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STUDY ON THE EFFECTIVENESS EVALUATION OF QINGDAO VTS

By

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DECLARATION

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

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

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ABSTRACT

Title: Study on the Effectiveness Evaluation of Qingdao VTS

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This paper raises the question how to carry out the effectiveness evaluation on a typical port VTS system rationally and comprehensively.

Firstly, this paper introduces the development and basic knowledge (definition, functions) of VTS. And VTS's four characters are summarized as: *Commonweal, Service, Hierarchy, Capital-intensive*. An overview of the previous literature has been examined for purpose of learning research process and experience, meanwhile avoiding and overcoming some existing problems.

Then Qingdao VTS is recommended as the research object on basis of both its type and class. And the *Grey System Theory* has been brought in to study the relationship between VTS and GDP, however, also proves that the VTS's function has the closest relation with regional economy.

This paper employs *With and Without Comparison* method and *Cost Benefit Analysis* to calculate the economic influence and demonstrates Qingdao VTS's considerable economic benefits. Further more, the deeper study is developed based on *Fuzzy Comprehensive Evaluation* method, and also testifies that Qingdao VTS is a rewarding and effective public project because its socio-economic influence is highly crucial to shipping industry and national economy.
KEYWORDS: Cost Benefit Analysis, Effectiveness, Evaluation, VTS, socio-economic influence.

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LIST OF ABBREVIATIONS

AIS	Automatic Identification System
B/C	Benefit Cost Ratio
CBA	Cost Benefit Analysis
CCTV	Closed Circuit TV Cameras
ENPV	Economic Net Present Value
FCE	Fuzzy Comprehensive Evaluation
GDP	Gross Domestic Product
GMDSS	Global Maritime Distress and Safety System
GRA	Grey Relational Analysis
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IMO	International Maritime Organization
IOPC	International Oil Pollution Compensation Funds
MOC	Ministry of Construction
MSA	Maritime Safety Administration
NDRC	National Development and Reform Commission
RDF	Radio Direction Finders
SOLAS	Convention on the Safety of Life at Sea
VHF	Very High Frequency
VLCC	Very Large Crude Carrier
VLOC	Very Large Ore Carrier
VTS	Vessel Traffic Service

CHAPTER 1

Introduction

1.1 Background of VTS

Transportation industry is one of the most significant and fundamental departments in national economy, and it is the basis for one country to manage its own politics, economy and culture along with the other public activities. The developing level of transportation industry is an important index to indicate the stage of economy-society development of the whole country. Karl Marx has already pointed out in *"The Capital Theory"* that, in addition to the mining, agriculture and processing industry, there is also a forth field of material production……is the transportation industry, including both the passenger and the freight (Zhao, 2009, pp.8-15).

And the shipping is the most vital transportation mean in the world trade, while shipping cargoes represent about 80% of the quantity of goods traded internationally. According to statistical data, approximately 80% of the maritime incidents happen around the harbor area or near the narrow channel (Shao et al, 2002, pp.10-13). As Adam Smith wrote in his famous book - *The Wealth of Nations*, that *The reform of transportation will be the most effective one in all kinds of reforms*. That considered, the coastal countries have already installed all kinds of aid navigation facilities in the ports, narrow channels and important waters.

Since 1940s, a kind of systems have been established gradually in the major ports and major rivers, for purposes of enhancing navigation safety, protecting marine environment and improving shipping efficiency. Then it has been well acknowledged that these systems can play the growing roles in increment of the port's operational benefit and reduction of accident risk along with oil pollution, all of the above should be based on monitoring of ships' movements dynamically. And the International Maritime Organization (IMO) call this system as the "Vessel Traffic Service" (VTS).

Figure 1: The First VTS Installed with Radar in Liverpool, British, in 1948.
Source: Huang, 2014, p.10.

1.2 Definition, Functions and Characters of VTS

As defined in *"GUIDELINES FOR VESSEL TRAFFIC SERVICES"*, Vessel Traffic Service (VTS) - a service implemented by a Competent Authority, is designed to improve the safety and efficiency of vessel traffic and to protect the environment. The service should have the capability to interact with the traffic and to respond to traffic situations developing in the VTS area (IMO, 1997, p.3). And the SOLAS has already formulated the purposes of VTS, to make contribution to the safety of life at sea, safety and efficiency of navigation, the protection of the marine environment, the adjacent shore area, work-sites, and offshore installations from possible adverse effects of maritime traffic. *IALA VTS Manual* (2012, p.220) has presented the three main objectives briefly: 1) to aid the mariner in the safe use of navigable waterways; 2) to afford unhindered access to pursue commercial and leisure activities; 3) to contribute to keeping the seas and adjacent environment free from pollution.

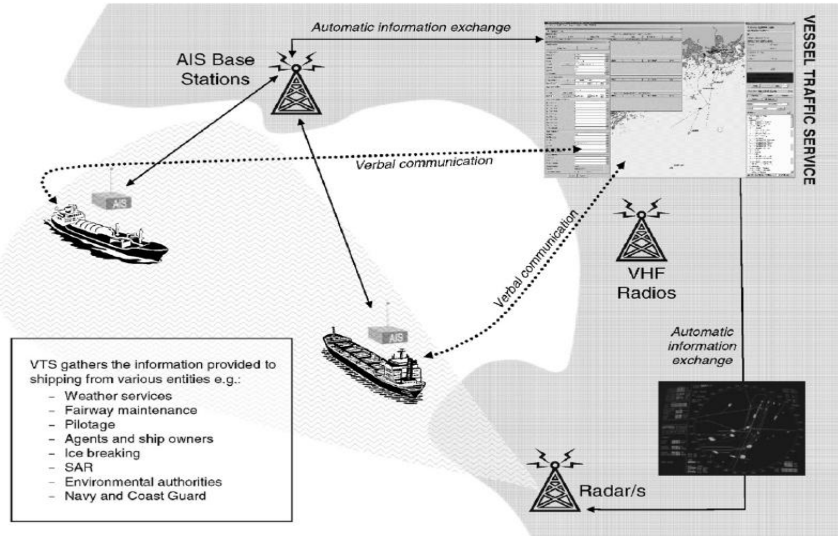

Figure 2: Means of General Information Exchange in the VTS Operations.
Source: The paper of Nuutinen et al, 2007, p.514.

On the basis of Resolution A.857(20) adopted by IMO in 1997, there are three main services provided by VTS: 1) The *information service* is provided by broadcasting information…and may include for example reports on the position, identity and intentions of other traffic…; 2) The *navigational assistance service* is especially important in difficult navigational or meteorological circumstances…normally rendered at the request of a vessel or by the VTS when deemed necessary; 3) The *traffic organization service* concerns the operational management of traffic and the forward planning of vessel movements to prevent congestion and dangerous situations. And according to VTS Manual adopted by IALA, the functions of a VTS carried out are related to the following seven factors showed in Figure 3:

Figure 3: Seven Factors Related to the Functions of VTS.
Source: Author Compiled from VTS Manual.

Based on the definition, functions and the other materials, there are four main characters could be summarized for VTS system:

1. *The Commonweal*. The type of services provided by VTS is society-oriented service whose primary motivation is to match the public needs (the ports, the vessels and the seafarers) rather than business. The VTS could supply services and create conditions for national economy directly and indirectly, to better the quality of life and aim of the common interests.

2. *The Service*. As shown in the item of VTS, the letter *"S"* just stands for service. All of the productions - information service, navigational assistance service and traffic organization service provided by VTS, indicate the nature of VTS is service-oriented. These services are just-in-time production and just-in-time consumption, and could not be expressed by physical form. As a result, the wealth of the production should be judged by clients through immaterial degree of satisfaction.

3. *The Hierarchy.* The hierarchy of VTS could be reflected by the institutions setting, due to that IALA have divided the leadership system of VTS into four ranks, from top to bottom, the competent authority, VTS authority, VTS center and VTS operator respectively.

4. *The Capital-intensive.* Usually a VTS center may include but not limited to the following facilities: main building, VHF communication device, VTS Radar System, Automatic Identification System (AIS), Closed Circuit TV Cameras (CCTV), Radio Direction Finders (RDF); hydrometry equipment and/or VTS Data System. Apparently to state that the construction cost of a VTS center is pretty expensive.

1.3 Objectives and Main Contents of This Paper

In consideration of the huge investment cost, the investors of a VTS center usually consist of the government department, shipping company, and/or harbor authority; however, these stakeholders would take a serious consideration on how to manage the VTS effectively and efficiently. Up to 2014, there are 33 VTS centers along with 140 radar stations which have been already completed and put into operation (Cao, 2014, pp.3-5). Be different from some foreign models, all of these facilities are invested and managed by China Maritime Safety Administration (MSA) - as a governmental agency who does pay more attention to the maritime safety, environmental protection along with quality system management. However, they often ignore the cost and benefit of VTS, which would result in the blind or repeated constructions, the waste of public resources and the taxpayers' faith; meanwhile the national economy would also suffer from the risk of loss.

By contrast with the United States, the country who have promulgated that every project shall pass the completion acceptance managed by authority or recognized organization before production, no matter who is the beneficial owner (Tian, 2000, p.18); however, China have not established the comprehensive and reasonable evaluation standards for VTS's effectiveness since the year of 1978 in which Ningbo VTS - the first VTS center of China - had been completed and operated. This paper states that China needs to set up its own evaluation system urgently, and the system should be scientific and sensible to assess both economic and social influence of VTS. The introduction of evaluation system would be meaningful and reformative for Chinese VTS due to that it could improve the level of investment decision-making based on Effectiveness Evaluation, especially for the reconstruction and expansion project of the existing VTS centers.

1.3.1 Objectives

The objectives of this paper could be concluded as the following two aspects:

1. To carry out a deep research on the effectiveness evaluation of a typical port VTS - Qingdao VTS, especially to clarify and define the relationship between VTS and regional economy (GDP), to quantify the direct economic benefits and assess the social benefits comprehensively.

2. To assist the authority (maritime department) to know well about the factor-product relationship of a VTS center, then to make the investment decision on both new-construction and re-construction more sensible and evidence-based, so that to use the financial funds rationally.

1.3.2 Main Contents

As an institution that provides public products, the costs of VTS often reflect the feature of internality while the benefits reflect the feature of externality (Zhang & Li, 2006). For instance, the costs of design, civil engineering and operation & maintenance and so on could be assigned to the internal cost; the benefits of accident reduction, environmental protection and enhancement of traffic efficiency should be assigned to the external benefit. In brief, the contents of VTS's socio-economic influence are so complex and far-ranging that should be taken into account seriously in the view of national economy (Yang, 1990, p.25).

In order to calculate and assess the effectiveness of VTS visually and comprehensively, this paper summarizes that the socio-economic influence is composed by three main domains: *investment costs*, *direct economic benefits* and *social benefits* which contain the indirect economic benefits.

1. The *costs* include initial investment cost, lifetime operating cost. By reason of the large-scale and long-term investment, the time value of money should be thought over sufficiently.

2. The *direct economic benefits* include three major aspects: safety benefit (accident reduction), environmental protection benefit and traffic efficiency benefit.

3. The *social benefits* mean the other contributions, such as government's reputation, port's image, public safety awareness, guarantee of rights and interests for seafarers and etc. Obviously these benefits are difficult to be counted by use of traditional

Numerical Computing Method, and therefore the *Fuzzy Comprehensive Evaluation* method should be introduced to address such problem.

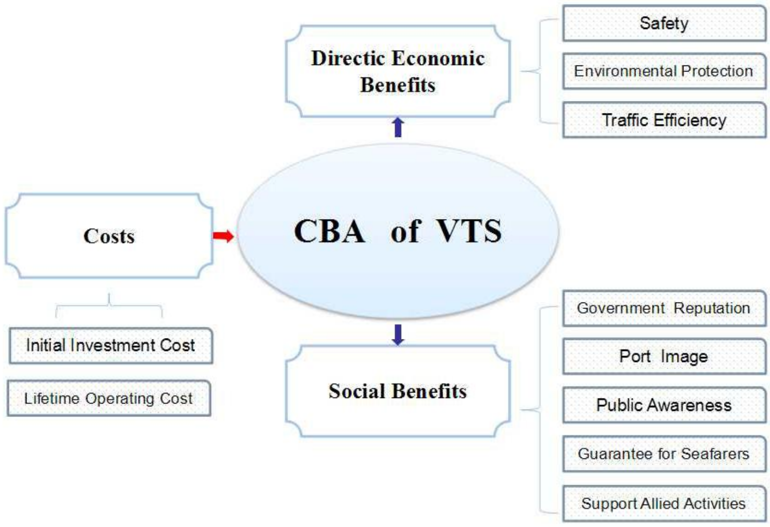

Figure 4: Sketch Map of the Main Contents of VTS's Socio-economic Influence.
Source: This paper.

