunker， the price of bunker should be changed and there is also no scrubber operation cost each day.

During calculation of IRR when using the high sulphur bunker , we should collect data for each parts of the operation cost and capital cost, such as Light oil, Engine oil, Maintenance cost, Port fee, Marketing fee, Administration fee, and Crew wage. From research， I got all the information of the operation cost of the ship, and obtained the operation cost data from Xiamen MZshipping. Under voyage charter, the shipowner must bear all costs related to crew, maintenance, insurance and bunker consumption. Finally, we got the daily operating cost of USD$6876, and this number includes the bunker fee.

Sustaining the operation of the ship will undoubtedly require a start-up capital, prompting the business to get on track quickly. This is because if the amount of start-up capital is underestimated, a financial problem may already occur before the business begins to make money (SCHINAS, O. 2016). And some of the forecasts for the start-up funds are too high, and may not be able to raise sufficient funds. In this case, I would like to set the start-up capital as 2Months cost of the ship operation.

As we know, based on the interest of U.S. national bonds, we get Rf = 1.92, and we calculate Rm = 15% based on the market average. The data obtained from Bank of China shows that the bank's debt interest has increased from 4.75% to 4.90%. In this case, we assume a fixed interest of 4.75% and the ship is in service 352 days a year. We choose the number 352 because the ship may require more time to be inspected and maintained (SCHINAS, O. 2016), and the rest of the 44 voyages may also require 352 days. Besides, since the ship was built in 2014, we assume that the ship can be used for 5 years. Financing costs in cash flow include capital costs, loans, interests and principal balance installments. Capital cost is the loan that should be repaid to the bank in every period. I divide the payback period into 5 years, 10 periods; each period is half a year. Therefore, The capital cost equals to repayment of the loan divided by 10.

In this scene, we use the repay method. The monthly principal is the same, and the loan interest decreases with the principal month by month. Monthly repayment amount = (loan principal ÷ repayment months) + (principal - accumulated amount of returned principal) × monthly interest rate . For example, when calculating the cash flow, a period is considered to be half a year. The operating costs equals to the daily operating costs times half the number of total days in service (182.5). Therefore, the actual costs in service days are higher than the nominal daily costs. The total amount of payment is operating costs plus financial costs.

From the cash-flow, we can find that the each period operation time is 176 days, The direct impact is how many voyage we can sail.In the final loan repayment period of the fifth year, when the loan is repaid, you will find that the cash flow has a change.

According to calculation, we find that the IRR during using high sulphur bunker is 635%.It is very high. And the total profit is about $2.5 million. This table clearly presents that when using the high sulphur bunker, how the profit goes on. On the other hand, in the calculation the IRR figure is quite high.

From the above table, we can find that NPV (2518752.807) is about how much money we can make in the project life period.Considering the time value of money (inflation depreciation), IRR refers to the currency time Under the value (inflation depreciation), and the internal rate of return (IRR) in this scene is 635%, which means that the project can bear a maximum currency devaluation rate of 635% per year. If the actual currency depreciation rate is only 4% (when the loan interest rate is 4%), then the remaining 631% will be our profit.

4.3.2 Using 0.5% Low sulphur Bunker

This provided cash-flow illustrates the process of calculation of the IRR and total profit of using 0. 5% low sulphur fuel oil , including operation cost calculation stage and capital cost calculation with the interest calculation in the earlier stages, which allows improvements and modifications throughout the process. And in the control emission area, also using 0.5% low sulphur fuel oil by the rules is more and more district.

It is obvious in the table that the total start-up fund has undergone dramatic changes. It has dropped considerably. What is the reason for this change? Mainly there are 2 reasons behind the situation reflected in the table. First of all, at beginning of the business，the ship needs not to pay for the investment of the desulfurization scrubber.

More importantly, due to changes of type of bunker， the cost of bunker is changed and there is also no desulfurization scrubber operation cost each day any more.

The conversion cost of ships using low-sulfur bunker systems is negligible, so the conversion costs of low sulfur oil systems are not considered in this case. Operation and maintenance costs are similar when using high sulphur bunker, so that they can also be ignored. Therefore, the main cost of ships using low sulfur bunker is the cost of bunker (SCHINAS, O. 2016).

Data collection:					1	variable cost	17403626.5	RMB					
	Total start-up fund	447,876	USD		1.1	Fuel	10412626.5	RMB					
	Loan percent	0.8			1.2	Light oil	621000	RMB					
	Loan amount	358,301	USD		1.3	Engine oil	108000	RMB					
	Ballon payment	-	USD		1.4	Maintenance cost	3100000	RMB					
	Libor	1.92%			1.5	Port fee	660000	RMB					
	Margin	2.68%			1.6	Marketing fee	693000	RMB					
	Operating Days	352	days		1.7	administration fee	270000	RMB					
	Facility term	5	years		1.8	crew wage	1530000	RMB					
	Daily OPEX	7464.61	USD		2	Fixed cost	6036150	RMB					
	Annual increase	2.0%			2.1	Manager wage	342000	RMB					
	T/C rates	8863.64	USD		2.2	Depreciation	4350000	RMB					
	Interest	4.601%			2.3	Insurance	1344150	RMB					
	Install tower time	0	days		3	Account fee	2458381	RMB					
	Voyage income	78000	$		4	Total cost	25898157.5	RMB					
	Desulfurization tower	0	RMB		5	Operating cost	19089776.5	RMB					
		0	$		6	Daily OPEX handys	2724580.963	$					
	Exchange rate	7.0065			7	Operation cost for T	0	RMB					
	Fuel Consume	7.2	tone/day					$					
	Total fuel	2534.4	tone		8	Total cost	7464.605373	$					

Financial cost and operating cost	YEAR	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
		HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2
	Loan at the beginning	358,301	322,471	286,641	250,811	214,981	179,151	143,320	107,490	71,660	35,830	-	(35,830)
	Interest	8,243	7,418	6,594	5,770	4,946	4,121	3,297	2,473	1,649	824	-	(824)
	Capital	35,830	35,830	35,830	35,830	35,830	35,830	35,830	35,830	35,830	35,830	35,830	35,830
	Total instalment(C+I)	44,073	43,249	42,424	41,600	40,776	39,951	39,127	38,303	37,479	36,654	35,830	35,006
	Loan amount remain after the half year	322,471	286,641	250,811	214,981	179,151	143,320	107,490	71,660	35,830	-	(35,830)	(71,660)
	Number of Operating days	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00
	financial break even per day	250	246	241	236	232	227	222	218	213	208	204	199
	Balloon Payment										-		
	Operating Expenses												
	Daily Expenses	7,465	7,465	7,614	7,614	7,614	7,614	7,614	7,614	7,614	7,614	7,614	7,614
	Number of Days (Operating Expenses)	182.50	182.50	182.50	182.50	182.50	182.50	182.50	182.50	182.50	182.50	182.50	182.50
	Total OPEX per half year	1,362,290	1,362,290	1,389,536	1,389,536	1,389,536	1,389,536	1,389,536	1,389,536	1,389,536	1,389,536	1,389,536	1,389,536
	Equivalent OPEX per day (350days of employme	7,740	7,740	7,895	7,895	7,895	7,895	7,895	7,895	7,895	7,895	7,895	7,895
	Toral Expenses (CAPEX + OPEX) per equivalent	7,693	7,690	8,136	8,133	8,132	8,128	8,117	8,113	8,106	8,101	8,095	8,094

Capital process:	YEAR	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
	half year	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2
	Operating days	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00
	Daily T/C rates	8,864	8,864	8,864	8,864	8,864	8,864	8,864	8,864	8,864	8,864	8,864	8,864
	Operating revenue	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000
	Operating Expenses	(1,362,290)	(1,362,290)	(1,389,536)	(1,389,536)	(1,389,536)	(1,389,536)	(1,389,536)	(1,389,536)	(1,389,536)	(1,389,536)	(1,389,536)	(1,389,536)
	Gross Revenue	197,710	197,710	170,464	170,464	170,464	170,464	170,464	170,464	170,464	170,464	170,464	170,464
	Capital Payment	(35,830)	(35,830)	(35,830)	(35,830)	(35,830)	(35,830)	(35,830)	(35,830)	(35,830)	(35,830)	(35,830)	(35,830)
	Interest Payment	(8,243)	(7,418)	(6,594)	(5,770)	(4,946)	(4,121)	(3,297)	(2,473)	(1,649)	(824)	-	824
	Net Cash Flow	153,637	154,461	128,039	128,864	129,688	130,512	131,337	132,161	132,985	133,809	134,634	135,458
	Accummulated Cash Flow	153,637	308,098	436,137	565,001	694,689	825,201	956,538	1,088,698	1,221,683	1,355,493	1,490,126	1,625,584
	Balloon Payment												
	Estimated Sale of the vessel										-		
	Total Net Cash Flow	153,637	154,461	128,039	128,864	129,688	130,512	131,337	132,161	132,985	133,809	134,634	135,458
	YEAR	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
	half year	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2
	Tower Projection FMV	403,089	358,301	313,513	268,726	223,938	179,151	134,363	89,575	44,788	0	(44,788)	(89,575)
	Loan FACILITY ENDING BALANCE	322,471	286,641	250,811	214,981	179,151	143,320	107,490	71,660	35,830	-	(35,830)	(71,660)
	Security Cover	125.00%	125.00%	125.00%	125%	125%	125%	125%	125%	125%	#DIV/0!	125%	125%

IRR CACULATION:													
Year	YEAR 0	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
half year	YEAR 0	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2
Total Net Cash Flow	-89575.26446	153,637	154,461	128,039	128,864	129,688	130,512	131,337	132,161	132,985	133,809	134,634	135,458
Total a year	-89575.26446	308097.6078		256903.1349		260200.2213		263497.3076		266794.3939		270091.4803	
IRR	331%												
NPV	1333492.30												
Total profit	1,355,493												

Table 5. Using 0.5% Low sulphur bunker cash-flow

During calculation of IRR when using the 0.5% sulphur bunker , we also should get the data of each parts of the operation cost and capital cost, but the most important is

the 5% sulphur bunker price much higher than high sulphur bunker. Finally, we got the daily operating cost of USD$7464, and this number is much higher than using high sulphur bunker.

For the start-up capital, I would like to still set the start-up capital as 2months of the ship operation cost. The Rf and Rm set as same as the first scene and the ship is still in service 352 days a year. The 44 voyages also require 352 days. As can be seen from the table, the IRR and profit has witnessed dramatic changes. From the above table , we can find that NPV (1333492.299) is about how much money we can make by using 5% Low sulphur bunker, and the internal rate of return (IRR) in this scene is 331%.While using high sulphur bunker,the IRR is 635%. It is obvious from the table that now the IRR is 331%，with a sharp decrease. What contributed to these changes? I think the reasons are as follows. To start with, the bunker price changes from high sulphur to 5% sulphur. Secondly, the profit of each period increases not too much but increase steadily. What is more, in the 0.5% bunker cash flow, we did not use the balloon method for repaying the loan.

4.3.3 Using Desulfurization Scrubber

We assume that the exhaust gas processing device is closed-loop. Both the main and the auxiliary engines still use High sulphur fuel. The device needs to process sulfides so that the bunker would meet the SECAYRD's 0.1% cap and global standard. The costs of installing exhaust gas processing equipment on ships include purchase cost, installation cost, maintenance cost and opportunity cost.

The purchase cost is about RMB￥600, 000; the installation cost is about RMB￥100, 000, totaling RMB￥700,000 (US$ 99, 907). The operation cost increases by about

RMB￥20, 000/year, including the exhaust gas processing cost of about US$2, 854.5. In addition, the exhaust gas processing device needs to consume about 2% of extra bunker. This is shown in the bunker consumption table above.

Assumption:

				1	variable cost	16252982.6	RMB
Total start-up fund	521,257	USD		1.1	Fuel	9261982.603	RMB
Loan percent	80%			1.2	Light oil	621000	RMB
Loan amount	417,005	USD		1.3	Engine oil	108000	RMB
Ballon payment	10,000	USD		1.4	Maintenance cost	3100000	RMB
Libor	1.92%			1.5	Port fee	660000	RMB
Margin	2.83%			1.6	Marketing fee	693000	RMB
Operating Days	352	days		1.7	administration fee	270000	RMB
Facility term	5	years		1.8	crew wage	1539000	RMB
Daily OPEX	7022.49	USD		2	Fixed cost	6036150	RMB
Annual increase	2.0%			2.1	Manager wage	342000	RMB
T/C rates	8863.64	USD		2.2	Depreciation	4550000	RMB
Interest	4.750%			2.3	Insurance	1344150	RMB
Install tower time	40	days		3	Account fee	2458381	RMB
Voyage income	78000	$		4	Total cost	24747513.6	RMB
Desulfurization tower	7000000	RMB		5	Operating cost	17939132.6	RMB
	99907.229	$		6	Daily OPEX handy	2560355.756	$
Exchange rate	7.0065			7	Operation cost for	20000	RMB
Fuel Consume	7.2	tone/day				2854.492255	$
Total fuel	2534.4	tone		8	Total cost	7022.49383	$

Financial cost and operating cost

YEAR	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2		
Loan at the beginning	417,005	376,305	335,604	294,904	254,203	213,503	172,802	132,102	91,401	50,701	10,000	(30,701)
Interest	9,904	8,937	7,971	7,004	6,037	5,071	4,104	3,137	2,171	1,204	237	(729)
Capital	40,701	40,701	40,701	40,701	40,701	40,701	40,701	40,701	40,701	40,701	40,701	40,701
Total instalment(C+I)	50,604	49,638	48,671	47,705	46,738	45,771	44,805	43,838	42,871	41,905	40,938	39,971
Loan amount remain after the half	376,305	335,604	294,904	254,203	213,503	172,802	132,102	91,401	50,701	10,000	(30,701)	(71,401)
Number of Operating days	136.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00
financial break even per day	372	282	277	271	266	260	255	249	244	238	233	227
Balloon Payment										10,000		
Operating Expenses												
Daily Expenses	7,022	7,022	7,022	7,022	7,163	7,163	7,163	7,163	7,163	7,163	7,163	7,163
Number of Days (Opersting Expen	182.50	182.50	182.50	182.50	182.50	182.50	182.50	182.50	182.50	182.50	182.50	182.50
Total OPEX per half year	1,281,605	1,281,605	1,281,605	1,281,605	1,307,237	1,307,237	1,307,237	1,307,237	1,307,237	1,307,237	1,307,237	1,307,237
Equivalent OPEX per day (350day	9,424	7,282	7,282	7,282	7,427	7,427	7,427	7,427	7,427	7,427	7,427	7,427
Total Expenses (CAPEX + OPEX)	9,796	7,564	7,555	7,553	7,693	7,688	7,682	7,677	7,671	7,666	7,660	7,655

Capital process:

YEAR	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
half year	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2
Operating days	136.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00	176.00
Daily T/C rates	8,864	8,864	8,864	8,864	8,864	8,864	8,864	8,864	8,864	8,864	8,864	8,864
Operating revenue	1,205,455	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000	1,560,000
Operating Expenses	(1,281,605)	(1,281,605)	(1,281,605)	(1,281,605)	(1,307,237)	(1,307,237)	(1,307,237)	(1,307,237)	(1,307,237)	(1,307,237)	(1,307,237)	(1,307,237)
Gross Revenue	(76,151)	278,395	278,395	278,395	252,763	252,763	252,763	252,763	252,763	252,763	252,763	252,763
Capital Payment	(40,701)	(40,701)	(40,701)	(40,701)	(40,701)	(40,701)	(40,701)	(40,701)	(40,701)	(40,701)	(40,701)	(40,701)
Inrrest Payment	(9,904)	(8,937)	(7,971)	(7,004)	(6,037)	(5,071)	(4,104)	(3,137)	(2,171)	(1,204)	(237)	729
Net Cash Flow	(126,755)	228,757	229,724	230,690	206,025	206,992	207,958	208,925	209,891	210,858	211,825	212,791
Accumulated Cash Flow	(126,755)	102,002	331,726	562,416	768,441	975,433	1,183,391	1,392,316	1,602,207	1,813,065	2,024,890	2,237,681
Balloon Payment										(10,000)		
Estimated Sale of the Tower										-		10000
Total Net Cash Flow	(126,755)	228,757	229,724	230,690	206,025	206,992	207,958	208,925	209,891	200,858	211,825	222,791
YEAR	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
half year	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2		
Tower Projection FMV	469,131	417,005	364,880	312,754	260,628	208,503	156,377	104,251	52,126	-	(52,126)	(104,251)
Loan FACILITY ENDING BALAN	376,305	335,604	294,904	254,203	213,503	172,802	132,102	91,401	50,701	10,000	(30,701)	(71,401)
Security Cover	124.67%	124.26%	123.73%	123%	122%	121%	118%	114%	103%	0%	170%	146%

IRR CACULATION:

Year	YEAR 0	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6	
half year	YEAR 0	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2	HALF1	HALF2
Total Net Cash Flow	-104251.3718	(126,755)	228,757	229,724	230,690	206,025	206,992	207,958	208,925	209,891	200,858	211,825	222,791
Total a year	-104251.3718	102002.0774		460414.084		413016.4312		416882.9833		410749.5354		434616.0876	
IRR	204%												
NPV	1824119.26												
Total profit	1,803,065												

Table 6. Using Desulfurization Scrubber cash-flow

The table above shows the the data about installing desulfurization Tower. From the graph, it can be seen that the progress of cash-flow in using desulfurization Tower is much different from before scenes.

During calculation of IRR of investment of the desulfurization Scrubbers, we should make sure each parts of the operation cost and capital cost, such as Light oil,Engine oil,Maintenance cost, Port fee ,Marketing fee, administration fee, Crew wage.

From research, I got all the information of the operation cost of the ship, and obtained the operation cost data from Xia'men MZshipping. Under time charter, the shipowner must bear all costs related to crew, maintenance, insurance and bunker consumption. Finally, we got the daily operating cost of USD$7022. For this scene, I would like to set the start-up capital as 2 months cost of the ship operation and plus the price of desulfurization Tower.

In this case, we assume that the ship is in service 352 days a year. We choose the number 352 because the ship and the scrubber may require more time to be inspected and maintained, and the rest of the 44 voyages may also require 352 days. Besides, since the ship was built in 2014, we assume that the ship and the equipment can be used for 5 years. After 5 years, the depreciation of the desulfurization scrubber is US$10, 000, because it is easy to compare with others' scene cash flow. I make the cash flow for 5 years also，because normally the scrubber can be use in 5 years.

When calculating cash flow, the principal is usually the same if "the balloon" method is applied when repaying the loan (SCHINAS, O. 2016). If we separate it from interest payments, and assume that the repayment of principal of each period occurs at the end of the year, we can calculate the present value of the principal repayment of the loan using the annuity formula. But in this case we decided to use "the balloon," a special loan method. This means that even if your repayment is less than the average amount of loan, you must be prepared for a large repayment at the end of the loan period (Arof, 2018).

Usually every interest payment of the loan for purchasing desulfurization scrubber is calculated, based on the outstanding balance of the loan, which can be repaid by the

principal of the same period. For example, when calculating the desulfurization scrubber's cash flow, a period is considered to be half a year, the same as before.. Operating costs equals to daily operating costs times half the year (182.5).

From the cash flow, we can find that the first period operation time is 136 days, and others' period is 176days. That is because the installment time for desulfurization scrubber needs about 40 days, The direct impact on cash flow is that the profit during this period has decreased, and there are even situations where you cannot make ends meet. In the final loan repayment period of the fifth year, when the loan is repaid, you will find a significant increase in cash flow (SCHINAS, O. 2016). According to calculation， we find that the IRR for installing the scrubber is 204%, it is very high. And the total profits are around $1.8 million.

According to the result in table, NPV(1824119.260) is positive, which means this investment is more profitable than putting the money in the bank. The IRR , which is more significant than NPV, can also support this view. However, the most significant defect of IRR index is the lack of reinvestment thinking. That is to say, the annual capital and interest profit can be reinvested in order to achieve higher returns than a single principal investment.

From the above, we can see that NPV (1824119.260) is talking about how much money we can make in the project cycle considering the time value of money (inflation depreciation). IRR is talking about considering currency time Under the value (inflation depreciation). So what is the maximum rate of currency depreciation that we can withstand during the project cycle period. More generally, it is assumed

that we can borrow money from bank to invest in this project, and what is the maximum annual interest rate that can be sustained. For example, the internal rate of return (IRR) of a project is 204%, which means that the project can bear a maximum currency devaluation rate of 204% per year, which means that if we invest in the project, the maximum annual interest rate of the loan is 487%. Investing in this project at a 204% annual interest rate on the loan is just capital preservation. When the actual currency depreciation rate is only 5% (when the loan interest rate is 4%), then the remaining 201% will be our profit.This is the ability to resist risks, and it can actually be said to be profit space and profitability. The simple prediction and calculation show that the desulfurization scrubber investment is profitable and attractive. If the investor is a rational person, he or she will invest in the ship if he or she believes in the analysis .

Break-Even Calculations is Estimate the minimum break-even time-charter rate required to cover debt financing cost, as well as operating expenses (OPEX). Break-even time-charter rate is equal to the sum of operational daily Capex and Opex. See the figure below for detailed calculation process. The follow below table is the break-even when installing the desulfurization scrubber， we can find that at least each earns the profit $9678 at first year, and we can cover the cost.

Purchase of the equipment (USD)	449,992	Operating Days per year	352
Leverage ratio	80%	Resale Value	20,348,945
Capital receipt	359,994	Daily OPEX (USD)	7,022
Balloon payment	10,000	OPEX Increment per annum	2.0%
LIBOR rate	1.92%	Number of repayment years	5
Margin	2.83%		

Repayment term	1		2		3		4		5			
Bi-annual projections	1	2	1	2	1	2	1	2	1	2		
Cumulative Cash Outflows												
	Capital Expenses (CAPEX)											
Loan at the beginning	359,994	324,994	289,995	254,996	219,996	184,997	149,997	114,998	79,999	44,999		
Interest	17,100	15,437	13,775	12,112	10,450	8,787	7,125	5,462	3,800	2,137		
Installment of the principal	34,999	34,999	34,999	34,999	34,999	34,999	34,999	34,999	34,999	34,999		
Total payment (P+I)	52,099	50,437	48,774	47,112	45,449	43,787	42,124	40,462	38,799	37,137		
Loan amount remain after the year	324,994	289,995	254,996	219,996	184,997	149,997	114,998	79,999	44,999	10,000		
Number of Operating days	136	176	176	176	176	176	176	176	176	176		
Bank payment equvalent per day	383	287	277	266	256	249	239	230	220	211		
Balloon Payment	0	0	0	0	0	0	0	0	0	10,000		
	Operating Expenses (OPEX)											
Daily Expenses	7,022	7,022	7,128	7,128	7,235	7,235	7,343	7,343	7,453	7,453		
Number of Operating Expenses Days	180	180	180	180	180	180	180	180	180	180		
Total OPEX every period	1,264,049	1,264,049	1,283,010	1,283,010	1,302,255	1,302,255	1,321,789	1,321,789	1,341,615	1,341,615		
OPEX per day	9,294	7,182	7,290	7,290	7,399	7,399	7,510	7,510	7,623	7,623		
	Total Expenses (CAPEX + OPEX) per equivalent earning days											
Breakeven point	9,678	7,469	7,567	7,558	7,657	7,648	7,750	7,740	7,843	7,834		

Table 7. Breakeven point

4.4 Results

	IRR	NPV
High sulphur+0.1%	635%	2518752.807
0.5%+MGO(sulphur emission control area)	331%	1333492.299
Desulfurization tower	204%	1824119.260

Table 8. Cash-flow by bunker price in shanghai

As is shown in the chart: to compare with the IRR and NPV from plan1 to plan 5. In the first chart(to compare with the IRR), the largest number of IRR is using the normal high sulphur bunker, without any solution for controlling sulphur emission, accounting for 635% . The next largest one is using 0.5% low sulphur fuel oil, being 331%， which is 204% lower than the former using high sulphur bunker and using 0.5% bunker. By way of contrast, the least IRR for using scrubber and this figure is only 204%.

In the second part of the chart related to NPV. Clearly, different from IRR, using the normal high sulphur bunker has the highest number of NPV, it is about 2.5million. Using scrubber comprises the next largest NPV (1.8 million). By contrast, using

0.5 % low sulphur fuel oil is the smallest number of NPV, which is only 1.3 million.

	IRR	NPV
High sulphur+MGO	2644%	6201486.88
0.5%+MGO(sulphur emission control area)	2173%	5520220.83
Desulfurization tower	1445%	5768753.37

Table 9. Cash-flow by bunker price in shanghai

In order to ensure the accuracy of the results, I have selected another set of shipping bunker data from Japanese to calculate and analyze. I selected a set of data on May 4th 2020. The high sulphur bunker price is138.64$, and 0.5 low sulphur fuel oil is 215.5$. The above is the result of the IRR and NPV in each plan. From the above table, we can find that the IRR have the same situation with the bunker used in shanghai:

IRR(High sulphur bunker) >IRR(0.5% Low sulphur bunker) > IRR(scrubber).

And the NPV also has the same situation:

NPV(High sulphur bunker) > NPV(scrubber)>NPV(0.5% Low sulphur bunker).

It is not difficult to arrive at some possible factors that are directly responsible for those changes as depicted above (Arof, A. 2018). The most important factor that needs to be highlighted here is that bunkers cost difference. One more factor, though not conclusive, that should also be brought into attention is that capital cost is different，because scrubber price plays an important role. Just like many other things, it is not easy to reverse the changes that have already taken place, which have already taken form especially the low sulfur bunker price changed by the supply and demand.Therefore, I predict that the current situation will continue for a short while.

However, further analyses of the costs of emission reduction measures show that low sulphur fuel oil are better than scrubber， from a cost-effective perspective (Arof, A. 2018). The cost-benefit analysis of emission reduction measures shows that the installation of exhaust gas processing equipment is better than the plan use of LSFO. In other words, the Scrubber is not the most cost-effective option. Yet, from NPV perspective, scrubber is better than Low sulphur bunker.

Chapter 5. Qualitative Interview and Analysis

5.1 Data collection

From above cash-flow calculation, we got the cost situation and profit situation due to both two methods. Aiming to understand the situation of in the real world of the shipping company how to control SOx emission, I design a interview to analyse advantages and disadvantages of scrubber and Low sulphur bunker. The first step is that we need to determine the final number of interview people(Hunter, 2002). I select 20 people， who are working in shipping industry to join this interview. Different from a survey, an interview needs to respect the interviewees by using expressions as close as possible to the interviewees and their expressions, so as to avoid some unnecessary misunderstandings and resonate with the interviewees (Sharma, 2009). For example, most of the interviewees are shipping industry staff in this Interview, and try to make them understand in straightforward language. As for face-to-face interviewees, I will try to take a recording after the interviewees agree so

that I can analyze the results later. If any interviewee is unable to conduct a face-to-face interview, as said in the above survey, Facebook and WeChat are also acceptable. The interview questions are in both Chinese and English for recording.

Different from a survey, an interview may encounter communication problems: (1) the respondents refuse to answer (2) the interview location is highly disturbed (3) the respondents are impatient during the interview, etc. My way of dealing with them is not to offend the taboos of the interviewees but keep the conversation harmonious, and leave controversial issues to the end. It is also important for interviewees to express their ideas as freely as possible(Sharma, 2009). APPENDIX: IV. The Interview Record Form, which is the overall framework of the interview process, includes introducing myself and this project, 10 questions, personal situation data collection， privacy statement and so on. you can read all the structure at end of this paper.

5.2 Interview Analysis

The main purpose of this interview is to deeply analyze the situation of shipping companies in China using scrubber or Low sulphur bunker for SOx control. According to the calculation, we already know that using scrubber has already been not so cost-effective. As the company still uses scrubber during the low difference between high sulphur bunker and Low sulphur bunker, what are the exact reasons?

At beginning, we asked interviewees the first question that the situation of their company for control SOx emission. To my surprise, all 20 interviewees said that their company is using low-sulfur bunker. 8 of them said that their company is using

low-sulfur oil and scrubber at the same time. The remaining 12 people said that their company only uses low-sulfur bunker and does not use scrubber. Therefore, none of the respondents' companies use scrubber for all ships. In fact, it shows that even a few years ago, the price difference between low-sulfur oil and high-sulfur oil was large, and still no company installed scrubber on all ships. Next, I will discuss this two types of companies one by one.

5.2.1 The Company Still Using Scrubber

As we find, in the past ,even though the advantage of scrubber in low cost was losing, still many companies in China used scrubber and did not give it up. However, there is no company choosing only scrubber as their method to control emission.

The first one is the use of Low sulphur bunker is also risky. At least 10 interviewees mentioned this risky in China. In less than a year of global use of Low sulphur bunker, there is still no consensus on whether Low sulphur bunker will cause damage to engine cylinders due to reduced sulphur content and reduced lubrication of engine cylinders. The emphasis is the effect on reducing cylinder scraping damage (Wang, Zhang & Gan, 2019). When using heavy fuel oil, the generally selected high TBN[13] value cylinder is used to neutralize the acidic substances generated by the bunker and slow down the corrosion and wear of the cylinder liner and piston ring. The related engine manufactures believe that once the engine is permanently powered by 0.5% sulphur bunker, the lubrication will be insufficient and wear and tear will increase.

[13] TBN: Total Base Number

As a result, some marine engine companies recommend that ship owners should install metal-ceramic-coated piston rings when switching to use low sulphur fuel oil. (Menachof & Dicer, 2001). Compared with the structure of traditional cast iron, the surface of ceramic-metal composite is harder, so the wear can be controlled. Therefore, as for a large scale company, using scrubber can share the risks of damaging engines..

And the quality of low sulfur oil is also not guaranteed. Low sulfur bunker oil (LSFO) breaks the boundary between oil products, and a variety of products can meet the requirements of low sulfur. From interviews, I know that, at present, there are the following low sulfur blending components in the global market:

A. Straight-run bunker oil, 0.5%, 0.1% sulfur content

B. The world's ultra-low sulfur crude oil (US shale oil, Algeria, Nigeria, Brazil, Australia, etc.). However, most of this crude oil is used by refineries to process and produce gasoline and diesel, etc., with a small amount of oil released.

C. Straight-run bunker oil after desulfurization of crude oil.

D. Refinery fractionates mixtures of products of different levels, or mixed products of residual oil and compounds. Among them, the difference of the base of the mixture is used to distinguish the categories. (Bolbot, Theotokatos, Boulougouris, Psarros & Hamann, 2020).

Strictly speaking, only the first two can be called real low-sulfur bunker oil, and the others are mixed oil. The source of low sulfur production can be divided into two types: trade middleman blended bunker oil and refinery produced bunker oil. The former is more supplied in the market and the blending quality is inferior to that of

the products produced by refineries. There is a high-quality guarantee for the finished products of refineries. In order to pursue profits, the trade middlemen may add cheap blending resources such as chemical waste. Although the indicators fully meet the requirements of viscosity and density of low-sulfur marine bunker, there are large potential safety risks. Therefore, although there are many low-sulfur bunker suppliers in the market at this stage, there are still few low-sulfur oil with stable quality (Wang, Zhang & Gan, 2019). Some large ports, such as Singapore port, Rotterdam port, etc., have the supply of high and low sulfur bunker oil, while small ports have the problem of high and low sulfur supply at the same time. In addition, due to the different sources of bunker, mixing bunker oil from different manufacturers will cause new problems such as compatibility, and the coexistence of multiple types of bunker market will bring new challenges and logistics problems for the port.

In addition, lines represented by container ships and ore carrying vessels, due to the relatively fixed affiliate ports for regular liners, it is easier to determine the ports for bunker supply, and therefore can sign long-term supply contracts with bunker suppliers in the global. The shipping company also be more inclined to choose using low sulphur bunker as the solution (Wang, Zhang & Gan, 2019). While, unscheduled cargo ships, such as oil tankers, bulk carriers and dry general cargo ships, are more likely to continue using scrubbers because of the uncertainty of their lines and the inability to ensure that low sulphur fuel oil can be procured at all ports. Compared with small-scale shipping enterprises, large-scale shipping enterprises are often of horizontal development with a variety of types of ships, so installation of scrubbers can solve the problem of their oil supply. And if only using low sulphur, the shipping

company which owns wide ship routes all over the world will suffer the risk of no enough Low sulphur fuel oil (Yan Hecheng, 2018).