CHAPTER 2

Literature Review and Methodology

2.1 Literature Review

The United States Coast Guard sorted the construction necessities of VTS amongst 22 major ports in line with accident analysis method; based on this study, the ports of San Francisco, New Orleans and New York built their own VTS centers in succession (USCG, 1973). Mr. Hans started to research the cost-benefit analysis for VTS and presented the qualitative analysis methodology (Hans, 1976, pp.11-15). It is worth to note that Professor Fujii and Professor Yamanouchi, who could be considered as the first scholars and created the systemic research on cost benefit analysis for VTS and presented the mean of quantitative analysis (Fujii & Yamanouchi, 1978). Mr. Loever and Mr. Kongsberg studied the economic and social benefits of VTS which were assumed located in the North Pole and the other environmentally sensitive area (Loever & Kongsberg, 2008). The Chapter 7 and Chapter 8 of VTS Manual-2012 introduced the theory of Cost Benefit Analysis (CBA) while offer outline guidance on how to carry out in practice, and expound that these *complex task as quantification of safety benefits and the translation of these benefits in monetary terms* is difficult but necessary.

In China, both the management capability and the research ability of effectiveness evaluation for VTS are more behindhand than the developed countries', because the government especially maritime authority did not pay sufficient attention to this field. Up to 1988, Professor Qiu used methods of fuzzy mathematics and system engineering to rank the port VTS centers into different classifications (Qiu et al, 1988, pp.4-12). Professor Wu Zhaolin - the ex-president of Dalian Maritime University and his colleagues Professor Zhu & Fang- the first scholars in China began to study the CBA of VTS initially (Fang, 1994, pp.149-153). And Dr. Li made a detailed research of VTS's efficiency evaluation in his doctor dissertation and put forward valuable assessing model (Li, 2010). Mr. Mou divided VTS's benefit into four parts: safety, environment protection, efficiency and supervising reduction, and illustrated the specific calculation (Mou et al, 2015, pp.22-31).

2.2 Existing Problems

By means of systemic study and comparative analysis of the relevant domestic and overseas literature, this paper would like to state that in most of the previous researches still exist some shortcomings still exist, which could be divided into the following three respects:

1. The former studies usually claim that the VTS plays an important role in the domain of shipping industry and even in national economy; however they only focus on the cost or benefit on VTS itself but do little research to seek the relevant relationship between VTS and regional economy - Gross Domestic Production (GDP) of the city.

2. The constituent parts of VTS's benefits should be determined cautiously and sensibly according to the characters of a VTS center. And most of the previous

studies owe the contribution of accident reduction and environmental protection to VTS entirely, because they usually overlook the improved effect of human factor (Schröder, 2015), technological innovation (Nakazawa, 2015), management ability (Fan, 2015) and navigation environment.

3. Most of the studies adopt quantitative and qualitative methods to analyze the economic and social benefits respectively. Absolutely, the effects of social benefit which are the very important element, usually are weakened due to the limitation of data and lack of comprehensive evaluation index.

2.3 Methodology of This Paper

This paper would try best to establish a reasonable and viable evaluation system for the selected and typical Port VTS in China - the Qingdao VTS. The methodology of *Grey System Theory* would be used in analysis of the relationship between primary activity of VTS and GDP of Qingdao (Problem 1); the method of questionnaire survey/expert meeting is introduced to resolve and confirm the weight of VTS in the reduction of accidents (Problem 2) along with other relevant problems; the methodology of *With and Without Comparison* would be applied in the calculation of direct economic benefits, meanwhile the method of *Fuzzy Comprehensive Evaluation* could be put into the use of the comprehensive evaluation of VTS's socio-economic influence (Problem 3); and the relevant theories of Maritime Economics, Environmental Economics and Transportation Economics also would be used. In brief, it could be meaningful and referable for the authority to decide the policy and enhance the efficiency of VTS.

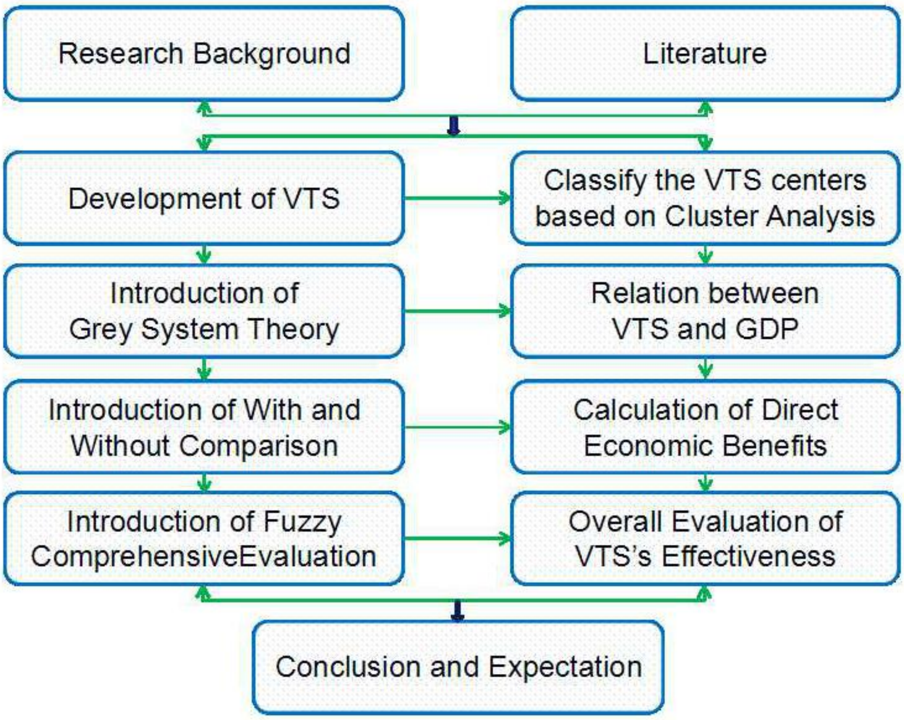

Figure 5: Technical Route for Assessing the Effectiveness of Qingdao VTS.
Source: This paper.

CHAPTER 3

Introduction of Qingdao VTS and Application of Grey System Theory

3.1 Development Process of VTS

The levels of technology and management have seen the great developments in the world wide VTS since 1940s, and the development process could be divided into four stages (China MSA, 2006). VTS centers were established and served for canals or narrow channels in the first generation, and at that time the simple systems contained with voice, light, mechanical signal and telegraph&telephone, were used to enhance the shipping efficiency. The second generation adopted radar and VHF to ensure the safety of navigation. The third generation paid more attention to the protection of marine environment so that the force of ship monitoring had been increased. Nowadays, the level of VTS has climbed up to the fourth generation in which the technology of GMDSS, AIS and satellites have been utilized comprehensively. And the status of VTS acted as the hinge of information and the center of commendation, becomes increasingly significant.

The starting of Chinese VTS is also much later than the developed countries. Until the middle of 1970s, China began to explore and touch the field of VTS, and the first VTS center - Ningbo VTS was built initially in 1978. In next decade, the large-scale construction of VTS centers were launched by the government; meanwhile academic research on VTS had also been developed rapidly; for example, the theory of Marine Traffic Engineering and System Engineering was introduced to guide the plan and design for VTS. By the end of 2014, there are 33 VTS centers along with 140 radar stations have been constructed and put into operation; the area of monitoring water reach at 84,300 square kilometers, and the marine traffic flow monitored by VTS exceeds 3,500,000 ships annually (Cao, 2014, p.5).

3.2 Introduction of Qingdao VTS

Generally, the main civil engineering of Qingdao VTS is started in 1997, completed in 1999 and has been put into use since December 8 of 1999. And both of the two years should be considered as the benchmark years in following analysis. Qingdao VTS consists of one center and three radar stations, and the monitoring area within the reporting lines regulated in *"Qingdao VTS Guide for Users"* (see in Appendix A) is about 400 square kilometers, which cover the whole port of Qingdao (Qingdao VTS, 2010).

Different VTS systems may contain different specific equipment due to the functional diversities, but they would usually include the following basic ones:

1. Radar sub-system is an essential part of VTS. It could guide vessels to navigate inboard/outboard, lie at anchor and even navigate in restricted visibility safely; and help VTS operators to monitor movements of vessels, navigation marks and etc.; also could provide navigation information for MSA, Harbor Control and Pilot Station to improve traffic efficiency and coordinate the port production.

2. Radar Data Processing sub-system based on computer science and technology is another vital element which is the main mark for the fourth generation of VTS.

3. VHF sub-system plays an important role in the communication between VTS center and vessels in VTS area. And it is one of the most primary measures to collect data because its operating range could not only cover but also exceed the radar's.

4. Radio Direction Finder sub-system is the supplementary method for VTS to

identify the vessels according that it could locate the vessel who is using VHF.

5. Information Transfer sub-system is to deal with the message communicated between VTS center and radar station or the other units.

Meanwhile, there are also Hydro Meteorology sub-system whose function is to gather the meteorological report broadcast by observatory; CCTV sub-system is the supplement for radar and it is capable to measure types and sizes of vessels.

3.3 Reasons for the Selection of Qingdao VTS

3.3.1 The Type

At present, in view of the monitoring area, functions and applications, the VTS systems could be divided into five types (Li, 2012):

1. Port VTS system - take charge of the marine traffic within port waters along with fairways, and this type of VTS centers accounts for more than 50% in the whole world. Qingdao VTS selected by this paper belongs to this major type.
2. Route VTS system - take charge of vessel traffic within the inland river, canal, bay and strait.
3. Regional VTS system - take charge of vessel traffic within international fairways.
4. Comprehensive VTS system - may consist of two or all the three types of VTS systems mentioned above.
5. Protective VTS system - usually take charge of bridge, dam and oil concession and so on.

3.3.2 The Class

The Cluster Analysis Methodology has been made good use by Dr. Cao on basis of the relevant data (investment scale, number of information service, navigation assistance service and traffic organization service) to study classification of the main VTS centers in China, and pointed out that these centers should be divided into the following three classes.

Table 1: The Classifications of VTS Centers in China.

Classification	Name of VTS Center	Character								
		Cargo Handling Capacity		Work load		Scale of VTS Center		Risk of waters		
		H	L	H	L	H	L	H*	M*	L*
First Class	Dalian VTS	√		√		√		√		
Second Class	Shanghai VTS(Yangshan&Wusong); Guangzhou VTS; Ningbo VTS; Qingdao VTS; Tianjin VTS; Zhoushan VTS.	√		√		√			√	
Third Class	Caofeidian VTS; Jingtang VTS; Shenzhen VTS; Qinhuangdao VTS; Zhanjiang VTS; Zhuhai VTS; Weihai VTS.		√		√		√			√

Note: H*, M* and L* is high, medium and low level respectively.
Source: Author Compiled from Dr. Cao's Dissertation (2014, pp.35-46).

It is distinct to demonstrate that the First Class only covers Dalian VTS whose four indexes all stay at the high levels, especially the Risk of Waters is obviously higher than the other centers; simultaneously the Third Class's indicators all remain in the low levels. The Shanghai VTS, Qingdao VTS and so on are assigned to the Second Class due to that even though all of them have the high levels of Cargo Handling Capacity, Work load and Scale, the Risk of Waters still belongs to the secondary standard. What is noteworthy is that all of the six VTS centers are located in the top ten ports in the world (Table 2), so that clearly to demonstrate Qingdao VTS is the member and typical representative among these major VTS centers.

Table 2: The World's Top 10 Ports from 2010 to 2014. Unit: million ton.