The second one is many interviewees said that due to too many factors affecting China's shipping bunker price with different effects, therein the possible factors affecting the price of refined oil products include: international refined oil price, international crude oil price (WTI), China's refined oil output, China's natural crude oil output, China's crude oil imports, China's crude oil price and so on, which have led to the price fluctuations of shipping Low sulphur fuel oil, so there is the risk of bunker supply. We further analyze the bunker supply factors based on a known Chinese impact model of refined shipping bunker (Li Xiaoyun, 2014),

$$P=0.09077R1+0.18664R2+0.19235R3+0.07151R4+0.06984R5+0.06984R6+0.18851R7$$

Formula 4. Factors for China bunker price

Therein R1 is domestic refined oil price; R2 is international refined oil price; R3 is international crude oil price (WTI); R4 is China’s refined oil output; R5 is China's natural crude oil output; R6 is China's crude oil imports; R7 is China's crude oil price; and P is a comprehensive measurement index (Li Xiaoyun, 2014). According to the model, it can be known that the price of China’s refined oil is greatly influenced by the price of international refined oil, the price of international crude oil, the output of China’ s refined oil and the price of China’ crude oil. So the ups and downs of international crude oil price have always been a major risk for low sulphur bunker, but many interviewees said that the bunker has the risk of increase price, but the scrubber also surfer the risk that the bunker price drops, Therefore, for companies

with large scale fleets, installing the scrubber in part of proportion can minimize the risks caused by fluctuations in bunker prices.

As for a company in China, which is still using the scrubber because they worry about the new regulation of emission control requirement, the last point was learned from an interviewee working in the Maritime Safety Administration (Han, 2010). He said that the policy is constantly changing and its development is towards a stricter sulfur restriction policy. 2018 China ECA emission control requirements are ("Chinese Government Website", 2020):

1. As of January 1, 2019, ships using marine bunker oil with a sulfur content of not more than 0.5% should be used for navigation and docking in coastal control areas.
2. As of January 1, 2020, marine vessels entering the inland river control area should use marine bunker with a sulfur content of not more than 0.1% .
3. From January 1, 2022, sea ships entering the coastal waters of Hainan should use marine bunker with a sulfur content of not more than 0.1% .
4. Evaluate the feasibility of using bunker with a sulfur content of not more than 0.1% in a timely manner, and determine whether it is required to use bunker with a sulfur content of no more than 0.1% from January 1, 2025.

From the requirements, we can find that the from 2022 0.1% Low sulphur bunker will also be required(IMO News, 2020). At that time, the supply of 0.1% low sulphur will also be enough? And its price will increase or not? They still worry about it.

5.2.2 The Company Only Using Low sulphur Bunker

The price difference between low-sulfur bunker and high-sulfur bunker is getting

smaller and smaller from the bunker price analysis before. In addition to the disadvantage that the cost is not lower than that of using low-sulfur bunker, scrubber has other problems. That is why there are many small shipping companies only using Low sulphur bunker as the method for controlling SOx emission.

The most important reason is that with the change of China's tax and subsidy policies for bunker oil, the relative prices of high-sulfur bunker oil and low-sulfur marine bunker oil and other refined oil will tend to be reasonable in the changing balance of market supply and demand(Svindland, 2018). In the past, the high taxes on bunker oil export led to the lack of enthusiasm of Chinese refineries in the production of marine bunker. And marine bunker was basically imported from the surrounding countries, so the price was obviously higher. In this case, most ships chose to fill low-cost bunker oil in the ports of the surrounding countries, which restricted the demand for bonded marine bunker in China. Therefore, some people mentioned in the interview that on January 22, 2020 the export tax rebate policy will be implemented for the bunker oil filled by international ships in China's coastal ports(Yan Hecheng, 2018). On April 28, 2020, the Ministry of Commerce and the General Administration of Customs of China simultaneously issued the

"Include Low-sulfur Marine bunker Oil in the List of Goods Under Export License Management (2020)"

and the" *Notice on Issuing the First Batch of Export Quotas for Low-sulfur Marine bunker Oil in 2020"*.

Among them, the "*list"* clearly stipulates that export license is required for the export

of low-sulfur marine bunker produced by domestic refineries; while the *"notice"* stipulates that the first batch of low-sulfur marine bunker export quota will be 10 million tons in 2020, and Sinopec, PetroChina and other five units have obtained the first batch of export quota ("Chinese Government Website", 2020). The introduction of three new policies in succession marks the formation of China's export tax rebate policy for low-sulfur bunker oil, which will greatly reduce the price of domestic export marine bunker oil, improve the competitive advantage, and thus enhance the enthusiasm of refineries to produce low-sulfur marine bunker oil. The following figures showing the change of bunker price by the demand and supply changed.

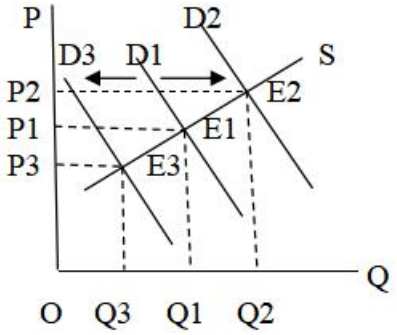


Figure 10. Impact of change of demand on equilibrium price

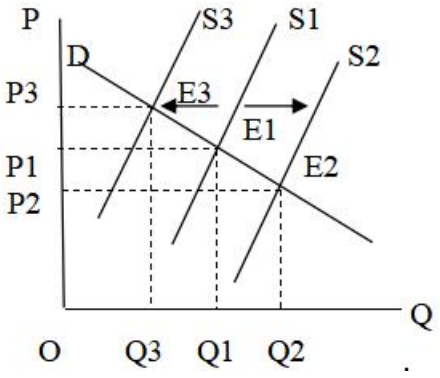


Figure 11. Impact of change of supply on equilibrium price

As the bunker supply curve S fixed, the initial demand curve D1 and the equilibrium price P1, more often than not, changed. When D1 shifts to the right to D2, the equilibrium price increases from P1 to P2, and the equilibrium quantity increases from Q1 to Q2. When D1 shifts to the left to D3, the equilibrium price decreases from P1 to P3, and the equilibrium quantity decreases from Q1 to Q3 (see Figure 10).

As the bunker demand curve D fixed, the initial supply curve S1 and the equilibrium

price P1, more often than not, changed. When S1 shifts to the right to S2, the equilibrium price decreases from P1 to P2, and the equilibrium quantity increases from Q1 to Q2. When S1 shifts to the left to S3, the equilibrium price increases from P1 to P3, and the equilibrium quantity decreases from Q1 to Q3 (see Figure 11).

The analysis above assumes that all variables remain constant except one. But in real life situations, supply and demand may change simultaneously (Bochet, İlkılıç, Moulin & Sethuraman, 2012). Under such condition, the equilibrium price and the quantity of a good are uncertain and should be determined by analyzing both supply and demand. If the equilibrium price is affected by both factors, it will depend on the respective extent of growth of supply and demand. Low sulphur fuel oil (LSFO) is the bunker with sulfur content being lower than 0.5%. Compare to the demand for LSFO, the current supply is obviously insufficient (Bochet, İlkılıç, Moulin & Sethuraman, 2012).

In addition, the emergence of new technology will also have a greater impact on the supply of low-sulfur bunker. The earliest production process of low-sulfur bunker started in the 1950s, using the technology of hydrodesulfurization of distillate oil of high sulfur crude oil (Wang, Zhang & Gan, 2019). Since the 1970s, the sulfur content of bunker oil has been increasingly restricted in the world, and the traditional production process has been unable to meet the requirements of the production of low-sulfur bunker oil, and the output is also difficult to meet the demand. Therefore, the technical reform has taken place. Due to the influence of MARPOL, now there are new technologies under development or mature in various countries, which will also increase the supply of low-sulfur oil and have an impact on the price(Yan

Hecheng, 2018)..

The second reason is that scrubber would damage the sea water environment. Generally, there are three types of scrubbers: Open-loop, closed-loop and mixed. Each type has its own advantages and disadvantages. And current cost of open-loop scrubber is lower than low-sulfur bunker and lower than closed-loop scrubber (Sethi, 2020).

But Currently many countries prohibit the use of open-loop scrubbers. The Chinese government has announced that starting from January 1, 2019, discharge of wash water from open-loop exhaust gas cleaning systems in rivers, port zones and the Bohai Sea is prohibited(Menachof & Dicer, 2001). From interview, many people's company is affected by the policy. The discharge prohibition in other coastal waters will also be announced and implemented in due course. Earlier, the Singaporean government announced that from January 1, 2020, discharge of sewage from open-loop scrubbers within the Port of Singapore is prohibited, which has led to strong repercussions in the shipping industry.

Besides China and Singapore, many other countries (regions) prohibit or will prohibit the discharge of wash water from open-loop desulfurization equipment in certain waters. Gard P&I Club indicates that the list of countries with such prohibition will become longer (Mori, T.2012). Below is a map of countries (regions) prohibiting the use of open-loop desulfurization equipment, including China, Singapore, Norway, Belgium, India, and several U.S. ports. Besides, according to Gard, many other countries (regions) will prohibit the use of desulfurization

equipment in certain ports and nature reserves.

Figure 12. Distribution of countries ban open-loop scrubber

Here is a brief illustration of the relevant regulations in some countries (regions):

The EU's "Commission's Views on the Discharge of Scrubber Wash Water" (Agenda item 6.C ESSF of 2016) introduces that according to Belgian laws (Organisation, 2020), it is prohibited to discharge wash water from desulfurization equipment in ports and inland waters (Wet van 26 maart 1971 op de bescherming van de oppervlaktewateren tegen verontreiniging (Vlaams Gewest)

BE	☑: only in coastal and open seawaters (off the limit of the base line)	• Discharge in coastal and open seawaters is only allowed if does not imperil WFD objectives. • Discharge from ships is not allowed in ports or inland waters. It should be noted that according to the law on protection of surface waters, a permitting system is in force for land-based installations with appropriate procedures for obtaining a permit (and taxation depending on the amount of pollution).*	• To date, no data indicating that discharges in coastal and open seawaters should be forbidden • Studies show a very quick dilution of discharge without effects on the environment at sea. In the case the contrary should be proved, rules might become more strict and discharge could be forbidden to protect the marine environment.	• Important to have enough data on the composition, concentration and volumes of wash water to estimate the effects on the environment with confidence, and to be able to set the conditions to allow discharge from ships, should that be estimated as feasible.	☑ From February 2015, discussions are ongoing between all relevant national and regional authorities in order to achieve a coordinated position and to implement this position in an appropriate way. So far we didn't come to final conclusions, but when discussing this complex issue, following concerns popped up: The importance to have enough data (see left); Every port is unique (closed/open docks, amount of ships, type of ships, amount of ships with scrubbers,...) and a common approach might be hard to find;	Competencies shared between maritime and environmental administrations and federal and regional authorities. Common position aimed at. The federal government is competent for the SD directive and the part of the WFD covering open sea waters and coastal waters below the base line. Regional governments are competent for ports, inland waters and coastal waters above the base line. In relation to the environmental aspects, the positions of the federal and regional administrations are different inasmuch as the situation of inland and sea waters is different. Dilution plays a larger role in sea waters than in inland waters, which allows for a more flexible position for the federal environmental administration considering discharge of washwater from scrubbers. *** Additional information of 14 January 2016:** The full title of the applicable legislation is: **"Wet van 26 maart 1971 op de bescherming van de oppervlaktewateren tegen verontreiniging (Vlaams Gewest), as amended."**

Figure 13. Belgian law

Malaysia has decided to prohibit vessels operating in its waters from using open-loop exhaust gas cleaning systems (EGCS)(Ezeoke, 2017). An announcement from the

Maritime Institute of Malaysia clearly states that "Malaysia prohibits the discharge of sewage from open-loop desulfurization systems in Malaysian waters 12 nautical miles from the nearest baseline." "Ships that bound for Malaysian ports are advised to use low-sulfur bunkers or switch to closed-loop mode (if using mixed system)."

Another statement from the Malaysian Ministry of Transport states that ships using Malaysian flag that have to use non-standard-compliant bunkers will need to obtain approval from the Department, the port authority where the bunkers are bought and the port authority of the destination (Sethi, 2020).

NOTIS PERKAPALAN MALAYSIA
MALAYSIA SHIPPING NOTICE

JABATAN LAUT MALAYSIA **MSN 07/2019**
MARINE DEPARTMENT MALAYSIA
Ibu Pejabat Laut Malaysia, Peti Surat 12, 42007 Pelabuhan Klang
Tel : 03-33467777, Fax : 03-31685289, E-mail : kpgr@marine.gov.my
Webpage : http://www.marine.gov.my

Notis kepada pemilik kapal, agen perkapalan, Nakhoda, pelaut, pengusaha pelabuhan dan industri maritim
Notice to shipowners, ship agents, Masters, seafarers, port operators and the maritime industry

SYARAT-SYARAT UNTUK KAPAL YANG MEMASANG SISTEM PEMBERSIHAN GAS EKZOS (EGCS - SCRUBBER) DAN MELEPASKAN SISA DAN *WASHWATER* KE LAUT

REQUIREMENT FOR SHIPS INSTALLED EXHAUST GAS CLEANING SYSTEM (EGCS - SCRUBBER) AND THE DISCHARGE OF RESIDUE AND WASHWATER TO THE SEA

Tujuan

1. Notis ini adalah untuk memaklumkan komuniti perkapalan mengenai keperluan Peraturan 14.1, Lampiran VI MARPOL 73/78 untuk kapal yang memasang EGCS.
2. Malaysia **melarang pelepasan *washwater*** dari *EGCS open-loop system* semasa kapal semasa berada dalam perairan Malaysia (12 batu nautika dari tanah terdekat).

   Kapal memasuki mana-mana Pelabuhan di Malaysia dinasihatkan untuk menukar kepada minyak bahan api yang patuh atau menukar kepada *close loop system* (jika sistem hibrid) sebelum memasuki Perairan dan Pelabuhan-pelabuhan di Malaysia.
3. Pengurus / Pemilik Kapal yang menguruskan Kapal Bendera Malaysia yang telah memasang EGCS dengan jenis *open-loop systems* dinasihatkan untuk mengambil perhatian terhadap mana-mana Pelabuhan Asing yang melarang pelepasan *washwater* dari *open-loop systems*.

Purpose

1. *This notice is to inform the shipping community on the requirement Regulation 14.1, Annex VI of MARPOL 73/78 for ships installed with the EGCS.*
2. *Malaysia **prohibits the discharge of washwater** from EGCS open-loop system whilst in Malaysian Water (12 nautical miles from the nearest land).*

   Ships calling to the Malaysian Ports are advised to change over to compliance fuel oil or change over to close loop system (if hybrid system) before entering Malaysian Waters and Ports.
3. *Ships Manager / Owner which managed the Malaysian Ships which has installed EGCS with open-loop systems are advised to take note of any foreign ports which have prohibited the discharge of washwater from open-loop systems.*

Figure 14. Malaysian law

Swedish researchers examine the sewage from open-loop scrubbers and find that

unprocessed wash water is heavily polluted and contains heavy metals, aromatic mixtures, soot particles, etc. In May 2019, 28 EU members jointly submitted a document to the IMO, stating that the use of open-loop scrubbers “may deteriorate marine environment because the discharged wash water contains toxic substances.”(Mori, T.2012)

Based on the interview information obtained from the 20 interviewees randomly selected, we find that another reason why companies dislike using scrubber is Technical Risk. "Any act of adding machinery to a ship increases the risk," said London Marine Insurance Company. Most interviewees whose company did not choose to continue using a scrubber also said adding machinery is a major concern for them(Jongsoon Koo, 2010). Among the risks of installation of a scrubber mentioned by the interviewees, there are the risk that the new technology will take place of the scrubber, the risk that whether the technology of the scrubber is mature, the risk of reconstruction of the ship for installation of a scrubber and the risk in the operation of the scrubber. Of course, the use of Low sulphur bunker is also risky. It has been suggested that low sulphur content of Low sulphur bunker will reduce engine lubrication, resulting in wear and tear reducing engine life. Low sulphur bunker price market volatility is also a huge risk. But most of the interviewees said that the technical risks are more worrisome.

As to a smaller shipping company in China, it is more afraid of technical risks. As the project management of the scrubber is a complex systematic project with large investment, long return period, multi-specialties, strong technicality and wide scope, in order to complete the project of scrubber installation, shipping enterprises need to

communicate and coordinate with banks, insurance companies, intermediaries, shipyards, classification societies, equipment factories and so on. Therefore, the risks do not only come from the shipping enterprises themselves, but also from many related enterprises (Mori, T.2012). In addition, there is also the risk of loss of investment brought by scientific and technological progress as well as technological structure and related factors change, including the risks in technology development, protection, acquisition, use and transfer. For example, the use of new equipment may pose a threat to the seaworthiness of the ship, forcing shipping companies to increase investment, upgrade techniques, etc., which may affect on-time delivery in severe cases like what happened to the companies where 5 of the 20 interviewees serve .

There is another Weakness for scrubber that a lot of small shipping companies lack of funds for investment of scrubber in China. Furthermore, the increase in costs is also a reason (Zhaozhe. 2019). The costs of installing a scrubber include upfront investment cost, installation cost, maintenance cost, financial interest cost, and the cost of additional work that may be brought to workers. As to the use of Low sulphur bunker, the costs mainly include the cost of rising prices and the cost of replacing different types of bunker in different regions (Wang, Z., Zhang, H., & Gan, X. 2019). Most of the interviewees thought that their companies were not so well-funded. Large-scale investment in new equipment is likely to result in a broken capital chain. Some of the interviewees work in large shipping companies such as Maersk, and they said that large shipping enterprises are likely to invest a huge amount in product research and development, scientific and technological system construction, brand construction and other aspects (especially the current large-scale investment projects of scrubbers) so as to continuously improve research and development capacity,

further improve the scientific and technological system, and enhance market adaptability. This is hard for small shipping companies to achieve(SCHLIEPHAKE & KIRSTEIN, 2013).

Insufficient cash flow is the biggest fatal problem for small and medium-sized shipping enterprises in China. It is well known that a stable and sufficient cash flow will enable an enterprise to survive and to develop for a long time (Zhaozhe. 2019). At present, the main reason that restricts small and medium-sized shipping enterprises and makes them face financing difficulty is the high cost, which is mainly caused by the preference of many banks on large enterprises, especially the state-owned banks (Wang, Z., Zhang, H., & Gan, X. 2019). Regardless of the size of the amount, the process of issuing loans by the banks, such as accepting, investigating, approving and so on, are similar, but the benefits to different sizes of enterprises are very different. In China, the big four state-owned commercial banks are currently taken as the main body of banks, and the banks generally believe that, state-owned enterprises' capital strength is strong, so the loan risk is small. Even if something goes wrong, they also have the state as the backing(Han, 2010).

Therefore, the state-owned banks are naturally inclined to loan business of a large amount and cannot well meet the short-term, small amount, frequent loan requirements of private enterprises. Small and medium-sized enterprises have to request state-owned enterprises to act as guarantors or intermediaries to obtain loans from banks (Chauhan, 2017). There are 15 of the 20 interviewees, accounting for 75% of the total, received loans that were not direct loans. As for the access to external funds for small and medium-sized shipping enterprises, in addition to

financial institutions, private loans have also become an important source of funding. The amounts obtained through direct financing channels are a very small, and 11 out of all interviewees said their companies often accepted private loans.

There are also practitioners who criticize banks for ignoring market rules, disrespecting markets and blindly following the advice of local governments to issue loans. One respondent with a background in banking said that although he did not run into a government-ordered loan, the government would suggest to give loan. for example, it would stress that the company business was in good shape, this is a policy intervention loan (Zhaozhe. 2019).

There is another threat is the Volatility in the Shipping Market in China. The shipping industry is closely related to the international economic and trade situation, and there are periodic and seasonal fluctuations in market demand (Chauhan, 2017). The companies of more than 80% of the 20 interviewees have established strategic partnership with import and export trading companies. When China's domestic and international economy boom, the shipping market demand will rise accordingly; if China's domestic and international economic growth slows down, the shipping market demand will be affected. Especially under the impact of the new coronavirus epidemic, the small and medium-sized enterprises in the upstream and downstream of the international industrial chain are further facing the problems of disconnection of the industrial chain and the supply chain, the shortage of material supply and the rapid increase of logistics transportation cost (Koilo, 2019).

The biggest challenge for small and medium-sized shipping enterprises in China is mainly reflected in the reduction of orders caused by the outbreak and the decline of production capacity caused by the disruption of the supply chain, which directly brought the loss and cash flow crisis to the enterprises and further led to a large number of small and medium-sized shipping enterprises' bankruptcy, restructuring, merger or being acquired (Mori, T.2012). The reason foresaid directly made the small and medium-sized enterprises hold a watch-and-see attitude to the investment projects such as scrubbers. One of the interviewees said in a humorous tone, "the invested desulfurization tower equipment can be operated for more than 5 years, but we are not sure if our company can still survive after 5 years".

And the LNG new technology also affects the Low sulphur fuel oil in China. That is because if the ship changes to use LNG on the ship the situation will totally change. Three of interviewees mentioned the new technology of LNG. Compare with bunker and scrubber, the LNG has the advantages as follows(Mori, 2012) :

(1) Small volume and high calorific value

The main component of natural gas is methane, which has a calorific value nearly 20% higher than diesel.

(2) Large reserves and sufficient supply

At present, the supply and demand of LNG are growing faster than other traditional energy types.

(3) Low pollution emissions

The carbon dioxide emitted when LNG is burned is much less than other marine bunkers. It can reduce emissions by nearly 100% of SOx (Han, 2010).

5.3 Results

"Any act of adding machinery to a ship increases risk," represents the thinking of many shipping companies (Koilo, 2019). In addition, insurance companies are evaluating the higher risks that ships equipped with scrubbers may face. At present, a number of ships have had accidents due to the installation of scrubbers. Some analysts said that the accidents were due to serious corrosion of equipment. It was also suggested that improper installation of the scrubbers or improper operation of the crew could also lead to accidents. Many ships with scrubbers are trying to make their system work properly, and many have to assign more crew for operation. These all are the problems the ships need to face. Even the large shipping companies with professional technical teams, when facing with these problems, are under great pressure, not to mention some small and medium-sized shipping companies in China. As to them, these risks are devastating.

Small and medium-sized shipping enterprises in China are obviously inferior to large ones in utilizing economic resources, obtaining market information and seeking external support. At the same time, the entry barriers of technology, capital and others for small and medium-sized enterprises in the field of production and operation are larger, and the existence of a large number of small and medium-sized shipping enterprises makes them face increasingly fierce competition. Therefore, in a time of severe market turbulence and in a financial crisis, small and medium-sized shipping enterprises are often the hardest-hit ones. The disadvantage of low anti-risk ability makes small and medium-sized enterprises in China, especially small and medium-sized enterprises established in a short time, have higher failure rate.

Compared with small-scale enterprises, the economies of scale of large-scale shipping enterprises are favorable for large-scale shipping enterprises to expand market coverage and spread operational risks. Investment in scrubber for large shipping company is also a way to diversify risk (Koilo, 2019).

The decisive factor is the difference between low-sulfur oil and ordinary bunker in China, which is getting smaller and smaller as the number of suppliers increases. The cost advantage of scrubber has gradually been lost. However, during the calculation of IRR and NPV form the cash-flow part, we can find that NPV using scrubber is relatively high. So currently using scrubber is not useless.

Although the current supply of low-sulfur oil has unstable factors, and the quality of low-sulfur oil is also not good, I believe that all of them will be resolved through the technological innovation. With the support of the Chinese government, the continued supply of high-quality low-sulfur oil in the future will solve the supply problem of China's low-sulfur oil market. In addition, emerging technologies， such as the LNG technology, are also an important factor for solving shipping enterprises' control of sulfur emissions. But could this results apply to the widely shipping industry in China ?

Chapter 6. Quantitative Survey and Analysis

6.1 Data Collection

Some people may ask, what is the purpose of this survey? For me, I hope to use this survey to determine what factors influence a company's decision on which solution to be used now. This survey could proving the results of the interview. And I want to confirm whether the results obtained by the interview are universal or only a small part of the particularity of the shipping company in China. This is a continue research of interview.

Before that, I have come up with a variety of methods to collect data via questionnaire surveys, in ways such as street interviews, telephone interviews and mailing questionnaire to the respondents. In the end, I decided to use a more targeted and feasible research approach. I found that more and more shipping workers in China have easy access to the Internet, so I decided to use Facebook, Twitter and WeChat as the main survey methods.

As we all know, we can post questionnaire forms about Facebook and Twitter functions, and I used this function to do the survey on Facebook and Twitter. On Facebook and Twitter, I can use Messenger to set up discussion groups and collect questions. At the same time, we use the WeChat group function to establish discussion groups, post questions and collect answers.

In this way, the location of the questionnaire survey is relatively casual. Even if the crew is working on a ship, they still have the opportunity to complete the questionnaire. As to the selection of surveyors, this survey focuses on shipping companies directly affected by MARPOL convention.

The data are Collected through the opinions of shipping companies and seafarers through questionnaires, as well as the staff of related logistics companies and research institutions in China. The target number of people is to randomly-selected 150 people, and they are required to complete the survey, and finally 143 questionnaires are gotten back. The jobs of the respondents are only limited to the relevant enterprises and positions, regardless of whether they are management level staff. The result of the Survey is analyzed, based on the number of recovered questionnaires ("FUNDAMENTALS OF SURVEY MEASUREMENT AND ANALYSIS", 1984). The APPENDIX: III. The Survey Questionnaire is the content of this survey， and you could find it at the end of this paper. It includes the information of introducing myself, hints for completing this questionnaire, 10 questions, and Privacy statement and so on.

6.2 Statistic Analysis

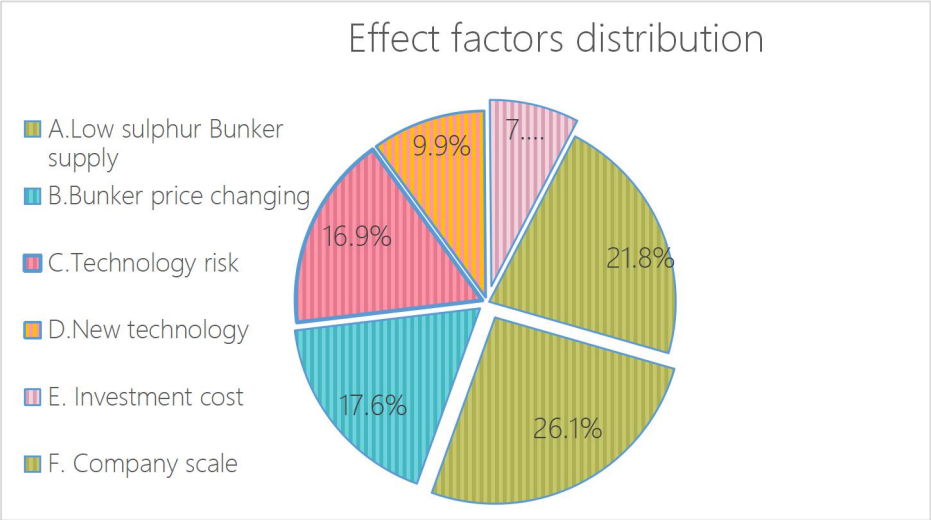


Figure 15. Using scrubber effect factors

From the survey about which kind of factors effecting the ship company in China still using scrubber need to deserve our attention. We find that the largest part of people believe Low sulphur bunker supply is the most important risk needing to take care, accounting for 26.1% of the total. The next largest one is company scale , being 21.8% lower than the former and followed by bunker price changing and technology risk. The above four Items altogether take up 82% of the total people. Some people would like to ask that why the bunker price changes is not the most important one, due to the analysis in cash flow part. That is because the price difference in high sulphur bunker and Low sulphur bunker affects the cost of each method a lot, and the price difference depends on the low sulphur supply.

Remarkably, investment cost constitutes the smallest part (7.7%). Under the circumstance, if Low sulphur bunker supply risk, Bunker price risk, and Damage engine risk increase, the shipping company will increase the willingness to install the

scrubber to control SOx emission. If New technology risk, Investment risk, and Keep long term risk increase, the shipowner and shipping company will prefer to choose using Low sulphur bunker to control SOx emission. Most of the respondents believe that using Scrubber will suffer more risks than using Low sulphur bunker, taking up 67% of the total people.

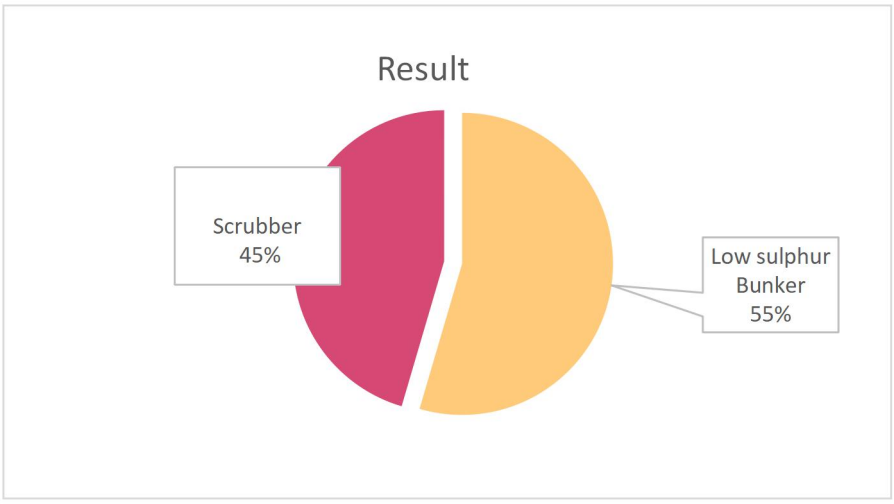


Figure 16. Company still using scrubber situation

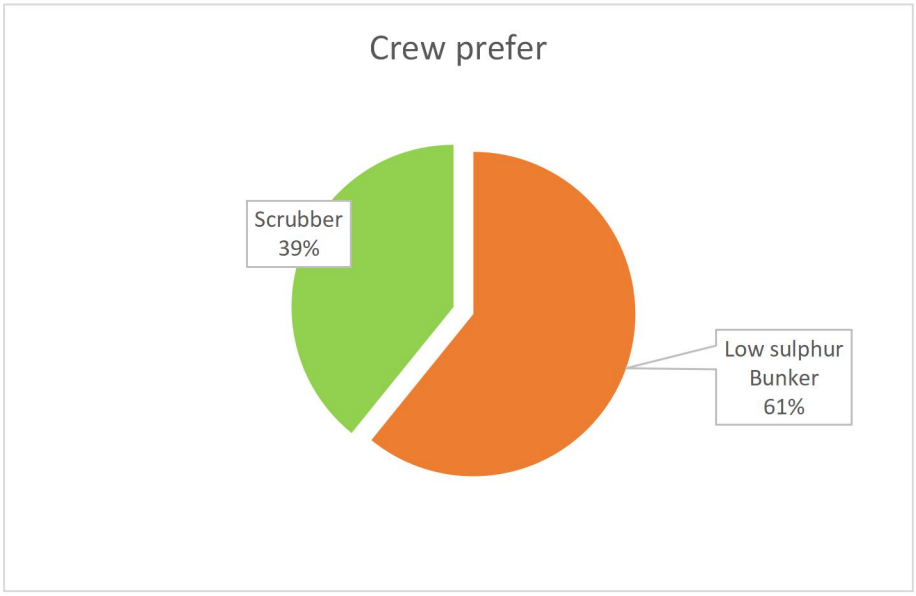


Figure 17. Crew prefer still using scrubber situation

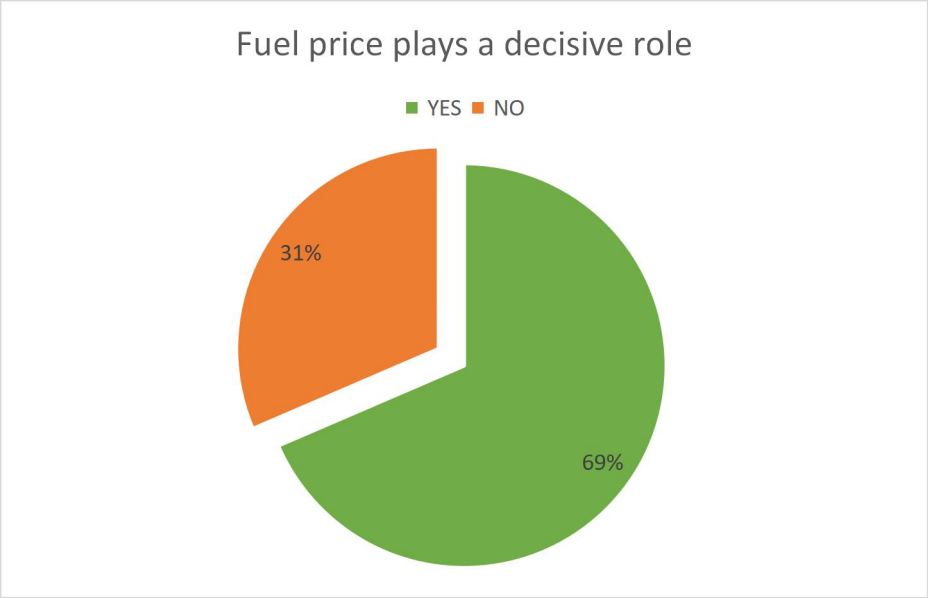


Figure 18. bunker price plays a decisive role

The analysis shows that 54.55% of shipping companies in China are using low-sulfur bunker instead of scrubber, while 45.45% of shipping companies are still using scrubber as the way to control emission. Although the IRR of scrubber is not better than Low sulphur bunker, I did not find that a company only use scrubber as the method for emission control, and 54.55% of companies only use low sulphur to control emission.