Port \ Year / Capacity	2010		2011		2012		2013		2014	
1	Shanghai Port	651	Shanghai Port	720	Ningbo-Zhoushan Port	744	Ningbo-Zhoushan Port	809	Ningbo-Zhoushan Port	873
2	Ningbo-Zhoushan Port	620	Ningbo-Zhoushan Port	678	Shanghai Port	736	Shanghai Port	776	Shanghai Port	755
3	Singapore Port	578	Singapore Port	615	Singapore Port	538	Singapore Port	558	Singapore Port	576
4	Guangzhou Port	411	Guangzhou Port	451	Tianjin Port	476	Tianjin Port	501	Tianjin Port	540
5	Rotterdam Port	410	Tianjin Port	448	Rotterdam Port	442	Guangzhou Port	455	Tangshan Port	501
6	Tianjin Port	410	Rotterdam Port	433	Guangzhou Port	434	Suzhou Port	454	Guangzhou Port	499
7	**Qingdao Port**	**350**	**Qingdao Port**	**375**	Suzhou Port	428	**Qingdao Port**	**450**	Suzhou Port	479
8	Dalian Port	311	Dalian Port	338	**Qingdao Port**	**402**	Tangshan Port	446	**Qingdao Port**	**465**
9	Busan Port	260	Tangshan Port	308	Dalian Port	374	Rotterdam Port	441	Rotterdam Port	445
10	Tangshan Port	250	Busan Port	293	Tangshan Port	364	Dalian Port	333	Dalian Port	428

Source: Author Compiled from the Various Internet Data.

And, to be honest, another special reason is that, the author has worked as a senor operator in Qingdao VTS for five years, and therefore I am so familiar with it that also hope to do some research not only for it but also for myself.

3.4 Relation Analysis Between VTS and GDP Based on *Grey System Theory*

Nearly all of the previous studies claimed that VTS plays a large role in regional economy and even in national economy; however, there is no study that gives a detailed explanation for the particular relation between VTS and regional GDP due to that it is hard for a public department to transfer all its actions into measurable benefits. This paper would try to study that relationship by the application of *Grey System Theory* whose obvious feature is to overcome the lack of partial information. In Grey System, the intensity of color is used to indicate whether the information provided is specific or not; and Ashby - the earlier organizer of Cybernetics - calls the object whose internal information is totally unknown as *Black Box*, while the totally clear one is called as *White Box*, and the color of *Grey* is used to stand for that partial information is clear while partial is not (Liu et al, 2010, pp.1-18).

And the Grey Relational Analysis (GRA) is based on qualitative analysis and quantitative analysis, and becomes the fundamental method used for systemic analysis. The object of GRA is to seek the major relation among all the factors, calculate the correlation coefficient and correlation degree, and then to confirm the most vital factor which affects the objective system (Deng, 2005, pp.22-23).

3.4.1 Principle Theory of *Grey Relational Analysis*

In GRA, the correlation degree is applied to describe the effect degree on the objective of different factors. In practical terms, the differences between factor curves and objective curve could be analysed and contrasted in the domain of geometrical shape. So simply, the fewer differences in geometrical shape and the more similarities in the changing trend, then we could say that curve has the largest correlation degree with the objective one (Wu & Zh, 2004, p.201).

The correlation degrees among the curves are defined as follows:

Given $x_0(t)\,(\mathrm{t} = 1,2,\ldots\mathrm{m})$ is the Objective Sequence (also called Master Sequence), $x_i(t)\,(\mathrm{t} = 1,2,\ldots\mathrm{m};\mathrm{i} = 1,2,\ldots\mathrm{n})$ is the Factor Sequence (also called Sub-sequence). For the purpose of studying the relevant correlation degrees, both of master sequence and sub-sequences should be converted into the same dimension. Therefore, all of the sequences should be transferred into the non-dimensional sequences when they have various dimensions. The common practice is to divide all the variable values by one fixed variable-value so that we could get the non-dimensional formula (3-1):

$$y_i(t) = \frac{x_i(t)}{x_i(1)} \qquad (3\text{-}1)$$

Where t=1,2,…m; i=1,2,…n. When t=k, the correlation coefficient can be calculated by formula (3-2):

$$\xi_i(k) = \frac{\Delta(\min) + \rho\Delta(\max)}{\Delta_i(k) + \rho\Delta(\max)}$$

$$= \frac{\min_i \min_k |x_0(k) - x_i(k)| + \rho \max_i \max_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \rho \max_i \max_k |x_0(k) - x_i(k)|} \qquad (3\text{-}2)$$

Where (i) ρ is correlation coefficient, 0< ρ <1, and conventionally ρ =0.5;

(ii) $\Delta(\min) = \min_i \min_k |x_0(k) - x_i(k)|$ stands for the two-stages' minimum difference: $\Delta_i(\min) = \min_k |x_0(k) - x_i(k)|$ is the minimum difference of first-stage, that means that the minimum one should be selected during the absolute difference $|x_0(k) - x_i(k)|$ while the value of k is variable; similarly, $\Delta(\min) = \min_i [\Delta_i(\min)]$ is the minimum difference of second-stage - the minimum one selected in $\Delta_i(\min)$.

(iii) $\Delta(\max) = \max_i \max_k |x_0(k) - x_i(k)|$ - the maximum difference can be defined in the same way.

The correlation degree r_i between $x_i(t)$ and $x_0(t)$ is defined by formula (3-3):

$$r_i = \frac{1}{m} \sum_{k=1}^{m} \xi_i(k) \qquad (3\text{-}3)$$

By comparison r_i with r_j , if $r_i > r_j$, it indicates the factor i has greater influence and more closely linked to the objective than the factor j .

3.4.2 Sample Calculation

This paper has already gathered the data on GDP of Qingdao, cargo handling capacity of Qingdao port, number of information service provided by Qingdao VTS along with the amount of merchant vessels monitored by VTS from 2000 to 2015, as showed in Table 3.

Table 3: The Relevant Data of GDP, VTS and Port.

Unit of *1 is million Yuan, Unit of *2 is million ton, Unit of *3 is time and Unit of *4 is ship.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
GDP*1	199100	136800	158300	177500	216400	261200	320600	378600	440100	485300	566600	661500	730200	800600	869200	940000
Port Capacity*2	86	100	122	141	163	187	223	264	300	315	350	375	402	450	465	485
Information Service*3	41092	55676	62159	68589	75138	91265	99259	103273	109246	117275	123806	124766	110368	111652	106500	106685
Merchant Vessel*4	14585	15520	18360	21130	23958	36500	46892	51874	58852	62417	71084	71365	69815	70326	68701	68800

Source: *2*3*4 Annual Report of Qingdao MSA; *1 Set of Government Work Report of Qingdao, Retrieved 25 June 2016 from the World Wide Web: http://www.qingdao.gov.cn/n172/n25685095/n25685320/n25685925/n25687788/index.html.

According to Table 3, given GDP is the objective sequence - $x_0(t)$, while port capacity/information service/merchant vessel is the sub-sequence - $x_1(t)$, $x_2(t)$, $x_3(t)$ respectively and the matrix is listed in equation (3-4):

$$\begin{bmatrix} x_0(t) \\ x_1(t) \\ x_2(t) \\ x_3(t) \end{bmatrix} = \begin{bmatrix} \text{GDP of Qingdao} \\ \text{Port Capacity} \\ \text{Information Service} \\ \text{Merchant Vessel} \end{bmatrix} \quad (3\text{-}4)$$

$$= \begin{bmatrix} 199100 & 13680 & 158300 & 17750 & 21640 & 26120 & 320600 & 378600 & 440100 & 485300 & 566600 & 661500 & 730200 & 800600 & 869200 & 940000 \\ 86 & 100 & 122 & 141 & 163 & 187 & 223 & 264 & 300 & 315 & 350 & 375 & 402 & 450 & 465 & 485 \\ 41092 & 55676 & 62159 & 68589 & 75138 & 91265 & 99259 & 103273 & 109246 & 117275 & 123806 & 124766 & 110368 & 111652 & 106500 & 106685 \\ 14585 & 15520 & 18360 & 21130 & 23958 & 36500 & 46892 & 51874 & 58852 & 62417 & 71084 & 71365 & 69815 & 70326 & 68701 & 68800 \end{bmatrix}$$

And the equation (3-4) should be disposed by the initialization formula (3-1) $y_i(t) = \frac{x_i(t)}{x_i(1)}$, and then the non-dimensional sequence could be computed in equation (3-5):

$$\begin{bmatrix} y_0(t) \\ y_1(t) \\ y_2(t) \\ y_3(t) \end{bmatrix} = \begin{bmatrix} x_0(t)/x_0(1) \\ x_1(t)/x_1(1) \\ x_2(t)/x_2(1) \\ x_3(t)/x_3(1) \end{bmatrix} = \begin{bmatrix} 1 & 0.69 & 0.80 & 0.89 & 1.09 & 1.31 & 1.61 & 1.90 & 2.21 & 2.44 & 2.85 & 3.32 & 3.67 & 4.02 & 4.37 & 4.72 \\ 1 & 1.16 & 1.42 & 1.64 & 1.90 & 2.17 & 2.59 & 3.07 & 3.49 & 3.66 & 4.07 & 4.36 & 4.67 & 5.23 & 5.41 & 5.64 \\ 1 & 1.35 & 1.51 & 1.67 & 1.83 & 2.22 & 2.42 & 2.51 & 2.66 & 2.85 & 3.01 & 3.04 & 2.69 & 2.72 & 2.59 & 2.60 \\ 1 & 1.06 & 1.26 & 1.45 & 1.64 & 2.50 & 3.22 & 3.56 & 4.04 & 4.28 & 4.87 & 4.89 & 4.79 & 4.82 & 4.71 & 4.72 \end{bmatrix} \quad (3\text{-}5)$$

And the correlation coefficients ξ_i can be counted according to formula (3-2), and the consequence is listed in equation (3-6):

$$\begin{bmatrix} \xi_1 \\ \xi_2 \\ \xi_3 \end{bmatrix} = \qquad (3\text{-}6)$$

$$\begin{bmatrix} 0.82372 & 0.90836 & 0.87728 & 0.85128 & 0.80304 & 0.75383 & 0.69719 & 0.64955 & 0.60565 & 0.57699 & 0.53173 & 0.48712 & 0.45923 & 0.43379 & 0.41156 & 0.39089 \\ 0.87752 & 1 & 0.97346 & 0.95198 & 0.90157 & 0.86116 & 0.79710 & 0.73935 & 0.68807 & 0.65754 & 0.60367 & 0.54732 & 0.50558 & 0.47542 & 0.44697 & 0.42275 \\ 0.84197 & 0.93205 & 0.90353 & 0.87982 & 0.83189 & 0.79325 & 0.74096 & 0.69164 & 0.64733 & 0.61713 & 0.57069 & 0.51975 & 0.48744 & 0.45905 & 0.43367 & 0.41081 \end{bmatrix}$$

Finally, the correlation degree r_i is completed in equation (3-7):

$$R = \begin{bmatrix} r_1 \\ r_2 \\ r_3 \end{bmatrix} = \begin{bmatrix} 0.6413 \\ 0.7156 \\ 0.6726 \end{bmatrix} \qquad (3\text{-}7)$$

By the contrast analysis, apparently to see $r_2 > r_3 > r_1$, so that the result is that the factor - Information Service provided by Qingdao VTS has the greater impact on the objective - GDP of Qingdao than the other two factors: cargo handling capacity and Number of merchant vessels. However, this analysis also demonstrates the close connection between VTS and GDP in detail and with scientific method rather than simple description in previous studies. In other words, it is worthy and meaningful to develop further research on the socio-economic influence of VTS.

CHAPTER 4

Cost Benefit Analysis of Qingdao VTS

With regard to the statistical materials, the U. S. Department of Transportation (1991, p.29) pointed out that the establishment of VTS system brings notable economic and social benefits because the probability of maritime accident (collision & grounding) has been reduced by a range of 29%. And taking the Tianjin VTS for example, although the marine traffic flows see a marked increase from 1995 to 2005, both the number and probability of accidents drop at the rates of 10.9% and 21.5% (Cai, 2006, pp.29-30).

Generally speaking, the investment scale is proportional to management level - higher level means higher cost. However, the management capacity could not keep on playing the effective role while the investment exceeds a specific level, and that would lead to the waste of resources.