And from the crew's perspective, most of the crew still like using Low sulphur fuel oil, taking up around 61% crew. However, only 39% of all crew members like using scrubber. This is related with the convenience of refueling and the supply of low-sulfur oil enough. If it is convenient to refuel and easily changing bunker, enter the emission control area ECA, the crew will still prefer to use low-sulfur bunker. But often contrary to expectations, many shipping companies with a wide

range of shipping routes will tend to choose some ships to install scrubber to prevent risks.

It is very interesting to set up a question about the situation use of low sulfur bunker for all respondents. As a result, 100% of shipping companies are using low-sulfur oil， and no company give up using Low sulphur bunker. Moreover, I also set up a question about whether oil prices play a decisive role. 69% of people choose YES. 31% believe that there are still other reasons, such as company scale, technical risk, bunker supply risk and so on.

6.3 Survey and Binary Logistic Regress Analysis

Before working on the regression analysis, I made a hypothesis through the intuitive analysis of the obtained data. The assumption is that the shipping company's decision in China on still using scrubber to control SOx depends on the company's size and suppliers of scrubber and Low sulphur fuel oil. Because several sets of data, such as the size of employees, the number of scrubber installed, etc, are very relevant to the decision to install Scrubbers, it is necessary for me to test this hypothesis (Chatterjee & Chatterjee, 2010).

As we know, the Logistic regression is a probabilistic non-linear regression model. It is a multivariate analysis that studies the relationship between classification observations (y) and some influencing factors (x). Logistic regression requires the dependent variable (Y) to be a categorical variable (two or more categories). The independent variable (Xj) is an influencing factor. It can be a continuous variable, a

rank variable, a categorical variable. There can be n independent variables X1 X2, ... Xn.

$$Y = \begin{cases} 1 \\ 0 \end{cases}$$

Logistic regression is used to calculate the probabilities of "Event = Success" and "Event = Failure". When the type of the dependent variable is a binary (1/0, true / false, yes / no) variable, we should use logistic regression (Chatterjee & Chatterjee, 2010). Such as: death or survival, male or female, yes or no, Yes or No, here we assign the use of desulfurization tower and non-desulfurization tower (Still using low sulfur bunker). 1 represents the way of still using the method scrubber. 0 represents using low-sulfur bunker. The value of Y ranges from 0 to 1, which can be expressed by the following equation.

odds= p/ (1-p) = probability of event occurrence / probability of not event occurrenceln (odds) = Ln(p/(1-p))Logit(p) = Ln(p/(1-p)) = b0+b1X1+b2X2+b3X3....+bnXn.

Formula 5. Logistic regression probability

This study uses IBM SPSS to perform statistical analysis of the data. This study first quantifies the data, and the results are shown in the following table.

Scrubber suppliers A. Not at all B. Hard to find supplies C. Few supplies D. Able to meet demand E. A lot supplies	A=1 B=2 C=3 D=4 E=5
Low sulphur bunker suppliers A. A lot supplies B. Able to meet demand C. Few supplies D. Hard to find supplies E. Not at all	A=1 B=2 C=3 D=4 E=5
Staff number =X A. X≤20 B. 20＜X≤100 C. 100＜X≤300 D. 300＜X≤1000 E. 1000≤X	A=1 B=2 C=3 D=4 E=5
Number of ship routs=X A Less than 10 B 10＜X≤20 C 20＜X≤30 D 30＜X≤40 E 40＜X≤50 F More than 50	A =1 B= 2 C=3 D=4 E=5 F=6
Scrubber cost	A=1 B=2 C=3 D=4

A. Too expensive B. Expensive C. Acceptable D. Cheap	
For using scrubber A. Still using B. Not using	A =1 B=0

Table 10. Variable assignment

In this study, the screening variables, Number of ship, Number of Scrubber Staff Working time, Low sulphur bunker suppliers, Scrubber Suppliers, Scrubber price, Number of Crew prefer and Number of ship routs are taken as independent variables, and the willingness to install the desulfurization tower is selected as the dependent variable to carry out the binary Logistic regression. The results are shown in the table below:

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	99.750[a]	.494	.660

a. Estimation terminated at iteration number 8 because parameter estimates changed by less than .001.

Table 11. Model Summary

Binary regression needs to evaluate "Overall significance test of model" and "-2 Log likelihood" (i.e. - 2LL). The smaller the value of "Overall significance test of model" is, the better the overall significance test of model is. The smaller the value of -2LL is, the greater the likelihood value reflecting the regression equation is, indicating the

better the fitting degree of the model is; otherwise, it means the worse the fitting degree of the model is. Cox & Snell R^2 and Nagelkerke R^2 play the same role as R^2 in linear regression, indicating the interpretation percentage. The -2LL of the regression model is 175.490; Cox & Snell R^2 is 0.494; Nagelkerke R^2 is 0.660, indicating that the interpretation degree of the model reaches 66.0%, which is relatively better.

Classification Table[a]

Observed			Predicted Y .00	Predicted Y 1.00	Percentage Correct
Step 1	Y	.00	72	6	92.3
		1.00	16	49	75.4
	Overall Percentage				84.6

a. The cut value is .500

Table 12. Classification Table a

From table 12, it can be seen that the overall prediction accuracy of the model is 84.6%. Among them, the prediction accuracy of choosing to install desulfurization tower is 75.4%, and the prediction accuracy of choosing to use low sulfur oil is 92.3%. The prediction effect of this study is preferable. In particular, the prediction accuracy of not choosing to install desulfurization tower is as high as 92.3%, which indicates that factors in regression are relatively scientific and effective on a secondary side.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	10.555	8	.228

Table 13. Hosmer and Lemeshow Test

From the results of goodness of fit test in table 13, the null hypothesis of Hosmer and Lemeshow test is to make the model fit data well. From the significance test result of the final model, Sig.=0.228 is not significant at the level of 0.05, and null hypothesis is accepted.

Variable in the Equation

		B	S.E	Wald	df	Sig	Exp(B)	95%C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Number of scrubber	0.035	0.082	0.178	1	0.673	1.035	0.881	1.217
	Staff Number	1.171	0.555	4.448	1	0.035	3.224	1.086	9.571
	Working time	-0.038	0.031	1.501	1	0.220	0.963	0.906	1.023
	Low sulphur bunker suppliers	3.077	0.722	18.160	1	0.000	21.693	5.269	89.314
	Scrubber Supplier	1.091	0.493	4.889	1	0.027	2.976	1.132	7.825
	Scrubber Price	1.983	0.576	11.849	1	0.001	7.262	2.349	22.458
	Number of ship routs	0.938	0.421	4.969	1	0.026	2.555	1.120	5.827
	Constant	-24.461	6.245	15.341	1	0.000	0.000		

a. Variable(s) entered on step 1 : Number of scrubber,Staff Number, Working time, Low sulphur bunker suppliers, Scrubber Supplier, Scrubber Price, Number of ship routs.

Table 14. Variables in the Equation

It can be seen from the above table 14 that most of the seven variables in the binary Logistic regression of variables selected by Chi-square test for enterprises to still

using desulfurization tower or using low sulfur oil have reached a significant level, indicating that these factors have a significant impact on the willingness to continue using desulfurization tower. As for the number of installed desulfurization tower, the regression coefficient is 0.035; the corresponding P value is 0.673, and significance is achieved at the level of 0.01, which means that the number of installed desulfurization tower has no significant influence on the willingness to continue using desulfurization tower. As for the scale of employees(staff numbers), the regression coefficient is 1.171, and the corresponding P value is 0.035, reaching a significant level at the level of 0.001. This indicates that the scale of employees has a significant influence on the willingness of employees to still use desulfurization tower, and there then will be more willingness to give up using scrubber. As employees become more, the degree of willingness to still use desulfurization tower will increase 3.224 times; As to the staff's work time, the regression coefficient is -0.38, indicating that the work time of staff does not have significant influence on the willingness to still use the desulfurization tower. Otherwise, there will be more willingness to give up using scrubber.

As for the Low sulphur bunker supplies, the regression coefficient is 3.077, and the corresponding P value is 0.000, which reaches a significant level at the level of 0.001, indicating that the more bunker suppliers is, the more significant the influence on the no willingness to continue using the Scrubber is. The companies having not too many Low sulphur bunker suppliers are 21.693 times more willing to use equipment with scrubber, when compared with those having too many Low sulphur bunker suppliers; meanwhile, the number of suppliers of the Scrubber has significant influence on the willingness to use the Scrubber. With the increase of number of

suppliers of Scrubber, the continuous willingness will also increase.

As for the number of ship routes, the regression coefficient is 0.938, and the corresponding P value is 0.26, which reaches a significant level at the level of 0.001, indicating that the more the routes are, the more significant the influence on the willingness to still use the Scrubber is. Compared with the ship companies having few shipping routes, the companies with many shipping routes are 7.267 times more willing to use scrubber equipment. In addition, the scrubber price has significant influence on the willingness to install the Desulfurization Scrubber. With the increase of scrubber price, the installation willingness will also decrease.

		B	S.E	Wald	df	Sig.	Exp(B)
Step 1[a]	Number of ships	.066	.013	25.367	1	.000	1.068
	Constant	-4.966	.810	37.617	1	.000	.007

Table 15. Variable in the Equation

For the number ships, from table 15, the regression coefficient is 0.066, and the corresponding P value is 0.000, which reaches a significant level at the level of 0.001, indicating that the more ships, the more significant the influence on the willingness to still use the Scrubber is. Otherwise, there will be more willingness to give up using scrubber.

6.4 Results

Most of companies in our survey prefer to use low-sulfur bunker as a measure to control SOx emissions. From the 143 questionnaires we recovered, there are 87 people (about 61% of the total) believing that crew preferred to use low-sulfur oil

solutions to control SOx emissions. And 56 people taking up around 39% of the total) believed that crew preferred continuing scrubber to control SOx emission. Because the crew are employees who directly operate the ship, their opinions are related to changing bunker or refuleing easily or not. In addition, crew's preferences are highly correlated with the company's decision. And the companies in our survey, 55% not using scrubber any more, and 45% companies still using scrubber， and in143 questionnaires all the companies are still using Low sulphur bunker. 69% of interviewees who completed questionnaires believe that shipping bunker prices have a decisive impact.

After I conducted a regression analysis, I learned that Number of scrubber, Staff number, Scrubber Supplier and number of ship routs have a positive correlation with shipping companies' selection of continuously using scrubber to control SOx emission. With an increase in the number of dependent variables above (Ship number, Staff number, Number of ship routes), it is more likely that shipping companies will choose to continue using scrubber. Scrubber price and the Low sulphur bunker suppliers have a negative correlation with the shipping companies choice of still using scrubber. As the number of the Scrubber price increases and the Low sulphur bunker supply variables increases, the probability of shipping companies' still using scrubber becomes smaller. The employees' working time and the number of Scrubber has no significant relationship with whether the enterprise will choose to continue using a scrubber or not. It is showing that your working time in the shipping company will not affect the decision making.

However, when we further analyze the positively-related influencing factors and find

that Number of ship， Number of scrubber, Staff number,and Number of ship routes are all related to the size of the enterprise, these factors determine the size of the enterprise. And the suppliers of bunker and scrubber also have positive effects on still using scrubber.

And according to the data from“ APPENDIX: III. The data collection from survey”, it is clear that among the 54.55% of shipping companies in China are now only using low-sulfur bunker, no matter whether they once used scrubber or not, and 90% of them have no more than 40 ships.Therefore, as far as the current Chinese market is concerned, most shipping companies use low-sulfur oil to control SOx emissions and some of them are also still using scrubber. 26.1% of total respondents claim that Low sulphur bunker supply is what most companies in China pay attention to. The regression results show that the results of the interview are credible.

Chapter 7. Conclusion

In the whole paper, I analyzed the research question step by step. Firstly, I got the NPV and IRR for both measures to control SOx emission. And secondly, in the interview I got the information that large scale companies in China still use scrubber, although the IRR is bad, and I got the factors still use scrubber or not. Finally the Regression could prove the results of interview within a small group to a wide shipping industry situation. In all cash flow calculations, the use of Low sulphur bunker is of the worst NPV and good IRR, but the increase in investment costs caused by it is less, and the reconstruction of ships is not much, so it is also the direct

choice for most ship companies. Although the price of Low sulphur bunker has greatly affected the economical efficiency and cost effectiveness of the measure. Especially in this period, due to the increase in the suppliers of Low sulphur bunker, and decrease the price difference between high sulphur bunker and Low sulphur bunker.

Therefore, the use of Low sulphur bunker is the most direct choice to meet the sulphur emission control and also a minimal risk option for shipping companies, which will not put huge pressure on the cash flow of shipping companies in the short term and will not affect the companies by sudden technical accidents. However, the quality of low-sulfur bunker and its impact on the ship's engine also exist. With the more and more strict requirements on bunker sulfur content, the types of bunkers will continue to increase, which is also a challenge for shipping companies.

The installation of scrubber is of more profitability due to the better NPV than the use of Low sulphur bunker but the IRR is the worst. It is an appropriate choice to install the tail gas treatment equipment in ocean routes. Although the increase in the cost caused by this measure is small, but the up-front investment is a relatively large investment only affordable for state-owned shipping enterprises with the large cash flow.

And for large companies in China, continuing to use desulfurization towers is an important way for companies to share risk. Scrubber is still a good solution when sulfur control policies continue to change. But technical risks and low oil prices still have a huge impact on scrubber. More and more small and medium shipping

companies in China are giving up using scrubber. At this moment, scrubber not a good choice.

OOCL
We take it personally

Jan 10, 2020

China FUEL COST RECOVERY/LOW SULPHUR ADJUSTMENT Notice

低硫燃油附加费通知

Dear Valued Customers,
尊敬的客户：

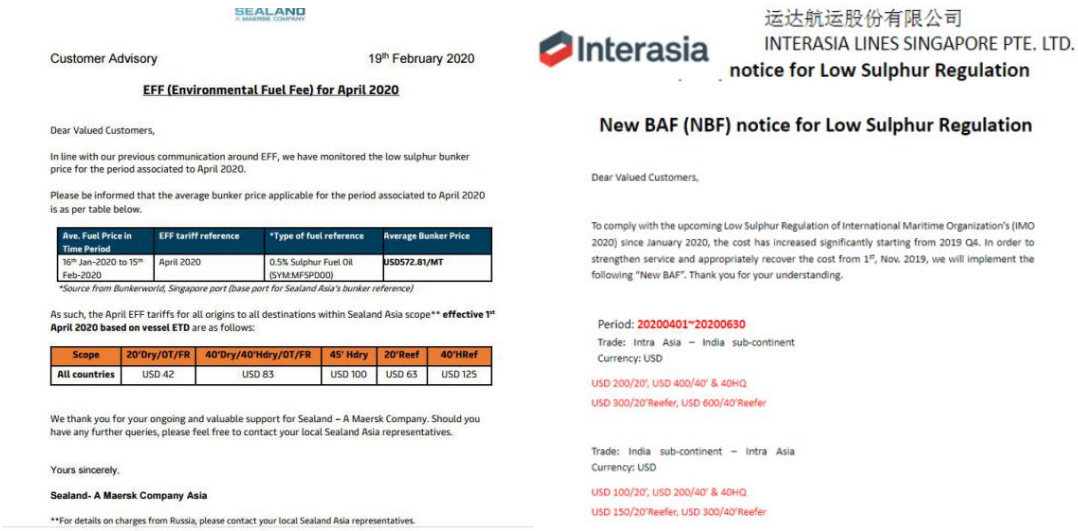
Please be advised that OOCL will increase the FUEL COST RECOVERY (FCR) or LOW SULPHUR ADJUSTMENT (LSA) from all China Ports with effective Feb.1, 2020 for Intra Asia Trade services. The effective date refers to BL on-board date and will be reviewed monthly if the fuel price fluctuation is more than USD25 per ton.

东方海外谨此通知您，我司将从2020年2月1日起上调对中国港口所有亚洲航线出口货物的低硫燃油附加费（FCR 或 LSA），调整后的费用以实际装船日起算，并且会在油价浮动超过25美金每吨时按月调整。

Fuel Cost Recovery (FCR) will be implemented for long-term contracts (validity is more than 3 months) and Low Sulphur Adjustment (LSA) shall apply for spot and shot-term contracts (equal or less than 3 months validity).

FCR:将适用于长期合约（合约有效期超过3个月），LSA适用于短期合约（合约有效期等于或者小于3个月）。

Figure 19. OOCL Low sulphur bunker fee adjustment



SEALAND
A MAERSK COMPANY

Customer Advisory 19th February 2020

EFF (Environmental Fuel Fee) for April 2020

Dear Valued Customers,

In line with our previous communication around EFF, we have monitored the low sulphur bunker price for the period associated to April 2020.

Please be informed that the average bunker price applicable for the period associated to April 2020 is as per table below.

Ave. Fuel Price in Time Period	EFF tariff reference	*Type of fuel reference	Average Bunker Price
16th Jan-2020 to 15th Feb-2020	April 2020	0.5% Sulphur Fuel Oil (SYM:MFSP000)	USD572.81/MT

Source from Bunkerworld, Singapore port (base port for Sealand Asia's bunker reference)

As such, the April EFF tariffs for all origins to all destinations within Sealand Asia scope** **effective 1st April 2020 based on vessel ETD** are as follows:

Scope	20'Dry/OT/FR	40'Dry/40'Hdry/OT/FR	45' Hdry	20'Reef	40'HRef
All countries	USD 42	USD 83	USD 100	USD 63	USD 125

We thank you for your ongoing and valuable support for Sealand – A Maersk Company. Should you have any further queries, please feel free to contact your local Sealand Asia representatives.

Yours sincerely,

Sealand- A Maersk Company Asia

**For details on charges from Russia, please contact your local Sealand Asia representatives.

Interasia 运达航运股份有限公司
INTERASIA LINES SINGAPORE PTE. LTD.

notice for Low Sulphur Regulation

New BAF (NBF) notice for Low Sulphur Regulation

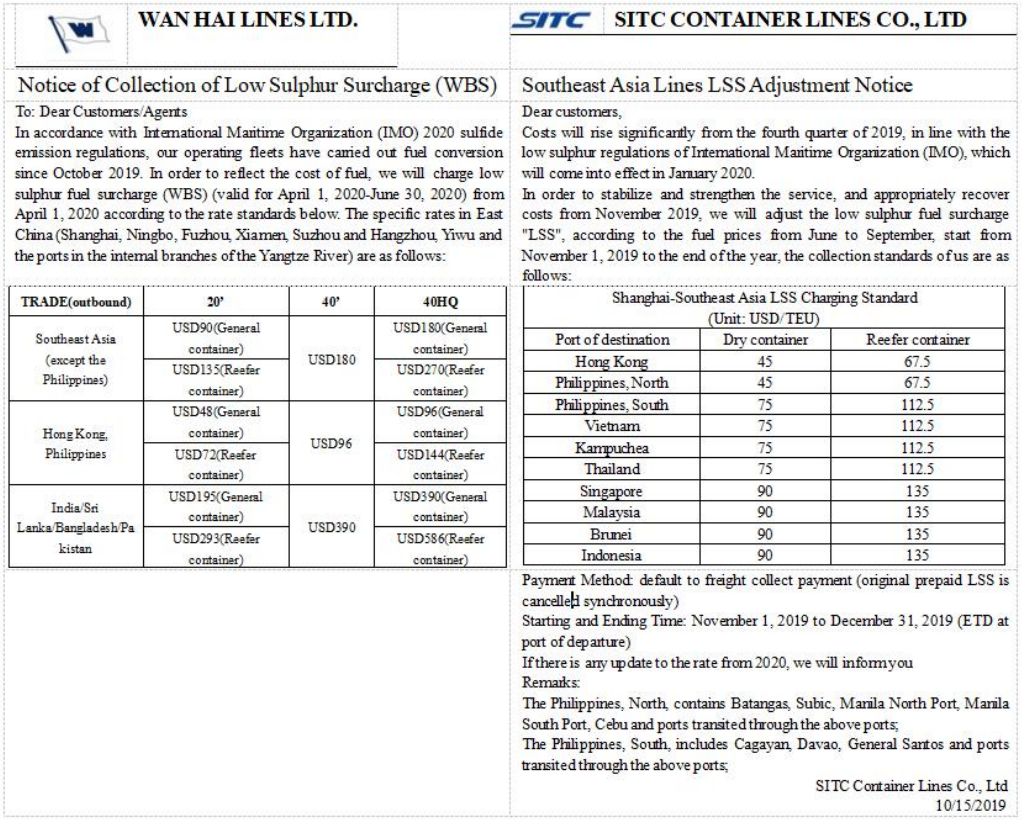
Dear Valued Customers,

To comply with the upcoming Low Sulphur Regulation of International Maritime Organization's (IMO 2020) since January 2020, the cost has increased significantly starting from 2019 Q4. In order to strengthen service and appropriately recover the cost from 1st, Nov. 2019, we will implement the following "New BAF". Thank you for your understanding.

Period: 20200401~20200630
Trade: Intra Asia – India sub-continent
Currency: USD
USD 200/20', USD 400/40' & 40HQ
USD 300/20'Reefer, USD 600/40'Reefer

Trade: India sub-continent – Intra Asia
Currency: USD
USD 100/20', USD 200/40' & 40HQ
USD 150/20'Reefer, USD 300/40'Reefer

Figure 20. Sealand and Interasia Low sulphur bunker fee adjustment



WAN HAI LINES LTD.

Notice of Collection of Low Sulphur Surcharge (WBS)

To: Dear Customers/Agents
In accordance with International Maritime Organization (IMO) 2020 sulfide emission regulations, our operating fleets have carried out fuel conversion since October 2019. In order to reflect the cost of fuel, we will charge low sulphur fuel surcharge (WBS) (valid for April 1, 2020-June 30, 2020) from April 1, 2020 according to the rate standards below. The specific rates in East China (Shanghai, Ningbo, Fuzhou, Xiamen, Suzhou and Hangzhou, Yiwu and the ports in the internal branches of the Yangtze River) are as follows:

TRADE(outbound)	20'	40'	40HQ
Southeast Asia (except the Philippines)	USD90(General container)	USD180	USD180(General container)
	USD135(Reefer container)		USD270(Reefer container)
Hong Kong, Philippines	USD48(General container)	USD96	USD96(General container)
	USD72(Reefer container)		USD144(Reefer container)
India/Sri Lanka/Bangladesh/Pakistan	USD195(General container)	USD390	USD390(General container)
	USD293(Reefer container)		USD586(Reefer container)

SITC CONTAINER LINES CO., LTD

Southeast Asia Lines LSS Adjustment Notice

Dear customers,
Costs will rise significantly from the fourth quarter of 2019, in line with the low sulphur regulations of International Maritime Organization (IMO), which will come into effect in January 2020.
In order to stabilize and strengthen the service, and appropriately recover costs from November 2019, we will adjust the low sulphur fuel surcharge "LSS", according to the fuel prices from June to September, start from November 1, 2019 to the end of the year, the collection standards of us are as follows:

Shanghai-Southeast Asia LSS Charging Standard
(Unit: USD/TEU)

Port of destination	Dry container	Reefer container
Hong Kong	45	67.5
Philippines, North	45	67.5
Philippines, South	75	112.5
Vietnam	75	112.5
Kampuchea	75	112.5
Thailand	75	112.5
Singapore	90	135
Malaysia	90	135
Brunei	90	135
Indonesia	90	135

Payment Method: default to freight collect payment (original prepaid LSS is cancelled synchronously)
Starting and Ending Time: November 1, 2019 to December 31, 2019 (ETD at port of departure)
If there is any update to the rate from 2020, we will inform you
Remarks:
The Philippines, North, contains Batangas, Subic, Manila North Port, Manila South Port, Cebu and ports transited through the above ports;
The Philippines, South, includes Cagayan, Davao, General Santos and ports transited through the above ports;

SITC Container Lines Co., Ltd
10/15/2019

Figure 21. Wanhai and SITC Low sulphur bunker fee adjustment

	Indo-Pakistani line	Middle East	European line	Southeast Asia	Sino-US line	Australian line	Africa
LSS USD/TUE	印巴航线	中东	欧洲线	东南亚	中美航线	澳洲线	非洲
OOCL	163	132	102	84			
YML	111	134	178	92	156	16	
IAL	200			100			
WHL	195			90	20		
ZIM	20			110			
HMM	101	101	124				
SAF	59						12
EVERGREEN			197				
KMTC		210		90			
APL		75					
CMA			90		5		129
ONE					15		
COSCO			50	80	140		

Influenced lines distribution

Table 16. Influenced ship lines distribution

No matter which way is chosen to control sulphur emissions, the changes in shipping costs construction are inevitable. Through the notices on the increase of low sulphur bunker surcharge from several shipping companies in China, it can be seen that all shipping companies from large shipping companies, such as OOCL, to small and medium-sized shipping companies, such as SITC and WAN HAI, have started to raise freight rates, and specifically marked the increase as the Low sulphur bunker surcharge, including INTERASIA LINES SINGAPORE PTE. LTD. From the table 16 showing that also has started to charge the low sulphur bunker surcharge covering hundreds of lines in most parts of the world from African lines to Australian lines as well as European India–Pakistan line. This fact shows that most companies in China are using low-sulfur bunker.

At the same time, the new technology of using LNG for shipping also becomes a new point for shipping industry, but it depends on the development of the technical. Because there are several reasons(Mori, 2012):

(1) The cost of ship reconstruction is high, and the endurance is weak

Although the volume of LNG storage tanks is small, the system is complicated and the layout is difficult. Moreover, the maximum endurance of ships currently bunkered by LNG ship is only 22 days.

(2) The supporting infrastructure is seriously insufficient

At present, the global marine bunker supply system has established a completed supply network, but the global LNG station is still unable to meet the demand. In particular, China's LNG facilities have been developed late, unevenly distributed, and the overall supply is difficult to meet demand. The challenge for shipping companies to shift risk to the supply chain is also growing (Billing, 2020). Furthermore, in the current state of the epidemic, the shutdown of the shipping market have brought new challenges to the shipping industry in China.

Chapter 8. Suggestions

First, at the national level, the Chinese government has started to support the production of low-sulfur oil,such as tax exemption policies and more investment in technology. Traditionally, support from the national level must have the following conditions: First, this technology can quickly and effectively absorb innovations and obtain new production capacity associated with new technologies; second, this

product has huge market potential, and is expected to achieve sustained high-speed growth in this product; third, the correlation coefficient with other industries is large, which can drive the development of related industries. This shows that low-sulfur oil has at least the above conditions, so low-sulfur oil has huge benefits for the entire country's industrial structure under economies of scale. Hence, in the future the Low sulphur bunker is a good choice in China context.

Secondly, at the enterprise level, with the development of Blockchain technology. Some large-scale enterprises with a large number of ships can use Blockchain technology to predict the future price of oil and the difference in high sulphur bunker and Low sulphur bunker. Although it is not very clear to choose a method for SOx control, it is possible to choose a variety of methods in a suitable ratio to control sulfur emissions simultaneously.

Finally, as for small shipping companies in China, it is necessary to analyze their own capital flow, and at the same time through the purchase forecast data with databases such as Clarkson. Through the analysis of internal and external data, the acceptable cost range is determined, and low-sulfur oil is preferred within the range.

In addition, new technologies are emerging one after another. LNG and shore power technologies are also constantly advancing. The advantages and disadvantages of these new technologies are also obvious. When these new technologies are not mature enough, small shipping companies should not try them easily. Large shipping companies in China can appropriately join their own options to diversify risks.

Reference

Arnold, T., & Crack, T. (2004). *Real Option Valuation using NPV*. SSRN Electronic Journal. doi: 10.2139/ssrn.644081.

Arof, A. (2018). *Decision Making Model for Ro-Ro Short Sea Shipping Operations in Archipelagic Southeast Asia.* The Asian Journal Of Shipping And Logistics, 34(1), 33-42. doi: 10.1016/j.ajsl.2018.03.005.

Bhattacharyya, N. (2004). *Why Do Managers Prefer IRR.* SSRN Electronic Journal. doi: 10.2139/ssrn.496482.

Borch, K. (1968). *Economic Equilibrium Under Uncertainty. International Economic Review*, 9(3), 339. doi: 10.2307/2556230.

Billing, E. (2020). *IMO 2020 and the outlook for marine bunkers.* Retrieved 23 May 2020, from https://www.mckinsey.com/~/media/McKinsey/Industries/Oil%20and%20Gas/Our%20Insights/IMO%202020%20and%20the%20outlook%20for%20marine%20bunkers/IMO-2020-and-the-outlook-for-marine-bunkers.ashx.

Balasubramanian, S. (2009). *BPO: A Swot Analysis. SSRN Electronic Journal.* doi: 10.2139/ssrn.1457838.

Bochet, O., İlkılıç, R., Moulin, H., & Sethuraman, J. (2012). *Balancing supply and demand under bilateral constraints. Theoretical Economics*, 7(3), 395-423. doi: 10.3982/te893.

Bolbot, V., Theotokatos, G., Boulougouris, E., Psarros, G., & Hamann, R. (2020). *A Novel Method for Safety Analysis of Cyber-Physical Systems—Application to a Ship Exhaust Gas Scrubber System. Safety,* 6(2), 26. doi: 10.3390/safety6020026.

Chatterjee, D., & Chatterjee, A. (2010). *Binary Logistic Regression Using Survival Analysis.* SSRN Electronic Journal. doi: 10.2139/ssrn.1672759.

Chauhan, P. (2017). *Maritime Affairs: Winter Edition 2017. Maritime Affairs: Journal Of The National Maritime Foundation Of India*, 13(2), v-vii. doi: 10.1080/09733159.2017.1415739.

Chen, L., Yip, T., & Mou, J. (2018). *Provision of Emission Control Area and the impact on shipping route choice and ship emissions.* Transportation Research Part D: Transport And Environment, 58, 280-291. doi: 10.1016/j.trd.2017.07.003.

China Government Website. (2020). *Notice from the Ministry of Transport on Printing and Distributing the Implementation Plan of Air Pollutant Emission Control Areas for Ships_Departmental Affairs* Retrieved 24 June 2020, from http://www.gov.cn/xinwen/2018- 12/20/content_5350451.htm.

Charter parties, (2020). *What are the differences between voyage and time charter parties?* Retrieved 21 May 2020, from https://www.advancedontrade.com/2015/06/what-are-differences-between-voyage-and-time-charter-parties.html.

Creswell, J. W. (2012). *Educational research : planning, conducting, and evaluating quantitative and qualitative research* (4th ed. ed.). Boston: Boston : Pearson.

Djadjev, I. (2015). *How to Comply with Marpol 73/78*. SSRN Electronic Journal. doi: 10.2139/ssrn.2617379.

Ezeoke, C. (2017). *The ASEAN Single Shipping Market: Towards a Regional Cabotage Regime.* Journal Of East Asia And International Law, 10(1), 5-5. doi: 10.14330/jeail.2017.10.1.05.

FUNDAMENTALS OF SURVEY MEASUREMENT AND ANALYSIS.

(1984). Survey Review, 27(212), 287-287. doi: 10.1179/sre.1984.27.212.287.

Han, C. (2010). *Strategies to Reduce Air Pollution in Shipping Industry*. The Asian Journal Of Shipping And Logistics, 26(1), 7-29. doi: 10.1016/s2092-5212(10)80009-4.

Hunter, L. (2002). *Interview: A pattern language for communication: An interview with Robert E. Horn. Document Design*, 3(2), 135-139. doi: 10.1075/dd.3.2.04hun.

IMO News, I. (2020). China announces new Emission Control Areas (ECAs). Retrieved 30 June 2020, from https://ibia.net/china-announce-new-emission-control-areas-ecas/.

IMO (2020). MARPOL Retrieved 21 May 2020, from http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx.

Jongsoon Koo. (2010). *Introduction of a shipping insurance as a stabilizer of shipping industry. Journal Of Shipping And Logistics*, 26(1), 171-189. doi: 10.37059/tjosal.2010.26.1.171.

Kilic, S. (2015). *Binary logistic regression analysis. Journal Of Mood Disorders*, 5(4), 191. doi: 10.5455/jmood.20151202122141.