Professor Fujii (1984, pp.35-45) has pointed that, in the domain of marine traffic, the sum of freedom degree and management degree is 100%. For cost and benefit, they are the integral whole of contradiction and unity: the safety administration (Coast Guard, MSA) want to built more VTS centers to ensure navigation safety while the investors (government, group and individual) keep stressing the cost-benefit analysis. The Figure 6 could expressly indicate the relations between management level and cost (Curve 1) / accident (Curve 2). Aiming at maximizing the comprehensive effectiveness, the administration should try to achieve the best balance between investment scale and actual demand rather than establish the VTS center with too high level stubbornly.

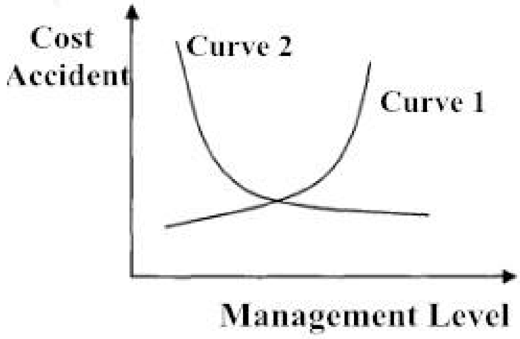

Figure 6: Relations between Management Level and Cost / Accident.
Source : Wu & Zhu, 2004, p.339.

The IALA Recommendation V -119 has already stated that *"The Cost Benefit Study should consider direct risk reduction (which may be vague)"*, and the other benefits - *a future VTS might offer and the further value added services for shipping in the future* - seem to be less evident. IALA guidelines and most of the previous studies, have divided the economic benefits of VTS into two aspects: direct benefit, and indirect benefit which part is too completely difficult to be calculated in practice. Totally different from that, this paper shall insist that it is meaningless to retain the aspect of indirect benefit which shall be assigned to the aspect of social benefit, due to that both of them are virtually impossible to be translated in monetary terms. Based on the Chapter 1, 2 and 3, this paper would like to state that the socio-economic aspects of VTS should consist of these three parts: *Direct Economic Benefits, Social Benefits* and *Costs*.

4.1 Direct Economic Benefits

Usually, the direct economic benefits could be reflected by three essential fields: safety benefits, environmental protection benefits and traffic efficiency benefits. There is one primary principle - *With and Without Comparison* - would be applied in the calculation of these benefits (Chen, 2009, p.117). In simple terms, the method of with and without comparison is to compute and analyse the difference and influence of a VTS center before and after its establishment.

4.1.1 Discussion of VTS's Weight in Reduction of Accident

Firstly and significantly, it is worth and debatable to note that the existing studies often owe the benefits of both safety and environment to the VTS totally. Meanwhile they may ignore the others elements such as reformative human factor, technology innovation and management ability due to that it is hard to distinguish the VTS's influence from the others factors clearly (Wu&Zhu, 2004, p.380). This paper adopts *Delphi Method* - developed by the US RAND Corporation during the Cold War to generate different images of the future, based on the shared knowledge of the involved experts (Markmann et al, 2013, p.1817) - to solve such a puzzle. Considering that the Delphi method is often applied in project management to analyze risks in large-scale and international projects, we apply it to assign and mark the weights in this case (see in Appendix B). This paper has invited 12 senior experts - 3 experts from MSA, shipping companies, maritime college and port group respectively - to participate in the questionnaire survey. According to experts' data, the weight calculation has been carried out and the outcomes are listed in Figure 7:

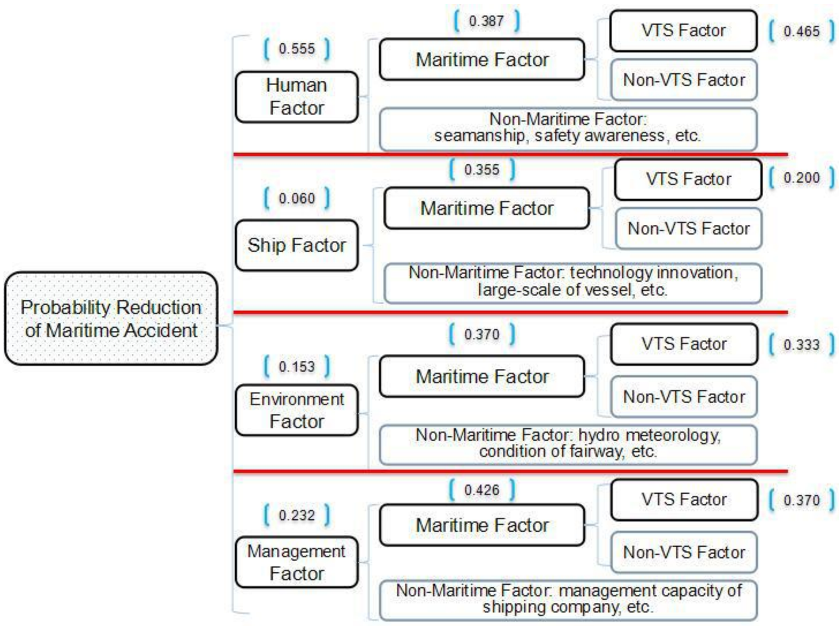

Figure 7: Weights of Factors related to Probability Reduction of Accident.
Source: This Paper.

It is clear to see that the factors' weights of human, ship, environment and management in accident reduction is 0.555, 0.060, 0.153 and 0.232 respectively, and the four factors should be divided into two aspects: non-maritime factor and maritime factor which classified as VTS factor and non-VTS factor. Consequently, the weight of VTS is computed by equation (4-1):

$$W_{VTS} = 0.555\times0.387\times0.465+0.060\times0.355\times0.200+0.153\times0.370\times0.333+0.232\times0.426\times0.370$$

$$= 0.0998+0.0043+0.0188+0.0366=0.1596 \qquad (4\text{-}1)$$

4.1.2 Safety Benefits

According to the statistics and experience, the types of accidents that can be avoided by VTS through monitoring and tracking vessels dynamically in supervised water are mainly the collision and grounding (excluding oil spilling accident). In other words, the loss of accidents which could be avoided by VTS shall represent the safety benefits. Usually, some previous studies would list a simple equation to count the safety benefits just like this: $\textit{Annual Safety Benefit} = \left(Rate_{Before} - Rate_{After}\right)\cdot \textit{Annual Absolute Loss}$

And this paper could not agree with that unreasonable points due to they did not take the increasing traffic flow into account. For the purpose of more rational assumption, this paper creates the item "annual relative loss" to replace the item of "annual absolute loss" after the construction of VTS in equation (4-2):

$$ARL_i = \frac{N_i}{N_{1999}} \cdot \frac{F_{1999}}{F_i} \cdot AAL_i \qquad (4\text{-}2)$$

Where, ARL_i is annual relative loss of the year i (i =2000,2001…2015), AAL_{1999} is annual absolute loss of the starting year (the year before the VTS-1999 in this case), N_i / F_i, N_{1999} / F_{1999} are accident rates in year i and starting year respectively. The spreads between AAL_{1999} and ARL_i is the safety benefits that can be calculated in equation (4-3):

$$\textit{Annual Safety Benefit} = \left(AAL_{1999} - ARL_i\right)\cdot W_{VTS} = \left(AAL_{1999} - \frac{N_i}{N_{1999}} \cdot \frac{F_{1999}}{F_i} AAL_i\right)\cdot W_{VTS} \qquad (4\text{-}3)$$

As described above, Qingdao VTS has been put into operation since December, 1999 which year should be taken as the starting year. Both Figure 8 and Table 4 reflect all the relevant data on the accidents along with losses and benefits from 1999 to 2015.

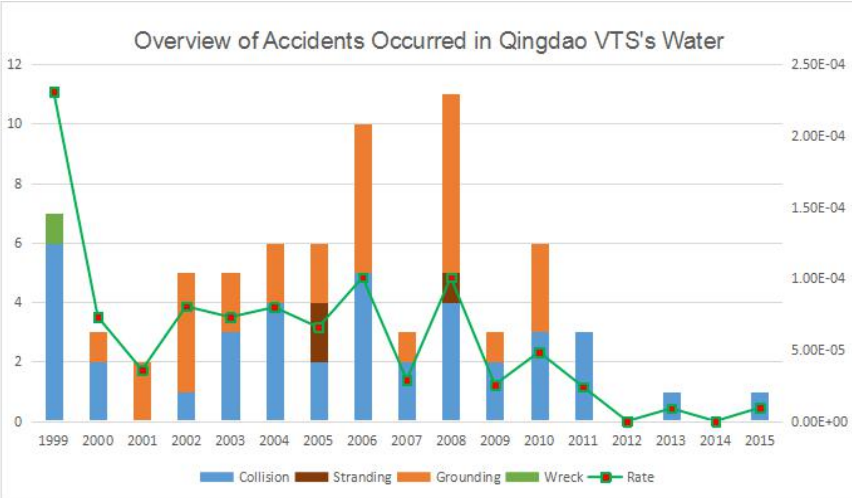

Figure 8: Overview of Accidents Occurred in Qingdao VTS Water.
Source: Author Compiled from Annual report of Qingdao MSA (1999-2015).

Table 4: Detailed Data of Accidents along with Losses and Benefits

	Collision	Stranding	Grounding	Wreck	Traffic Flow	Accident Rate	Annual Absolute Loss/ Yuan	Annual Relative Loss/ Yuan	Annual Safety Benefit/Yuan
1999	6	--	--	1	30,348	2.31E-04	15,317,524	--	--
2000	2	--	1	--	41,092	7.30E-05	3,221,801	1,016,359	**2282468**
2001	--	--	2	--	55,676	3.59E-05	3,467,789	538,268	**2358771**
2002	1	--	4	--	62,159	8.04E-05	5,488,095	1,907,532	**2140236**
2003	3	--	2	--	68,589	7.29E-05	14,987,776	4,721,033	**1691202**
2004	4	--	2	--	75,138	7.99E-05	15,754,164	5,435,897	**1577109**
2005	2	2	2	--	91,265	6.57E-05	5,582,707	1,585,901	**2191569**
2006	5	--	5	--	99,259	1.01E-04	10,068,864	4,383,236	**1745114**
2007	2	--	1	--	103,273	2.90E-05	2,871,214	360,400	**2387159**
2008	4	1	6	--	109,246	1.01E-04	16,689,766	7,261,422	**1285756**
2009	2	--	1	--	117,275	2.56E-05	2,907,067	321,333	**2393394**
2010	3	--	3	--	123,806	4.85E-05	6,013,477	1,259,272	**2243699**
2011	3	--	--	--	124,766	2.40E-05	2,990,356	310,693	**2395092**
2012	--	--	--	--	110,368	0	0	0	**2444678**
2013	1	--	--	--	111,652	8.96E-06	1,160,000	44,893	**2437514**
2014	--	--	--	--	106,500	0	0	0	**2444678**
2015	1	--	--	--	106,685	9.37E-06	857,000	34,711	**2439139**

Source: Author Compiled from Annual report of Qingdao MSA (1999-2015).

4.1.3 Environmental Protection Benefits

Usually, the accidents of collision, grounding and stranding would cause oil pollution to marine environment. Therefore, the reduction of clean-up cost, compensation to fishery and so on could represent the environmental protection benefits.

Compared with traffic accidents, the amount of oil spill accidents is much fewer. The first recorded oil spill accident occurred in 1974 while the latest one happened in 2014 based on files of Qingdao MSA. During the past 40 years, there are 27 oil spill accidents occurred in Qingdao offshore waters (Zhao, 2015, p.17). Among these accidents, 16 accidents were caused by the overfull cargo tanks (6), drop/crack of oil delivery pipes (5) and misoperation carried out by crews (3) and explosions (2) - all of these causes are out of the VTS's functions so that should not be taken into account. The rest but vital 11 accidents related to VTS are listed in Table 5:

Table 5: Oil Spilling Accidents Occurred in Qingdao Port's Water.

	Year	Vessel's Name	Nationality of Vessel	Position	Types of Accident	Account of Oil Spilling /Ton
1	1974	Daqing 31	China	Fairway (Zhongsha Reef)	Stranding	895
2	1975	Daqing 30	China	Fairway (Mati Reef)	Stranding	33
3	1975	Daqing 53	China	Fairway	Collision	3
4	1979	Serose	Brazil	Fairway	Collision	350
5	1980	Daqing 256	China	Fairway (Zhongsha Reef)	Stranding	43
6	1983	Feoso Ambassador	Panama	Fairway (Zhongsha Reef)	Stranding	3343
7	1984	JACUI	Brazil	Fairway (Zhongsha Reef)	Stranding	757
8	1994	Prabal	Cyprus	Anchorage	Collision	100
Period I (1974-1999)		**Total 1-8**				**5524**
9	2004	Zheleyou 7	China	Fairway	Collision	3
10	2006	Fuhai	Bahama	Fairway	Collision	64
11	2014	Oriental Sunrise	Panama	Fairway	Collision	30
Period II (2000-2015)		**Total 9-11**				**97**

Source: Author Compiled from Mr. Zhao's Master Thesis (2015).

Taking the year 2000 as the boundary, the past 42 years has been divided into two periods I and II and *With and Without Comparison* method would also be applied in the calculation again. The designed equation (4-4) is :

$$Annual\ Envrionmental\ \Pr otection\ Benefit = \left(\sum_{i=1974}^{N_I} \frac{AOS_I}{N_I} - \sum_{j=2000}^{N_{II}} \frac{AOS_{II}}{N_{II}} \right) \cdot C \cdot W_{VTS} \qquad (4\text{-}4)$$

Where AOS_I and AOS_{II} are accounts of oil spilling, meanwhile N_I and N_{II} are sums of years in period I and period II respectively; and the four parameters are easy to obtain in Table 5. W_{VTS} is the weight of VTS in reduction of maritime accidents and its value is 0.1596. C is the average cost for one ton spilled oil, and due to the lack of detailed records, this parameter should be captured in light of following statistic data. According to Mr. Liu (2004, pp.3) - the former Director General of China MSA - in China, the cost of clean-up is only about RMB 13,600 for one ton oil while the international standard is 2090 pounds based on the compensation records provided by IOPC. As is known that the clean-up cost is the easiest item to acquire fund compensation; for instance, this cost accounts for about 58% in total compensation under 1971 Fund Convention, and this ratio climbs up to approximately 78% under 1992 Fund Convention (Lu, 2016, p.6). During the implementation of 1971 Fund Convention, until 2001, there are 104 claim cases and 8,606,000 pounds have been paid for fishery and aquaculture industry, and this cost accounts for about 23% of whole compensation. Some studies argue that the spilled oil would cause tremendous pollution to marine environment, and therefore, such benefit should be also calculated. However, actually the environmental damage has not been assigned into the economic loss while only a few countries accept and compensate the claim of such damage. For instance, the IOPC Fund Claims Manual states that the compensation of environment shall be accepted only when the loss could be measured by currency. Consequently, this paper would accept the reduced cost of clean-up and fishery & aquaculture industry to represent the environmental protection benefits.

Based on the above description, the clean-up cost for one ton oil in China should be considered as RMB 13,600 and accounts for 80% in the total cost, which also means that the cost of fishery occupies the rest 20 percents. Thus, the total cost C for one ton oil could be calculated in equation (4-5):

$$C = {Clean\text{-}up\ \ Cost} / {Ratio} = 13600 / 0.8 = 17000 Yuan \qquad (4\text{-}5)$$

So that,

$$Annual\ Envrionmental\ \Pr otection\ Benefit = \left(\sum_{i=1974}^{N_I} \frac{AOS_I}{N_I} - \sum_{j=2000}^{N_{II}} \frac{AOS_{II}}{N_{II}} \right) \cdot C \cdot W_{VTS} \qquad (4\text{-}6)$$

$$= (5524/26 - 97/16) \cdot 17000 \cdot 0.1596 = 558919\ Yuan$$

4.1.4 Traffic Efficiency Benefits

In general, the traffic efficiency benefits are to improve fairway capacity and to shorten navigation time based on two primary functions of VTS: *information service* and *traffic organization service*.

There are some studies claiming that the improved night-navigation or fog-navigation should be also considered (Lu, 2004, pp.21-22). And, this paper would declare that, for this case, there are no distinct differences in night and fog navigation before and after the establishment of Qingdao VTS. Therefore, the services supplied for night and fog navigation should be still allocated to daily actions. With due regard for specific circumstance of Qingdao VTS, this paper would focus on one special aspect - the large-scale vessels whose drafts exceeds 20 meters, and this kind of vessels could not navigate in the main channel whose depth of shallow spots are approximately 19.5 meters which are not competent for the large-scale vessels. For the development of local national economy, therefore, the large-scale vessels are permitted to navigate through the Navy Prohibited Area - this is the unique case in China. The particular plan for each vessel should be negotiated with North China Sea Fleet by Qingdao VTS, and then both navigation schedule and route would be designed also by Qingdao VTS and then assigned to these vessels to organize the marine traffic. According to the data provided by Qingdao Pilot Station, the saving time for each inbound large-scale vessel is about 1.2 hours.

As is known that, the large-scale vessels usually consist of two kinds of vessels: one is Very Large Ore Carrier (VLOC) who is the newborn things since 2006 at that time there were only 13 vessels severed in seaborne trade (Gu, 2006, p.113), and thus, the relevant institutions such as Clarkson and so on have not published the exact rents for VLOC (Xiang, 2010, p.29); so that the rent data should be referred to the other classical type - Very Large Crude Carrier (VLCC) - who is also the absolutely major contents amongst the imported large-scale vessels in Qingdao Port. So it is obvious to compute the benefit for large-scale vessels in equation (4-7) and Table 6:

$$Large\text{-}scale\ Vessels'\ Benefit = \sum_{i=2000}^{2015} N_i \cdot R_i \cdot \frac{1.2}{24} \quad (4\text{-}7)$$

Table 6: Calculation of Large-scale Vessels' Benefits. Unit: thousand USD/CNY

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
No. of Large Vessel	91	122	105	155	202	222	231	273	304	371	387	391	470	458	388	446
Rent of VLCC/day	50	53	25	40	65	55	80	220	160	60	45	35	30	25	35	68
$Large\text{-}scale\ Vessels'\ Benefit = \sum_{i=2000}^{2015} N_i \cdot R_i \cdot \frac{1.2}{24}$																
Benefit	**228**	**323**	**131**	**310**	**657**	**611**	**924**	**3000**	**2430**	**1110**	**871**	**684**	**705**	**573**	**679**	**1520**
Further Computation with USD/CNY Exchange Rate (1 USD=7.5 CNY)																
Benefit*	**1710**	**2420**	**980**	**2330**	**4920**	**4580**	**6930**	**22520**	**18240**	**8350**	**6530**	**5130**	**5290**	**4290**	**5090**	**11370**

Source: Author Compiled from Both Qingdao Pilot Station and Various Internet Data.

4.2 Cost

4.2.1 Basic Principle

As described in IALA VTS Manual (2012, p.65), the cost of VTS consists of two distinctive elements, namely the initial investment costs and the lifetime operating costs. All cost components should be identified and quantified in terms of amount and the budget time-line.

The initial investment costs are the total costs initially incurred, such as: preparation (e.g. feasibility studies, tendering); building works (e.g. VTS centers, radar stations, VHF masts, power/water/telephone connections); equipment purchase and installation (e.g. radar, VHF, computers, work consoles, vessels/vehicles); project management and administration; and organization set-up (e.g. recruitment and training of staff). Significantly to note that investment costs are sometimes depreciated as capital costs during the lifetime of the VTS. And at the end of VTS's lifetime, the investments should still have a residual value which needs to be deducted from the initial investment costs as present value.

The lifetime operating costs are the annual costs incurred over the lifetime of VTS for expenditure such as: maintenance and repairs of the building works and equipment(including spare parts); personnel (including additional/refresher training); consumables (e.g. power, water, telephone) and so on. Electronic equipment quickly becomes out-dated and unvalued to maintain. Therefore, regular replacement by more up-to-date equipment during the lifetime of the VTS needs to be considered in the operational costs assessment.

There are two primary methods to compute the cost of VTS, one is macro-approach and the other is micro-approach. And micro-approach is to measure and calculate all cost of the elements, such as labor force, equipment, management and etc. Actually, it is too difficult to clarify the clear boundary of each element in the practice of micro-approach. As a result, the macro-approach would be adopted to estimate the cost of Qingdao VTS.

The cost-benefit assessing of VTS belongs to the scope of economic evaluation in the domain of national economy. Both of the investment costs and operating costs are the costs paid by the national economy. Thus, the social internal transferred payments should not be listed as expenses; for instance, loan interests of the domestic banks is the content of internal transferred payments, while interests of the foreign banks shall be assigned to the costs. Both of the purchase of land and subsides which could be considered as the taxes of reverse transferred payments, are also not the contents of the costs (NDRC & MOC, 2006).

4.2.2 Practical Case of Qingdao VTS

For Qingdao VTS, the first-stage project - one center installed with German ATLAS system, as well as two radar stations have been started construction since August 1997, completed in December 1999 and then put into operation. The second-stage project - one more radar station has been established and the new Norwegian NORCONTROL system is imported to replace the former system in 2005. And the initial investment costs for the two stages were 22,000,000 Yuan and 10,000,000 Yuan respectively. The lifetime operating costs of Period I (2000-2005) were about 3,000,000 Yuan annually and costs of Period II (2006-2015) were about 5,000,000 annually. This paper supposes the lifetime of Qingdao VTS center is 20 years which complies with physical truth in China. Considering the major operating system along with a mess of electronic components have been replaced in 2005, the factor of aging equipment is not need to be taken into account due to the fact that the cost of maintenance and management would see a clear increase only since the tenth year of installation of equipment.

Because that the assumed lifetime of the civil engineering is 20 years, the rate of depreciation is 5% annually and there would be some residual value at the end of 2015. Consequently, the real initial investments cost of the Period I and II can be counted in equations (4-8) and (4-9):

$$Cost\ I = 22000000 \times (2015 - 2000 + 1) \times 5\% = 17600000\ Yuan \tag{4-8}$$

$$Cost\ II = 10000000 \times (2015 - 2005 + 1) \times 5\% = 5500000\ Yuan \tag{4-9}$$

And both investment and operating costs as well as the benefits computed above shall be corrected to the benchmark year to equalize the influence of time-value cost (NDPC & MOC, 2006). In this case, the starting year of 1997 should be regarded as the benchmark year for following evaluation; and the range of social discount rate is 2%-10% that has been promulgated by National Development and Reform Commission of China, and this paper selects the average value 6% as the specific rate. The relative cost is : $Relative\ Cost = \frac{Cost_i}{(1+6\%)^{i-1997}}$ (4-10)

Where i is the following year (i=2000, 2001…2015).

Table 7: Annual Costs of Qingdao VTS (1997-215). Unit: million Yuan.

Year / Cost	1997	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Cost	17.6	3	3	3	3	3	8.5	5	5	5	5	5	5	5	5	5	5
Relative Cost	**17.6**	**2.52**	**2.38**	**2.24**	**2.11**	**2.00**	**5.33**	**2.96**	**2.79**	**2.63**	**2.48**	**2.34**	**2.21**	**2.09**	**1.97**	**1.86**	**1.75**

Source: This Paper.

4.3 Cost Benefit Analysis

At present, more and more public projects invested by financial funds have been put into Cost Benefit Analysis in order to evaluate the effectiveness. In brief, CBA is to translate all of the influences and effects of one particular economic action into cost and benefit reflecting in monetary terms. By comparing cost and benefit, the effectiveness evaluation of the project could be determined rationally. The key, which is also the difficulty for most of the specific CBA cases is to determine the contents of both cost and benefit. Even if not all costs and benefits can be translated into monetary terms, the CBA can also assist in a more complete and rational decision-making process (IALA, 2012, p.63).

In view of the long-term implementation and influence of Qingdao VTS, the method of Economic Net Present Value (ENPV) is adopted to act as the evaluation tool due to that ENPV index could reflect time value of money. To ensure more accurate, the Benefit Cost Ratio is also accepted to analyse the efficiency. In decision-making system, the project should be considered as feasible and effective when the value of ENPV is greater than 0 or the value of B/C are greater than 1 (Wu & Zhu 2004, pp.386-340).

Table 8: Summary Statement of Costs and Benefits. Unit: million Yuan.