Koilo, V. (2019). Sustainability issues in maritime transport and main challenges of the shipping industry. Environmental Economics, 10(1), 48-65. doi: 10.21511/ee.10(1).2019.04

Kang, H., Wang, G., Bang, H., & Woo, S. (2015). *Economic performance and corporate financial management of shipping firms.* Maritime Economics & Logistics. doi: 10.1057/mel.2015.8.

Lewellen, J., & Lewellen, K. (2010). *Investment and Cash-flow.* SSRN Electronic

Journal. doi: 10.2139/ssrn.1570640.

Li Xiaoyun, (2014). *Mathematical Models for Chinese Oil Product Price Forecast*, SHANXI SCIENCE AND TECHNOLOGY, 1004-6429 (2014) 05-0041-04, School of Environment and Resources, Jilin University, Changchun, Jilin, 130012.

MARPOL 73/78.(2020). *The International Convention for the Prevention of Pollution of Ships,* 1973. Retrieved 6 June 2020, from http://www.vliz.be/docs/Zeecijfers/MARPOL.pdf.

Moon. J . (1986). *MARPOL 73/78. Marine Pollution Bulletin*, 17(6), 237-238. doi: 10.1016/0025-326x(86)90040-8.

Menachof, D., & Dicer, G. (2001). *Risk management methods for the liner shipping industry: the case of the Bunker Adjustment Factor.* Maritime Policy & Management, 28(2), 141-155. doi: 10.1080/03088830118491.

Mori, T. (2012). *Use of LNG fuel for Shipping. Marine Engineering*, 47(6), 796-800. doi: 10.5988/jime.47.796

Marketing Research. (1958). *Journal Of Marketing,* 22(3), 316. doi: 10.2307/1247126.

Organisation, E. (2020). *European Maritime Law Organisation.* Retrieved 24 June 2020, from https://www.emlo.org/.

QUANTITATIVE AND QUALITATIVE METHOD IN SOCIOLOGICAL RESEARCH. (1942). *Nature*, 149(3784), 516-518. doi: 10.1038/149516a0.

Sharma, U. (2009). *Qualitative Research in Business & Management20091Michael D. Myers. Qualitative Research in Business & Management.* London: Sage 2009. Qualitative Research In Accounting & Management, 6(4), 292-296. doi: 10.1108/11766090910989536.

Shuo ma.(2020).*Using Economic Measures for Global Control of Air Pollution from Ships*.Retrieved 8 March 2020, from https://lawexplores.com/using-economic-measures-for-global-control-of-air-pollution-from-ships/.

Svindland, M. (2018). *The environmental effects of emission control area regulations on short sea shipping in Northern Europe*: The case of container feeder vessels. Transportation Research Part D: Transport And Environment, 61, 423-430. doi: 10.1016/j.trd.2016.11.008.

Sethi, S. (2020). *A Guide To Scrubber System On Ship.* Retrieved 24 June 2020, from https://www.marineinsight.com/tech/scrubber-system-on-ship/.

Ship. Charter-Party. (1911). The Virginia Law Register, 17(1), 88. doi: 10.2307/1102599.

SCHLIEPHAKE, E., & KIRSTEIN, R. (2013). *Strategic Effects of Regulatory Capital Requirements in Imperfect Banking Competition. Journal Of Money, Credit And Banking,* 45(4), 675-700. doi: 10.1111/jmcb.12020.

SCHINAS, O. (2016). HSBA HANDBOOK ON SHIP FINANCE. [Place of publication not identified]: SPRINGER-VERLAG BERLIN AN.

Walker, D., & Smith, T. (2016). *JMASM36: Nine Pseudo R^2 Indices for Binary Logistic Regression Models (SPSS)*. Journal Of Modern Applied Statistical Methods, 15(1), 848-854. doi: 10.22237/jmasm/1462077720.

Wang, Z., Zhang, H., & Gan, X. (2019). *Research on Solution of Ship Low sulphur fuel oil based on IMO Sulphur Limitation Regulation. IOP Conference Series: Earth And Environmental Science,* 401, 012012. doi: 10.1088/1755-1315/401/1/012012.

Yan Hecheng, Qiu Xiaoxin, & Hu Hanqiang. (2018). *Comparison of global ship*

sulfur emission control and recommendations for China's sulfur limit program. World Shipping, 041(012), 16-22.

Zhaozhe. (2019).D*oes the Government Drive Chinese Banking Performance* – An Analysis of the Chinese Banking System. Journal Of Applied Business And Economics, 21(7). doi: 10.33423/jabe.v21i7.2550.

APPENDIX:I. The Information Letter of Interview

Thank you for taking time to accept my interview. my interview is a Master thesis project to obtain some information about the reasons or factors of how to choose the solution to control SOx emission, and this interview with you is part of the research (The whole research includes a survey and a interview). During the interview processing, we will record all the interview content, and some information will be recorded by hand writing paper. If the interview involves people, places, or organizations that you do not want to mention, you can use a symbol to replace it. The in-depth qualitative interview lasts for about 60 minutes. It could be longer or shorter. Besides, respondents can withdraw from the project at any time after the interview if you have any discomfort.

If you have any questions concerning the project, please do not hesitate to contact me. The study has been confirmed to the Data Protection Official for Research, NSD - Norwegian Centre for Research Data.

_____

(Signed by participant, date)

Contact information：
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APPENDIX:II.The Interview Record Form

No.		Time		Location	
Interviewee		Position		Company of the Interviewee	
Email		Questioner		Note-keeper	

Interview opening:

Hello, I am a master student of International Maritime University (ITL). Since the IMO is about to implement MARPOL convention worldwide to limit sulfur emissions from ships and reduce environmental pollution from ships. I am currently conducting an interview on whether shipping companies choose to install desulfurization scrubber to reduce sulfur emissions or use low-sulfur oil to reduce sulfur emissions. So if I may, take you a few precious minutes to complete this interview. This interview is mainly conducted in the form of Q & A. The interview content will be kept strictly confidential! To ensure the effectiveness of the interview, please answer each question truthfully. The interview will take approximately 15-20 minutes to complete. If there is no doubt, let's get started!

Contents:

Q: Please briefly describe the scope and content of your work.

A：

Q: Are your company still using scrubber for control SOx emission and your company also using Low sulphur bunker or not?

A:

Q: Which kind scale of your company?

A:

Q: Is your company still using scrubber to control SOx emissions and is your company also using Low sulphur bunker?

A:

Q: What is the disadvantage of using scrubber that your company cannot accept?

A：

Q: What is the disadvantage of using Low sulphur bunker that your company cannot accept?

A:

Q: Will oil prices affect your company's decision making?

A：

Q: What do you think is the first thing to consider when choosing to give up using scrubber or use low-sulfur oil?

A:

Q: Why your company consider this factor in the first place?

A：

Q: Is there any new policy afflicting your company's make choice?

A:

Steps of Interview: (1) Observe the interview site; (2) Draw subjects; (3) Start the interview and record (4) Reflect and evaluate the interview

Privacy statement:

1. This survey does not involve any personal privacy and business confidential information.

2. All survey related information will be encrypted and saved in the computer and destroyed after the study.

APPENDIX:III. The Information Letter of Survey

Thank you for taking time to accept my survey. My survey is a Master thesis project to obtain some information about how shipping companies choose their way to control SOx emission, and this survey with you is part of the research (The whole research includes a survey and a interview). In order to work on the project of how the IMO MARPOL Convention affects shipping companies' choices to reduce sulfur pollution emissions. The questionnaire should be completed by people who are aged over 18 or adults. Please read each question carefully and tick a box to indicate your answer. In most cases you will only have to tick one box but please read the questions carefully as sometimes you will need to tick more than one box. Once you have finished, please take a minute to check whether you have answered all the questions that you should have answered. Once you have completed the questionnaire, please return by Email or We-chat or Facebook by 1st May 2020. If you have any queries about the questionnaire, please do not hesitate to contact me. Besides, you can withdraw from the project at any time if you are uncomfortable. The study has been confirmed to the Data Protection Official for Research, NSD - Norwegian Centre for Research Data.

Contact information：
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(P.O. Box500, 20124, Malmö, Sweden)
Email：1263290364@qq.com

APPENDIX:IV. The Survey Questionnaire

Dear Sir and Madam; Hello! I am a Master student from World Maritime University. In order to work on the project of how the IMO MARPOL Convention affects shipping companies' choices to reduce sulfur pollution emissions, and give advice for shipping companies to choose a more economical method, especially the information get form this survey,your suggestions will be highly valuable information to my future research. Thank you very much for taking time to fill out this questionnaire!
Question 1. How long have you been working in this position? ( )
Question 2. How many ships are there in your company? ( )
Question 3. How many Desulfurization scrubbers are installed on ships that belong to your company? ( )
Question 4. The cost of scrubber is a huge expense for your company ? ( ) A. Not at all B. Acceptable C. Expensive D. Can not afford
Question 5. How many routs your company need to sailing? ( ) A. X＜10 B. 10≤X＜20 C. 20≤X＜30 D. 30≤X＜50 E. 50≤X

Question 6.Are there enough companies to provide desulfurization tower installation technology for your company? ( )

A. Not at all

B. Hard to find supplies

C. Few supplies

D. Able to meet demand

E. A lot supplies

Question 7.Are there enough companies to provide Low sulphur bunker for your company? ( )

A. A lot supplies

B. Able to meet demand

C. Few supplies

D. Hard to find supplies

E. Not at all

Question 8. How many staff are there in your company? X=Number of staff ( )

A. X＜20

B. 20≤X＜100

C. 100≤X＜300

D. 300≤X＜1000

E. 1000≤X

Question 9. Which factor is the first consideration in choosing a solution to reduce sulfur emissions in your company ? ( )

A.Low sulphur bunker supply

B.Bunker price changing

C.Technology risk

D.New technology

E. Investment cost

F. Company scale

Question10. Which plan to control sulphur emission is CREW prefer implementation? ( )

1.- Installation of desulfurization tower

0. -Use low-sulfur bunker

Question 11. Are your company still using scrubber to deal with the implementation of MARPOL convention?

( )

A.- Installation of Desulfurization tower

B. -Use low-sulfur bunker

Question 12. Bunker price in your company plays a decisive role ? ( )

A. Yes

B. No

Privacy statement:

1. This survey does not involve any personal privacy and business confidential information.

2. All survey-related information will be encrypted and saved in the computer and destroyed after the study.

APPENDIX:V. The Data Collect from Survey

ID	Number of ship	Number of scrubber	Staff	Working time	LSFO suppliers	Scrubber Suppliers	Scrubber price	Number of ship routs	Crew prefer	The company still using Scrubber	Company using low sulphur bunker	Fuel price plays a decisive role
ID	ID0	X1	X2	X3	X4	X5	X6	X7	X8	Y		
1	1288	37	5	5	4	5	1	5	1	1	0	1
2	17	0	1	15	5	3	2	1	0	0	0	0
3	877	10	4	2	4	5	1	2	0	1	0	0
4	35	6	2	3	4	4	1	1	0	0	0	0
5	24	2	2	17	3	4	1	1	0	0	0	0
6	55	7	3	1	4	4	1	2	1	1	0	0
7	40	0	3	16	5	3	4	1	0	0	0	0
8	35	3	3	6	5	3	2	1	1	1	0	1
9	17	0	2	7	4	3	2	1	0	0	0	0
10	1288	37	5	3	4	5	1	5	1	1	0	1
11	26	0	2	32	5	4	1	1	0	0	0	0
12	61	1	2	28	3	5	2	2	0	0	0	0
13	16	0	1	22	4	3	2	1	0	0	0	0
14	24	2	2	17	5	4	1	1	1	1	0	1
15	40	0	3	4	4	3	1	1	0	0	0	0
16	25	4	2	5	5	4	1	1	0	0	0	0
17	24	2	2	3	4	4	2	1	0	0	0	0
18	40	0	3	37	3	3	1	1	0	0	0	0
19	26	0	2	23	4	4	2	1	0	0	0	0
20	40	1	3	14	5	3	1	1	1	1	0	0
21	24	2	2	17	4	4	1	1	0	0	0	0
22	28	0	2	18	5	4	1	1	0	0	0	0
23	40	1	3	14	4	3	2	1	0	0	0	0
24	35	3	3	13	4	3	1	1	0	0	0	0
25	611	38	5	3	3	5	3	6	1	1	0	0
26	17	0	2	3	4	3	2	1	0	0	0	0
27	26	0	2	6	4	4	3	1	1	1	0	1
28	14	0	1	8	5	5	2	1	1	1	0	0
29	22	0	2	10	4	4	2	1	1	1	0	0
30	611	38	5	1	4	5	2	6	1	1	0	0
31	24	0	2	6	3	4	3	1	0	0	0	0
32	31	4	3	10	4	4	1	1	0	0	0	0
33	16	0	1	14	4	3	1	1	0	0	0	0
34	1288	37	5	30	5	5	1	5	1	1	0	1
35	1288	37	5	1	2	5	1	5	1	1	0	0
36	18	0	2	11	4	2	4	1	1	1	0	1
37	14	0	1	18	3	5	2	1	0	0	0	0
38	611	38	5	15	5	5	3	6	1	1	0	1
39	35	0	3	12	4	3	1	1	0	0	0	0
40	22	0	2	10	5	4	4	1	1	1	0	1
41	85	6	3	24	5	4	1	1	1	1	0	1
42	24	2	2	13	4	4	2	1	0	0	0	0
43	28	0	2	15	3	4	1	1	0	0	0	0
44	35	3	3	6	4	3	3	1	1	1	0	1
45	17	0	2	6	5	3	2	1	0	0	0	0
46	31	4	3	5	4	4	1	1	0	0	0	0
47	1288	37	5	5	4	5	2	5	1	1	0	1
48	877	10	5	9	4	5	1	6	1	1	0	1
49	611	38	5	7	5	5	3	5	1	1	0	0
50	109	9	4	15	4	3	1	1	0	0	0	0
51	61	1	2	28	4	5	2	2	1	1	0	1
52	877	10	5	5	5	5	1	1	0	1	0	0
53	611	38	5	3	2	5	1	1	0	0	0	0
54	31	4	3	3	3	4	2	1	0	0	0	0
55	35	3	3	4	5	3	1	1	1	1	0	1
56	1288	37	5	4	4	5	1	5	1	1	0	1
57	877	10	5	6	5	5	2	6	1	1	0	0
58	611	38	5	6	4	5	3	6	1	1	0	1
59	109	9	4	22	4	3	1	4	1	1	0	1
60	61	1	2	21	3	5	2	2	0	0	0	0
61	109	9	4	29	4	3	1	3	0	0	0	0
62	61	1	2	20	4	5	1	2	0	0	0	0
63	1288	37	5	12	5	5	2	5	1	1	0	1
64	61	1	2	28	4	5	1	2	0	0	0	0
65	28	0	2	33	4	4	2	1	1	1	0	1
66	31	4	3	5	4	4	1	1	0	0	0	0
67	16	0	1	28	4	3	1	1	0	0	0	0
68	109	9	4	8	3	3	2	1	0	0	0	0
69	1288	37	5	5	4	5	2	5	1	1	0	1
70	877	10	5	9	4	5	1	6	1	1	0	0