	1997	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Cost	17.6	3	3	3	3	3	8.5	5	5	5	5	5	5	5	5	5	5
$Relative\ Cost = \frac{Cost_i}{(1+6\%)^{i-1997}}$																	
Relative Cost	17.6	2.52	2.38	2.24	2.11	2.00	5.33	2.96	2.79	2.63	2.48	2.34	2.21	2.09	1.97	1.86	1.75
Total Cost	**57.27**																
Safety Benefit	--	2.28	2.36	2.14	1.69	1.58	2.19	1.75	2.39	1.29	2.39	2.24	2.40	2.44	2.44	2.44	2.44
Environment Benefit		0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Efficiency Benefit		1.71	2.42	0.98	2.33	4.92	4.58	6.93	22.5	18.2	8.35	6.53	5.13	5.29	4.29	5.09	11.4
Sum of Benefits		4.6	5.3	3.7	4.6	7.1	7.3	9.2	25.5	20.1	11.3	9.3	8.1	8.3	7.3	8.1	14.4
$Relative\ Benefit = \frac{Benefit_i}{(1+6\%)^{i-1997}}$																	
Relative Benefit	--	3.82	4.23	2.75	3.23	4.70	4.60	5.47	14.2	10.6	5.62	4.37	3.58	3.46	2.87	3.00	5.04
Total Benefit	**81.51**																

Source: This Paper.

$$ENPV = \sum_{t}^{n}(B_t - C_t)\cdot\frac{1}{(1+i_s)^t} = 81.51 - 57.27 = 24.24\ million\ Yuan \qquad (4\text{-}11)$$

$$BCR = \frac{\sum_{t}^{n} B_t \cdot \frac{1}{(1+i_s)^t}}{\sum_{t}^{n} C_t \cdot \frac{1}{(1+i_s)^t}} = \frac{81.51}{57.27} = 1.42 \qquad (4\text{-}12)$$

According to the equation (4-11), (4-12) and Table 8, it is so evident to state that:

1) The Economic Net Present Value (ENPV) of Qingdao VTS is 24.24 million Yuan which is far greater than 0. It is rewarding and rational for the government (China MSA) to invest capital on such project - Qingdao VTS, due to that its surplus complies with the profit of national economy considering the social discount rate.

2) The Benefit Cost Ratio (BCR) is 1.42 which is also greater than the reference value 1. Apparently to declare that such a project is feasible and should be taken into account by the authority.

The indexes of ENPV, B/C ratio, Internal Rate of Return and Pay-back Period could be used to describe the correlation between cost and benefit for various cases on basis of different mathematical methods. However, the author wants to point out that, the evaluation standards of VTS could be attempted to analyse and establish through Cost Benefit Analysis just in the field of economy, and the result computed above just represents the direct economic benefits which are only the countable part of the whole benefits of Qingdao VTS.

The method of CBA is not suitable to assess the social benefits by reason that its relevant data is hard to be obtained while the degree or scope is tough to be measured. However, practices indicate that, sometimes the proportion of social benefits, although which is impossible to be computed, could even account for the majority in the whole system (Chen, 2002, p.43). Thus, Qualitative Analysis methods - Fuzzy Comprehensive Evaluation - should be introduced as the necessary foundation in Chapter 5.

CHAPTER 5

Comprehensive Evaluation of Qingdao VTS's Socio-Economic Influence

On account of the above systemic analysis, this paper has already obtained the clear awareness on the functions, costs, direct economic benefits and CBA of Qingdao VTS. In this Chapter, the comprehensive evaluation including social benefits would be carried out by the method of *Fuzzy Comprehensive Evaluation (FCE)*.

The establishment of evaluation index system for VTS is to seek the representative methodology that could reflect and assess the VTS across-the-board. There are some methods, e.g. Culture Analysis, Data Development Analysis and FCE, which could be employed to execute the assessment. The choice of Fuzzy Comprehensive Evaluation has been made because FCE is a feasible method to deal with a partial fuzzy system with quantitative method, so that this method could not only match very well with the costs and direct economic benefits, but also with the social benefits. Meanwhile, as presented by Professor Wu (2004, pp.271-272), FCE has already made good contributions in territories of marine traffic control and maritime casualty investigation.

5.1 Marking the Factors of Social Benefits

Differing from those enterprise projects whose ultimate aims are to make profits, as a typical public project - the primary goal of VTS is to pursue comprehensive benefits for socio-economy. As mentioned above, the primary contents of Qingdao VTS could be divided into three aspects: investment costs, direct economic benefits and social benefits, while each aspect consists of some sub-items listed in Table 9:

Table 9: Contents and Factors of Qingdao VTS's Effectiveness Evaluation.

	Content	Influencing Factor
Comprehensive Social-economic Influence of Qingdao VTS	Cost	Initial Investment Cost
		Lifetime Operating Cost
	Direct Economic Benefit	Safety Benefit
		Environmental Protection Benefit
		Traffic Efficiency Benefit
	Social Benefit	Government Reputation - GR*
		Port Image - PI*
		Public Awareness - PA*
		Guarantee for Seafarer - GS*
		Support Allied Activities (Search and Rescue, etc.) - SAA*

Source: This Paper.

Evidently that the sub-items of both costs and direct economic benefits have been analysed and calculated in detail. Meanwhile, there is no suitable quantitative method to compute the sub-items belonging to social benefits. However, the means of Brain-Storming / Expert Meeting shall be brought in to dispose those fuzzy system (Skjon, 2016) (see in Appendix B). There are five levels : A, B, C, D and E with the value of 1.0, 0.8, 0.6, 0.3 and 0.1 respectively, that provided for experts to judge and choice according to the specific actions of Qingdao VTS in the relevant year. Therefore the final result is computed and showed in Table 10. Based on that, the theory of FCE could be made good use to assess the socio-economic influence of Qingdao VTS.

Table 10: Fuzzy Evaluation Datum Supplied by Experts.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
GR*	0.2	0.4	0.4	0.4	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
PI*	0.3	0.3	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
PA*	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.6	0.6
GS*	0.2	0.2	0.2	0.2	0.3	0.3	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6
SAA*	0.4	0.4	0.4	0.4	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.7	0.7	0.7	0.7	0.7

Source: This Paper. **Note: GR*, PI* and so on stand for the relevant factors listed in Table 9.**

5.2 Introduction of Fuzzy Comprehensive Evaluation

Fuzzy Comprehensive Evaluation is according to fuzzy relationship synthetic principle, and on the basis of determined factor sets, weight sets and evaluation sets. And it could analyse membership function, quantitative process, fuzzy boundary of factors through the multilevel integrated computation, eventually determine the level of evaluation objects (Li et al, 2015, p.217).

5.2.1 Basic Elements of Fuzzy

The fuzzy comprehensive evaluation mainly consists of the following elements:

1. To establish the Factor Sets.

The factor set is the foundation of evaluation, which is the various factors influencing the evaluation objects common set, and can be indicated as:

$U = \{u_1, u_2, ..., u_m\}$, where, $u_i, i = (1,2,3,...,m)$ is the evaluating factor.

2. To establish the Evaluation Sets.

Evaluation sets is composed of evaluation object judgment result sets, and can be indicated as:

$V = \{v_1, v_2, ..., v_n\}$, where, $v_j, j = (1,2,3,..., n)$ is the indicator of various possible total evaluation results.

3. To establish the Weight Sets.

According to the important degree of each factor, give different weights, then establish the weight sets:

$\mathbf{W} = \{w_1, w_2,..., w_n\}$, where, $w_i, i = (1,2,3,..., n)$, $0 \le w_i \le 1$, and $\sum_1^n w_i = 1$.

4. To establish the Membership Matrix.

Supposing that we carry out the evaluation between the factor u_i and the relevant object factor v_i, then the fuzzy vector could be obtained:

$\mathbf{R}_i = (r_{i1}, r_{i2},...r_{in})$, where $i = (1,2,3,..., m)$ and $j = (1,2,3,..., n)$.

If we carry out evaluation on all the factors in factor set $U = \{u_1, u_2,..., u_m\}$, then we would obtain the $n \times m$ membership matrix (5-1):

$$\mathbf{R} = \begin{bmatrix} r_{11} \ r_{12} \cdots r_{1n} \\ r_{21} \ r_{22} \cdots r_{2m} \\ \cdots\cdots\cdots\cdots \\ r_{n1} \ r_{n2} \cdots r_{nm} \end{bmatrix} \quad (5\text{-}1)$$

5. To calculate the final Evaluation Results.

According to the Weight sets and evaluation matrix Calculate factors layer and index layer fuzzy comprehensive evaluation sets:

$$\mathbf{B} = \mathbf{W} \circ \mathbf{R} = \{w_1, w_2,..., w_n\} \circ \begin{bmatrix} r_{11} \ r_{12} \cdots r_{1n} \\ r_{21} \ r_{22} \cdots r_{2m} \\ \cdots\cdots\cdots\cdots \\ r_{n1} \ r_{n2} \cdots r_{nm} \end{bmatrix} = (b_1, b_2, \cdots b_m) \quad (5\text{-}2)$$

Where, $bj = \sum_1^n w_i r_{ij}$.

5.2.2 Determination of Weights

After the selection of indexes, the next process is to determine the weight for each factor, which is also the key point. Presently, there are two main methods: one is subjective weighting method while the other is objective weighting method. The subjective method would invite the experienced professors to participate in the questionnaire survey or expert meeting, hoping to achieve the reasonable decision. To some degree, the subjective method also could be a certain kind of objective while the evaluation standards are judged in light of the long-term practice supplied by competent experts. In contrast, the most obvious difference of objective method is that it would likely depend on the analysis of statistic data rather than the experts' opinions to give a weight for each factor (Li, 2010, p.76). Considering the characters of convenience and maneuverability, this paper would adopt questionnaire survey (see in Appendix B) to assign the specific weight that is showed in Figure 9.

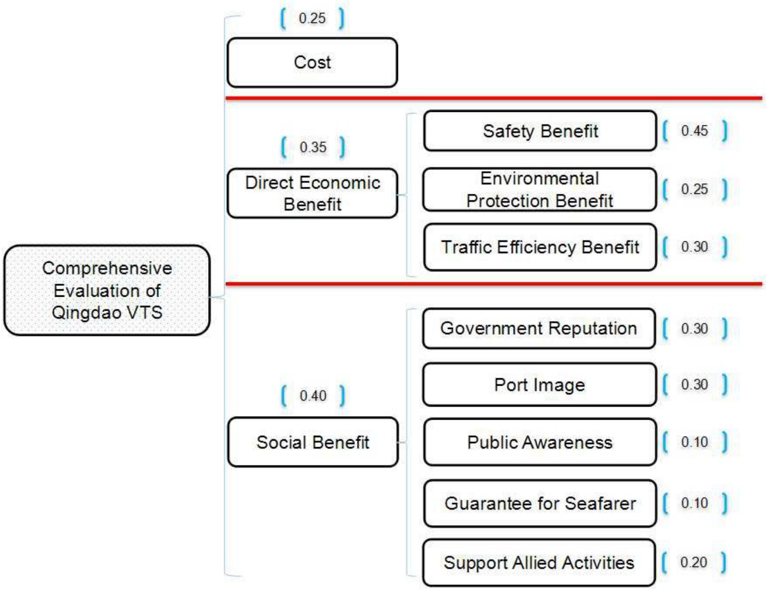

Figure 9: Comprehensive Evaluation Factors of VTS.
Source: This Paper.

5.3 Practical Case

Firstly all these factors should be collected, compiled and showed in Table 11, and the following procedure is to dispose these initial indexes with normalization method to achieve the membership matrix (5-3).

Table 11: Values of the Factors 2000 - 2015.

Year / Factor	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Cost	2.52	2.38	2.24	2.11	2.00	5.33	2.96	2.79	2.63	2.48	2.34	2.21	2.09	1.97	1.86	1.75
Benefit 1	2.28	2.36	2.14	1.69	1.58	2.19	1.75	2.39	1.29	2.39	2.24	2.40	2.44	2.44	2.44	2.44
Benefit 2	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Benefit 3	1.71	2.42	0.98	2.33	4.92	4.58	6.93	22.5	18.2	8.35	6.53	5.13	5.29	4.29	5.09	11.4
GR*	0.2	0.4	0.4	0.4	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
PI*	0.3	0.3	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
PA*	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.6	0.6
GS*	0.2	0.2	0.2	0.2	0.3	0.3	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6
SAA*	0.4	0.4	0.4	0.4	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.7	0.7	0.7	0.7	0.7

Source: This Paper.

$$\mathbf{R} = \begin{bmatrix} 0.0635 & 0.0600 & 0.0565 & 0.0532 & 0.0504 & 0.1344 & 0.0746 & 0.0703 & 0.0663 & 0.0625 & 0.0590 & 0.0557 & 0.0527 & 0.0497 & 0.0469 & 0.0441 \\ 0.0662 & 0.0685 & 0.0621 & 0.0490 & 0.0459 & 0.0636 & 0.0508 & 0.0694 & 0.0374 & 0.0694 & 0.0650 & 0.0696 & 0.0708 & 0.0708 & 0.0708 & 0.0708 \\ 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 \\ 0.0155 & 0.0219 & 0.0089 & 0.0211 & 0.0445 & 0.0414 & 0.0626 & 0.2033 & 0.1645 & 0.0755 & 0.0590 & 0.0464 & 0.0478 & 0.0388 & 0.0460 & 0.1030 \\ 0.0211 & 0.0421 & 0.0421 & 0.0421 & 0.0526 & 0.0632 & 0.073 & 0.0737 & 0.0737 & 0.0737 & 0.0737 & 0.0737 & 0.0737 & 0.0737 & 0.0737 & 0.0737 \\ 0.0280 & 0.0280 & 0.0467 & 0.0561 & 0.0561 & 0.0561 & 0.0654 & 0.0654 & 0.0748 & 0.0748 & 0.0748 & 0.0748 & 0.0748 & 0.0748 & 0.0748 & 0.0748 \\ 0.0351 & 0.0351 & 0.0351 & 0.0351 & 0.0351 & 0.0526 & 0.0526 & 0.0526 & 0.0702 & 0.0702 & 0.0702 & 0.0702 & 0.0877 & 0.0877 & 0.1053 & 0.1053 \\ 0.0256 & 0.0256 & 0.0256 & 0.0256 & 0.0385 & 0.0385 & 0.0641 & 0.0641 & 0.0897 & 0.0897 & 0.0897 & 0.0897 & 0.0897 & 0.0897 & 0.0769 & 0.0769 \\ 0.0412 & 0.0412 & 0.0412 & 0.0412 & 0.0619 & 0.0619 & 0.0619 & 0.0619 & 0.0619 & 0.0825 & 0.0825 & 0.0722 & 0.0722 & 0.0722 & 0.0722 & 0.0722 \end{bmatrix} \quad (5-3)$$

According to formula (5-2),

$$\mathbf{B} = \mathbf{W} \circ \mathbf{R} = \{w_1, w_2, \ldots, w_n\} \circ \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix} =$$

$$\{0.25, 0.1575, 0.0875, 0.105, 0.12, 0.12, 0.04, 0.04, 0.08\} \circ \begin{bmatrix} 0.0635 & 0.0600 & 0.0565 & 0.0532 & 0.0504 & 0.1344 & 0.0746 & 0.0703 & 0.0663 & 0.0625 & 0.0590 & 0.0557 & 0.0527 & 0.0497 & 0.0469 & 0.0441 \\ 0.0662 & 0.0685 & 0.0621 & 0.0490 & 0.0459 & 0.0636 & 0.0508 & 0.0694 & 0.0374 & 0.0694 & 0.0650 & 0.0696 & 0.0708 & 0.0708 & 0.0708 & 0.0708 \\ 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 & 0.0625 \\ 0.0155 & 0.0219 & 0.0089 & 0.0211 & 0.0445 & 0.0414 & 0.0626 & 0.2033 & 0.1645 & 0.0755 & 0.0590 & 0.0464 & 0.0478 & 0.0388 & 0.0460 & 0.1030 \\ 0.0211 & 0.0421 & 0.0421 & 0.0421 & 0.0526 & 0.0632 & 0.073 & 0.0737 & 0.0737 & 0.0737 & 0.0737 & 0.0737 & 0.0737 & 0.0737 & 0.0737 & 0.0737 \\ 0.0280 & 0.0280 & 0.0467 & 0.0561 & 0.0561 & 0.0561 & 0.0654 & 0.0654 & 0.0748 & 0.0748 & 0.0748 & 0.0748 & 0.0748 & 0.0748 & 0.0748 & 0.0748 \\ 0.0351 & 0.0351 & 0.0351 & 0.0351 & 0.0351 & 0.0526 & 0.0526 & 0.0526 & 0.0702 & 0.0702 & 0.0702 & 0.0702 & 0.0877 & 0.0877 & 0.1053 & 0.1053 \\ 0.0256 & 0.0256 & 0.0256 & 0.0256 & 0.0385 & 0.0385 & 0.0641 & 0.0641 & 0.0897 & 0.0897 & 0.0897 & 0.0897 & 0.0897 & 0.0897 & 0.0769 & 0.0769 \\ 0.0412 & 0.0412 & 0.0412 & 0.0412 & 0.0619 & 0.0619 & 0.0619 & 0.0619 & 0.0619 & 0.0825 & 0.0825 & 0.0722 & 0.0722 & 0.0722 & 0.0722 & 0.0722 \end{bmatrix}$$

$$= (0.0450, 0.0477, 0.0467, 0.0462, 0.0509, 0.0763, 0.0650, 0.0816, 0.0744, 0.0708, 0.0675, 0.0652, 0.0655, 0.0638, 0.0641, 0.0693)$$

Table 12: Final Value of the Comprehensive Index for Qingdao VTS 2000-2015.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
INDEX	0.0450	0.0477	0.0467	0.0462	0.0509	0.0763	0.0650	0.0816	0.0744	0.0708	0.0675	0.0652	0.0655	0.0638	0.0641	0.0693

Source: This Paper.

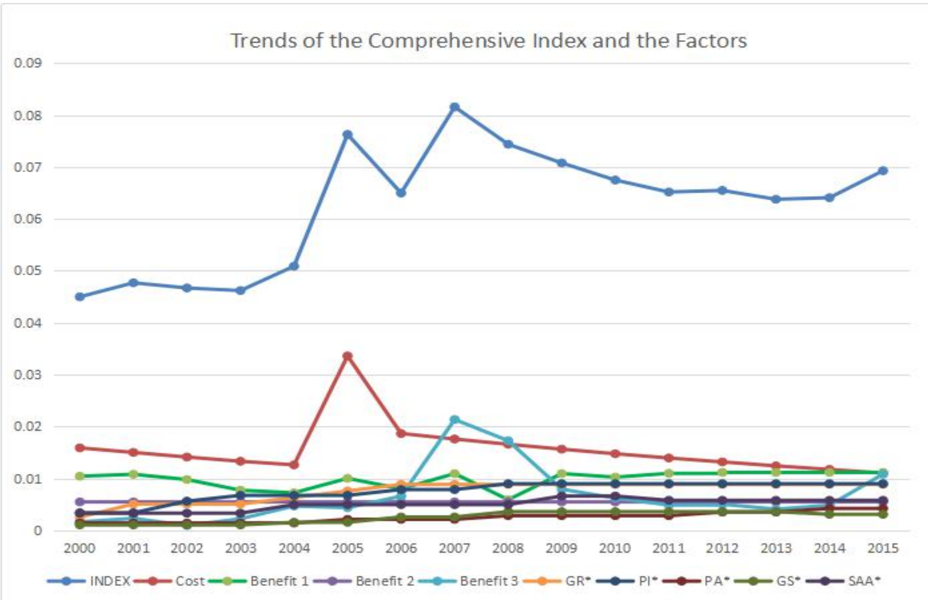

Figure 10: Trends of the Comprehensive Index along with the Factors.
Source: This Paper.

A glance at Figure 10, firstly and most vitally, it could see a significant growth of the curve - Comprehensive Index - during the period from 2003 to 2015. This trend obviously indicates that the comprehensive evaluation of Qingdao VTS's socio-economic influence has kept climbing up since 2003, and reached at the high level around 2007, and then still maintain at the stable and good value.

Also it is evident to see that, the Index curve reaches at two peaks, at 0.0763 in 2005 and at 0.0816 in 2007 respectively. The primary reason for the 2005 is the huge contribution of investment cost - the third radar station has been established and the new NORCONTROL system has been imported from Norway to replace former one in that year. Meanwhile, the main causes for the 2007 are the contributions provided by benefit 1 (safety benefit) and benefit 3 (traffic efficiency benefit), and both of the two factors stand at their highest points; however, apparently the deep reason is the booming and even crazy shipping industry lead to that unique period.

Another point is that, the Comprehensive Index curve stays at a low and stead level in the beginning 4 years (2000-2003) due to that all of the factors remain at the low standards, so that the early 3-5 years could be considered as the run-in period for a new VTS center.

CHAPTER 6

Summary and Conclusion

6.1 Limitation of This Study

This paper has focused on the effectiveness evaluation of a particular case - Qingdao VTS center. Just like most of the other studies which also carry out the similar researches on VTS, there are two fundamental limitations which should be presented and hopefully be conquered in further research.

6.1.1 Lack of Data

Maybe most of the similar studies would suffer from the embarrassing lack of relevant data. For instance, the traffic efficiency benefits (Chapter 4) are impacted greatly on account of that only the improved efficiency of large-scale vessels has been taken into account; and, the most major component - the vessels whose drafts below 20 meters - have to be ignored by the author artificially, which could generate the huge loss for the total benefits and then the final comprehensive index would be underestimated absolutely. The significant cause is that, both the authority - Qingdao MSA and the Pilot Station just do the simple statistics on the number of these vessels rather than the detailed types, sizes and average navigation time.

6.1.2 Systemic Error

Although this paper has adopted Delphi Method and expert meeting to judge and grade VTS's weight in probability reduction of maritime accidents as well as the various factors' weights in comprehensive evaluation of VTS respectively. However, on purpose of overcoming the systemic errors, e.g. subjectivity or uncertainty, the common features and demands for both the two methodologies are that: the sample size of experts should be as sufficient as possible and these experts should be independent, experienced and objective adequately. In practice, the actual operation may try the best but could hardly achieve the optimal level within the restricted time and resources.

6.2 Conclusion

By providing safe and effective services, the VTS facility could generate huge benefits that feature the non-excludable and non-rival characteristics of public goods (Lee et al, 2015, p.153). Due to that the construction of a VTS facility requires the governmental support, quantifying the economic value and study the social influence of a VTS facility, via the CBA and FCE are of great importance. Therefore, this study devised an analytic tool to capture effectiveness evaluation of a non-market nature for such projects.

In this paper, we present a framework to analyse the effectiveness evaluation of Qingdao VTS. With the aim to provide suggestion and reference for decision-makers, this paper employs the Grey System theory to study the relationship between VTS and regional economy; uses With and Without Comparison method to compute the direct economic benefits; introduce Fuzzy Comprehensive Evaluation to assess the socio-economic influence of VTS. And the method of Delphi and expert meeting have played significant roles in the determinations of VTS's weight in accident reduction and weights allocation of social benefits respectively. For case study, the project of Qingdao VTS is evaluated with the 17-year data. And on basis of the analysis, this paper would like to restate the following core points.

Firstly, this paper has developed a deep study on the effectiveness evaluation on Qingdao VTS. It is meaningful and vital for that VTS because that this paper has filled its nearly two-decades' gap, and also significantly is that it proves Qingdao VTS is a rewarding and effective public project who is closely related to the regional economy.

Another critical point is that, the result of this study illustrates Qingdao VTS's socio-economic influence is also highly crucial to the shipping industry and maintains a stable and incremental trend since its establishment in 1999.

Furthermore, the analytical results could serve as a reliable starting point in strategic planning for the authority to develop policies on the similar port VTS centers. It is expected that this study will motivate future research in this area, the results of which will help draft policies encouraging VTS development and also for the ultimate goals of IMO: *Safe, secure and efficient shipping on clean oceans*.

Word count: 10557.