71	611	38	5	3	5	5	3	6	0	1	0	0
72	109	9	4	13	2	3	1	4	0	0	0	0
73	26	0	2	23	4	4	2	1	0	0	0	0
74	61	1	2	8	4	5	1	2	0	0	0	0
75	1288	37	5	13	4	5	2	5	1	1	0	1
76	31	4	3	23	3	4	1	1	0	0	0	0
77	16	0	1	28	5	3	1	1	0	0	0	0
78	877	10	5	8	4	5	2	6	1	1	0	1
79	611	38	5	7	4	5	1	6	0	1	0	0
80	109	9	4	14	3	3	1	4	0	0	0	0
81	26	0	2	16	5	4	2	1	1	1	0	1
82	61	1	2	28	4	5	2	1	1	1	0	1
83	109	9	4	1	3	3	2	4	1	1	0	1
84	85	6	3	15	4	4	1	3	0	1	0	0
85	40	0	3	7	4	3	2	1	0	1	0	0
86	25	4	2	7	3	4	1	1	1	0	0	1
87	14	0	1	9	4	5	2	1	1	0	0	1
88	85	6	3	2	3	4	2	1	0	0	0	0
89	24	2	2	2	5	4	1	1	0	1	0	0
90	85	6	3	2	4	4	4	3	0	1	0	0
91	24	1	2	2	4	4	1	1	0	0	0	0
92	17	0	2	3	3	3	4	1	0	0	0	0
93	28	0	2	33	4	4	2	1	0	0	0	0
94	55	7	3	4	4	4	1	3	0	0	0	0
95	35	3	3	4	3	3	2	1	0	0	0	0
96	14	0	1	9	4	5	1	1	1	0	0	1
97	17	0	2	9	5	3	2	1	0	0	0	0
98	55	7	3	2	4	4	1	3	0	0	0	0
99	26	0	2	23	3	4	4	1	0	0	0	0
100	26	0	2	32	5	4	1	1	0	0	0	0
101	61	1	2	28	3	5	2	2	0	0	0	0
102	16	0	1	22	4	3	2	1	0	0	0	0
103	24	2	2	17	5	4	1	1	1	0	0	1
104	40	0	3	4	4	3	1	1	1	0	0	1
105	25	4	2	5	5	4	1	1	0	1	0	0
106	24	2	2	3	4	4	2	1	0	0	0	0
107	40	0	3	37	3	3	1	1	0	0	0	0
108	26	0	2	23	4	4	2	1	0	0	0	0
109	40	1	3	14	5	3	1	1	1	1	0	1
110	24	2	2	17	4	4	1	1	0	0	0	0
111	28	0	2	18	5	4	1	1	1	1	0	1
112	40	1	3	14	4	3	2	1	1	1	0	1
113	877	10	5	6	5	5	2	6	0	1	0	0
114	10	0	1	9	4	5	2	1	0	0	0	0
115	22	0	2	10	4	4	2	1	1	1	0	1
116	109	9	4	15	4	3	1	1	0	0	0	0
117	10	0	1	9	4	5	2	1	1	1	0	1
118	40	0	3	37	3	3	1	1	0	0	0	0
119	1288	37	5	5	4	5	2	5	1	1	0	1
120	22	0	2	10	4	4	2	1	0	0	0	0
121	17	0	1	15	5	3	2	1	1	1	0	1
122	109	9	4	15	4	3	1	1	0	0	0	0
123	877	10	5	6	5	5	2	6	1	1	0	1
124	12	0	1	15	5	3	2	1	0	0	0	0
125	10	0	1	9	4	5	2	1	0	0	0	0
126	611	38	5	7	4	5	1	6	1	1	0	1
127	13	0	1	15	5	3	2	1	0	0	0	0
128	17	0	1	15	5	3	2	1	1	1	0	1
129	17	0	1	15	5	3	2	1	0	1	0	0
130	1288	37	5	5	4	5	2	5	1	1	0	1
131	40	0	3	37	3	3	1	1	0	0	0	0
132	22	0	2	10	4	4	2	1	1	1	0	1
133	18	0	2	11	4	2	4	1	0	1	0	0
134	14	0	1	18	3	5	2	1	0	0	0	0
135	40	0	3	37	3	3	1	1	0	0	0	0
136	22	0	2	10	4	4	2	1	0	0	0	0
137	877	10	5	6	5	5	2	6	0	1	0	0
138	22	0	2	10	4	4	2	1	1	1	0	1
139	24	2	2	3	4	4	2	1	1	1	0	1
140	109	9	4	15	4	3	1	1	0	0	0	0
141	10	0	1	9	4	5	2	1	0	0	0	0
142	611	38	5	7	4	5	1	6	0	1	0	0
143	1288	37	5	5	4	5	2	5	1	1	0	0

APPENDIX:VI. Japan Shipping Bunker Price from Winter Database

Date	0.5% Low sulphur bunker Japan	High sulphur bunker Japan	Difference of prices
2019-07-01	563.00	437.26	125.74
2019-07-02	558.00	419.37	138.63
2019-07-03	542.00	414.76	127.24
2019-07-04	555.50	427.60	127.9
2019-07-05	560.50	428.90	131.6
2019-07-08	565.50	435.21	130.29
2019-07-09	560.50	437.25	123.25
2019-07-10	565.50	455.80	109.7
2019-07-11	592.50	491.71	100.79
2019-07-12	574.50	470.68	103.82
2019-07-15	554.50	446.99	107.51
2019-07-16	540.50	435.76	104.74
2019-07-17	542.50	443.54	98.96
2019-07-18	536.50	441.81	94.69
2019-07-19	540.50	445.43	95.07
2019-07-22	543.50	446.78	96.72
2019-07-23	532.50	429.55	102.95
2019-07-24	535.50	430.46	105.04
2019-07-25	543.50	437.36	106.14
2019-07-26	545.50	441.19	104.31
2019-07-29	544.50	432.56	111.94
2019-07-30	550.50	435.93	114.57
2019-07-31	567.50	452.67	114.83
2019-08-01	562.50	445.01	117.49
2019-08-02	536.50	406.90	129.6
2019-08-05	532.50	398.31	134.19
2019-08-06	524.50	384.88	139.62
2019-08-07	519.50	356.43	163.07
2019-08-08	504.50	335.65	168.85
2019-08-13	499.50	329.14	170.36
2019-08-14	515.50	346.18	169.32
2019-08-15	497.50	324.72	172.78
2019-08-16	505.50	335.90	169.6
2019-08-19	512.50	342.69	169.81
2019-08-20	514.00	342.06	171.94
2019-08-21	517.00	346.35	170.65
2019-08-22	529.50	361.71	167.79
2019-08-23	535.50	360.76	174.74
2019-08-26	538.50	363.50	175
2019-08-27	543.50	373.09	170.41
2019-08-28	553.50	390.96	162.54
2019-08-29	543.50	371.44	172.06
2019-08-30	553.50	376.85	176.65
2019-09-02	528.50	348.95	179.55
2019-09-03	523.50	342.78	180.72
2019-09-04	535.50	351.46	184.04
2019-09-05	550.50	355.66	194.84
2019-09-06	555.50	388.18	167.32
2019-09-09	545.50	378.13	167.37
2019-09-10	555.50	391.97	163.53
2019-09-11	545.50	372.68	172.82
2019-09-12	550.50	401.61	148.89
2019-09-13	535.50	431.63	103.87
2019-09-16	560.50	459.38	101.12
2019-09-17	595.50	531.90	63.6
2019-09-18	570.50	476.51	93.99
2019-09-19	550.50	441.77	108.73
2019-09-20	570.50	471.93	98.57
2019-09-23	560.50	431.96	128.54
2019-09-24	555.50	401.56	153.94
2019-09-25	560.50	421.03	139.47
2019-09-26	591.75	427.60	164.15
2019-09-27	584.75	409.48	175.27
2019-10-04		329.07	-329.07
2019-10-07	574.75	303.10	271.65
2019-10-08	572.75	291.13	281.62
2019-10-09	572.75	293.89	278.86

2019-10-10	587.75	314.40	273.35
2019-10-11	607.75	341.91	265.84
2019-10-14	590.50	320.02	270.48
2019-10-15	594.75	315.59	279.16
2019-10-16	594.75	317.48	277.27
2019-10-17	600.50	324.03	276.47
2019-10-18	605.50	325.47	280.03
2019-10-21	604.25	321.60	282.65
2019-10-22	595.50	317.54	277.96
2019-10-23	594.25	322.33	271.92
2019-10-24	607.25	334.87	272.38
2019-10-25	601.75	328.64	273.11
2019-10-29	591.75	319.56	272.19
2019-10-30	597.75	320.08	277.67
2019-10-31	591.75	324.39	267.36
2019-11-01	587.50	318.81	268.69
2019-11-04	592.50	325.96	266.54
2019-11-05	590.75	317.78	272.97
2019-11-06	598.25	311.37	286.88
2019-11-07	592.25	293.87	298.38
2019-11-08	591.25	276.88	314.37
2019-11-11	586.25	261.80	324.45
2019-11-12	588.25	255.71	332.54
2019-11-13	582.25	234.19	348.06
2019-11-14	576.25	225.81	350.44
2019-11-15	585.25	241.20	344.05
2019-11-18	605.25	255.34	349.91
2019-11-19	589.25	242.72	346.53
2019-11-20	579.25	240.53	338.72
2019-11-21	590.25	252.42	337.83
2019-11-22	599.25	258.89	340.36
2019-11-25	591.25	257.80	333.45
2019-11-26	593.75	254.48	339.27
2019-11-27	600.50	259.13	341.37
2019-11-28	600.50	257.17	343.33
2019-11-29	590.50	246.36	344.14
2019-12-02	585.50	233.60	351.9
2019-12-03	580.50	244.70	335.8
2019-12-04	570.50	253.27	317.23
2019-12-05	572.25	260.53	311.72
2019-12-06	581.75	270.58	311.17
2019-12-09	592.00	279.00	313
2019-12-10		283.14	-283.14
2019-12-11	580.50	300.12	280.38
2019-12-12	579.25	297.18	282.07
2019-12-13	589.50	297.83	291.67
2019-12-16	601.50	297.85	303.65
2019-12-17	616.75	298.26	318.49
2019-12-18	625.50	307.82	317.68
2019-12-19	620.50	312.33	308.17
2019-12-20	630.50	340.07	290.43
2019-12-23	615.50	328.01	287.49
2019-12-24	615.50	321.20	294.3
2019-12-26	605.50	315.13	290.37
2019-12-27	630.25	332.32	297.93
2019-12-30	635.50	333.51	301.99
2019-12-31	631.50	328.60	302.9
2020-01-02	638.50	337.80	300.7
2020-01-03	658.50	358.26	300.24
2020-01-06	665.50	380.87	284.63
2020-01-07	650.50	377.42	273.08
2020-01-08	640.50	392.03	248.47
2020-01-09	620.50	383.09	237.41
2020-01-10	630.50	371.91	258.59
2020-01-13	660.50	373.93	286.57
2020-01-14	650.50	357.33	293.17
2020-01-15	646.50	346.69	299.81
2020-01-16	650.50	345.53	304.97
2020-01-17	655.50	341.90	313.6
2020-01-20	665.50	350.55	314.95
2020-01-21	655.50	341.91	313.59
2020-01-22	655.50	338.66	316.84
2020-01-23	635.50	347.29	288.21
2020-01-24	635.50	349.17	286.33
2020-01-28	600.50	313.82	286.68
2020-01-29	615.50	325.49	290.01
2020-01-30	600.50	318.22	282.28
2020-01-31	595.50	310.06	285.44
2020-02-03	570.50	288.10	282.4
2020-02-04	555.50	302.86	252.64

2020-02-05	545.50	303.36	242.14
2020-02-06	560.50	303.54	256.96
2020-02-07	550.50	295.40	255.1
2020-02-10	530.50	297.71	232.79
2020-02-11	525.50	306.38	219.12
2020-02-12	525.50	310.17	215.33
2020-02-13	520.50	316.98	203.52
2020-02-14	527.75	319.36	208.39
2020-02-17	525.50	323.43	202.07
2020-02-18	522.50	315.22	207.28
2020-02-19	520.50	323.80	196.7
2020-02-20	520.50	327.21	193.29
2020-02-21	514.50	329.79	184.71
2020-02-24	490.50	317.65	172.85
2020-02-25	490.50	323.43	167.07
2020-02-26	470.50	308.40	162.1
2020-02-27	440.50	295.65	144.85
2020-02-28	435.50	293.04	142.46
2020-03-02	440.50	304.95	135.55
2020-03-03	435.50	288.66	146.84
2020-03-04	430.50	280.24	150.26
2020-03-05	420.50	287.11	133.39
2020-03-06	395.50	271.97	123.53
2020-03-09	324.50	201.01	123.49
2020-03-10	334.00	212.67	121.33
2020-03-11	335.50	207.62	127.88
2020-03-12	326.75	193.45	133.3
2020-03-13	343.25	214.73	128.52
2020-03-16	317.75	205.15	112.6
2020-03-17	319.75	205.98	113.77
2020-03-18	300.25	194.76	105.49
2020-03-19	286.75	182.90	103.85
2020-03-20	305.50	210.73	94.77
2020-03-23	291.75	190.87	100.88
2020-03-24	307.75	189.17	118.58
2020-03-25	316.25	186.59	129.66
2020-03-26	303.50	189.01	114.49
2020-03-27	295.50	186.80	108.7
2020-03-30	285.50	179.70	105.8
2020-03-31	279.50	184.17	95.33
2020-04-01	265.50	178.51	86.99
2020-04-02	255.50	187.19	68.31
2020-04-03	255.50	191.17	64.33
2020-04-06	265.50	207.11	58.39
2020-04-07	270.50	212.51	57.99
2020-04-08	265.50	211.22	54.28
2020-04-09	260.50	203.92	56.58
2020-04-13	240.50	193.28	47.22
2020-04-14	250.50	190.37	60.13
2020-04-15	230.50	167.82	62.68
2020-04-16	235.50	166.30	69.2
2020-04-17	240.50	166.61	73.89
2020-04-20	240.50	158.46	82.04
2020-04-21	223.25	143.49	79.76
2020-04-22	201.75	127.83	73.92
2020-04-23	222.75	143.55	79.2
2020-04-24	226.75	141.65	85.1
2020-04-27	219.25	145.61	73.64
2020-04-28	203.75	139.47	64.28
2020-04-29	200.50	134.55	65.95
2020-04-30	227.25		227.25
2020-05-04	215.50	138.64	76.86
2020-05-05	235.50	161.47	74.03
2020-05-06	245.50	175.18	70.32
2020-05-08	230.50	166.03	64.47
2020-05-11	242.25	164.74	77.51
2020-05-12	237.50	159.77	77.73
2020-05-13	230.25	165.91	64.34
2020-05-14	233.25	173.99	59.26
2020-05-15	235.50	187.34	48.16
2020-05-18	245.50	196.93	48.57
2020-05-19	251.50	217.81	33.69
2020-05-20	245.50	213.81	31.69
2020-05-21	249.50	219.89	29.61
2020-05-22	233.50	206.17	27.33
2020-05-26	267.75	215.93	51.82
2020-05-27	276.25	201.17	75.08
2020-05-28	261.00	198.13	62.87
2020-05-29	266.50	204.40	62.1

APPENDIX:VII. Shanghai Shipping Bunker Price from Clarkson Database

Date	Shanghai 0.5%Low s	Shanghai High S	Difference of prices
2020-04-24	4,800.00	3,425.00	1,375.00
2020-04-26	4,900.00		
2020-04-27	4,950.00	3,425.00	1,525.00
2020-04-28	4,950.00	3,425.00	1,525.00
2020-04-29	4,950.00	3,425.00	1,525.00
2020-04-30	4,950.00	3,425.00	1,525.00
2020-05-01	4,950.00	3,425.00	1,525.00
2020-05-04	4,950.00	3,425.00	1,525.00
2020-05-05	4,950.00	3,425.00	1,525.00
2020-05-06	4,950.00	3,425.00	1,525.00
2020-05-07	4,950.00	3,425.00	1,525.00
2020-05-08	4,950.00	3,425.00	1,525.00
2020-05-09	4,950.00		
2020-05-11	4,950.00	3,425.00	1,525.00
2020-05-12	4,950.00	3,425.00	1,525.00
2020-05-13	4,950.00	3,425.00	1,525.00
2020-05-14	4,950.00	3,425.00	1,525.00
2020-05-15	4,950.00	3,425.00	1,525.00
2020-05-18	4,950.00	3,425.00	1,525.00
2020-05-19	4,950.00	3,425.00	1,525.00
2020-05-20	4,950.00	3,425.00	1,525.00
2020-05-21	4,800.00	3,425.00	1,375.00
2020-05-22	4,800.00	3,425.00	1,375.00
2020-05-25	4,800.00	3,425.00	1,375.00
2020-05-26	4,800.00	3,425.00	1,375.00
2020-05-27	4,800.00	3,425.00	1,375.00
2020-05-28	4,800.00	3,425.00	1,375.00
2020-05-29	4,800.00	3,425.00	1,375.00
2020-05-31	4,800.00		
2020-06-01	4,800.00	3,425.00	1,375.00
2020-06-02	4,700.00	3,425.00	1,275.00
2020-06-03	4,600.00	3,425.00	1,175.00
2020-06-04	4,600.00	3,425.00	1,175.00
2020-06-05	4,700.00	3,425.00	1,275.00
2020-06-08	4,400.00	3,425.00	975.00
2020-06-09	4,400.00	3,425.00	975.00
2020-06-10	4,400.00	3,425.00	975.00
2020-06-11	4,100.00	3,225.00	875.00
2020-06-12	4,100.00	3,225.00	875.00
2020-06-15	4,100.00	3,225.00	875.00