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APPENDIX 1

QINGDAO VTS GUIDE FOR USERS

Edition Ⅱ

2010-01-01

1．Qingdao VTS Center：

Name: Vessel Traffic Service Center, Qingdao Maritime Safety Administration of The People’s Republic of China
Add: Maritime Building, 21 Wuxia Road, Qingdao, P.R.China
Post Code: 266002
Fax: +86-532-82680919
Tel: +86-532-86671271 86671272 82826589
Maritime Distress Emergency Call: +86-532-12395
E-mail: vtsqd@sdmsa.gov.cn qdvts@263.net

2. VTS Services

2.1 Users

Vessels of 50m in length or above， and other vessels requiring services.

2.2 VTS Area

The water area within the reporting lines regulated in "The Ship’s Reporting System in Qingdao Water Area", but the following areas can not be effectively covered by the VTS radars:
(1) Basin waters and the waters of quayside
(2) The waters of Xiaocha Wan and Xuejia Dao Wan
(3) The waters north of Jiaozhou Wan Bridge

2.3 Services Provided

Information service, navigational assistance service and traffic organization service are available.

2.4 Working Time

24 hours

2.5 Working Language

Mandarin & English

3 Public VHF Channel

CALL SIGN	VHF CHANNEL
QINGDAO VTS	08
QINGDAO PILOT	09
QINGDAO RADIO	16

4 Reports

CATEGORY	Calling-in-points(CIP)	GIVING
Entry Report	1.**Foreign vessels**: when being abeam of Chaolian Dao 2.When passing the line joining Dagong Dao and Xiaogong Dao 3. When passing the line extended eastward and westward from Lian Dao Light Beacon on the east of Zhucha Dao 4.When being abeam of Tuandao Zui Lighthouse（vessels equipped with AIS are released） 5. All fast in berth	1. vessel's name and call sign 2. vessel's position 3.vessel's draft （at the initial report） 4. other information required by VTS
Departure Report	1.Before departing 2. When being abeam of Tuandao Zui Lighthouse（vessels equipped with AIS are released） 3.When passing the line joining Dagong Dao and Xiaogong Dao 4. When passing the line extended eastward and westward from Lian Dao Light Beacon on the east of Zhucha Dao	1.vessel's name and call sign 2.vessel's position 3.next port of call 4. other information required by VTS
Anchorage Report	1.After anchoring 2.Before heaving up anchor	1.vessel's name and call sign 2.vessel's position 3. other information required by VTS
Special Report	1. When being involved in or finding any traffic accident 2. When bringing on or finding any abnormality of navigation aids 3. When finding obstructions 4. When being involved in pollution incident or finding polluted waters 5.Vessel not under command 6.Other emergency or abnormal situation	1. vessel's name and call sign 2. detail 3. other information required by VTS

5 Route regulations

5.1 Vessels of 50m in length or above shall navigate in the traffic lanes only; the others shall navigate in the navigable waters out of the traffic lanes.
5.2 Vessels navigating in the No.1 traffic lane of Qingdao TSS (Traffic Separation Scheme) shall proceed with the speed less than 10 knots, and overtaking is prohibited.
5.3 Vessels entering the No.1 traffic lane from north of the dummy navigation mark in the No.1 precautionary area and vessels leaving the No.1 traffic lane from south of the dummy navigation mark in the No.1 precautionary area must pass by the west of dummy navigation mark, and navigate with caution.
5.4 When seaplanes take off or land in Seaplane Area, the relevant vessels shall use the provisional fairway which join the following two points:
36 ° 04 '.300 N, 120 ° 15' .650 E
36 ° 02 '.550 N, 120 ° 15' .250 E
in course 190 ° - 010 °.
5.5 Without approval, foreign vessels are prohibited to enter the fourth line of Qingdao harbor.

6 Pilot Boarding Area

6.1 Vessels with a draft of less than 15 meters:
No.2 precautionary area of the TSS (Traffic Separation Scheme) in Qingdao waters, bounded by a line joining the following four positions :
36 ° 01 '.783 N, 120 ° 19' .183 E
36 ° 01 '.133 N, 120 ° 19' .017 E
36 ° 01 '.583 N, 120 ° 20' .400 E
36 ° 00 '.900 N, 120 ° 20' .200 E
6.2 Vessels with a draft of 15 meters or above:
NO.1 Temporary Boarding Position: 35°50′.00N/120°16′.00E
NO.2 Temporary Boarding Position: 35°48′.50N/120°16′.00E
NO.3 Temporary Boarding Position: 35°47′.00N/120°15′.00E

7 The Relevant Regulations:

7.1 The vessels using "The Ship Reporting System in Qingdao Water Area" shall keep watching on VHF Channel 08 while Navigating and being at anchor.
7.2 Without approval, anchoring outside anchorage is prohibited.

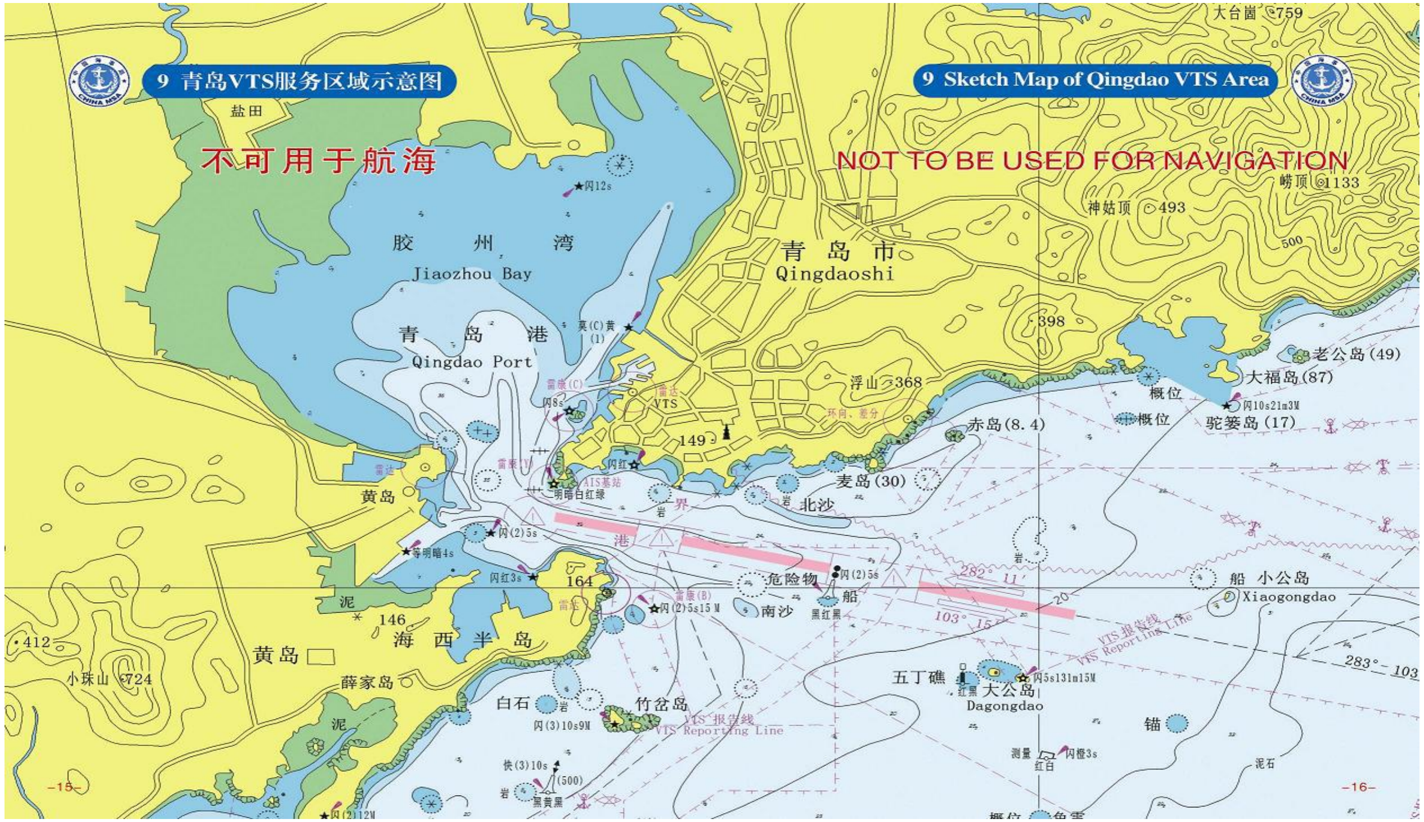
7.3 Without approval, navigation trial and/or speed-test in fairway and anchorage are prohibited.
7.4 Without approval, mooring side by side and/or overside delivery in anchorage are prohibited.

8 Responsibilities

8.1 Under all circumstances, any service, information, advice, warning and instruction provided by Qingdao VTS are only reference for masters and pilots.

8.2 Under all circumstances, Qingdao VTS operations do not exempt the master and the pilot from the responsibility for safe navigation and do not disturb the traditional relationship between them.

9. Sketch Map of Qingdao VTS Area



APPENDIX 2

Questionnaire

Dear Expert:

Thank you so much for your attention to this questionnaire. And the author is carrying out the research on the effectiveness evaluation of Qingdao VTS. So glad to hear that sir you are the experienced and senior expert in this field, and invite you to participant in this survey. I really hope to get your precious help and support through completing this questionnaire on basis of the physical truth. And this questionnaire consists of three main parts as follows.

1. Assigning Weights for Factors related to Accident Reduction.

This is a series of tables that reflect the roles of Qingdao VTS and other factors in the reduction of accident probability (collision, grounding and stranding). Now please assign the specific weight for each factor, and notable to state that the summation of each table's weights should be 1.

Table 1 Weights of the Four Essential Factor in Accident Reduction.

Factor / Weight	Human	Ship	Environment	Management
Weight				

Table 1.1 Weights of Two Main Factors in Human.

Factor / Weight	Maritime Factor	Non-Maritime Factor
Weight		

Table 1.1.1 Weights of Two Main Factors in Maritime Factor.

Factor / Weight	VTS Factor	Non-VTS Factor
Weight		

Table 1.2 Weights of Two Main Factors in Ship.

Factor / Weight	Maritime Factor	Non-Maritime Factor
Weight		

Table 1.2.1 Weights of Two Factors in Maritime Factor.

Factor / Weight	VTS Factor	Non-VTS Factor
Weight		

Table 1.3 Weights of Two Main Factors in Environment.

Factor / Weight	Maritime Factor	Non-Maritime Factor
Weight		

Table 1.3.1 Weights of Two Factors in Maritime Factor.

Factor / Weight	VTS Factor	Non-VTS Factor
Weight		

Table 1.4 Weights of Two Main Factors in Management.

Factor / Weight	Maritime Factor	Non-Maritime Factor
Weight		

Table 1.4.1 Weights of Two Factors in Maritime Factor.

Factor / Weight	VTS Factor	Non-VTS Factor
Weight		

2. Marking for the Comprehensive Evaluation Factors of VTS.

This is a series of tables that concern the primary factors which impact the socio-economic influence of Qingdao VTS. Now please mark the specific weight for each factor, and the summation of each table's weights should also be 1.

Table 2 Weights of Three Essential Factors related to Socio-economic Influence.

Factor / Weight	Cost	Direct Economic Benefit	Social Benefit
Weight			

Table 2.1 Weights for Three Main Factors of Direct Economic Benefit.

Factor / Weight	Safety Benefit	Environmental Protection Benefit	Traffic Efficiency Benefit
Weight			

Table 2.2 Weights for Five Main Factors of Social Benefit.

Factor / Weight	Government Reputation	Port Image	Public Awareness	Guarantee for Seafarers	Support Allied Activities
Weight					

3. Grading for the Contents of Social Benefits.

Considered that, there is no suitable quantitative method to compute the contents belonged to social benefits. However, this paper provides five levels : A, B, C, D and E with the value of 1.0, 0.8, 0.6, 0.3 and 0.1 respectively, and please fill the Table 3 with the levels mentioned above in light of your experience as well as the specific actions of Qingdao VTS in the relevant year.

Table 3 Grading for the Contents of Social Benefits.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
GR*																
PI*																
PA*																
GS*																
SAA*																

Note: GR* is the Government Reputation; **PI*** is the Port Image; **PA*** is the Public Awareness; **GS*** is the Guarantee for Seafarers; **SAA*** is the Support Allied Activities.

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Thank you so much again! Best regards!