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Research on the benefit evaluation of ships' routeing systems in Jiangsu Section of the Yangtze River

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RESEARCH ON THE BENEFIT EVALUATION OF SHIPS' ROUTEING SYSTEMS IN JIANGSU SECTION OF THE YANGTZE RIVER

By

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The People's Republic of China

A research paper submitted to the World Maritime University in partial Fulfillment of the requirements for the award of the degree of

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Declaration

I certify that all the material in this research paper 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 research paper reflect my own personal views, and are not necessarily endorsed by the University.

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Abstract

Title of Research paper: **Research on the Benefit Evaluation of Ships' Routeing Systems in Jiangsu Section of the Yangtze River**

Degree: **MSc**

The Ships' Routeing Systems in Jiangsu section of the Yangtze river(SRSJS) is the first ships' routeing system for the inland river in China. This system fundamentally solves the contradiction between the traditional backward navigation rules of the Yangtze river and the development of modern shipping. Since the implementation of this system, the navigation order of the Jiangsu section has been fundamentally improved, and the economic and social development of Jiangsu province has been promoted rapidly.

This dissertation makes a comprehensive benefit evaluation of the Ships' Routeing Systems in Jiangsu section from three aspects: safety benefit, social benefit and economic benefit.

Firstly, this dissertation evaluates the safety benefits of the SRSJS from the perspective of navigation safety and navigation efficiency. In addition, the questionnaire is used to collect the feedback of seafarers, pilots and shipping companies on the SRSJS.

Secondly, this dissertation comprehensively evaluates the social benefits brought by the SRSJS from the aspects of improving port competitiveness, promoting local employment and reducing environmental pollution.

Thirdly, this dissertation calculates the economic benefits of SRSJS by using multiple linear regression prediction model.

Finally, This dissertation analyzes the new changes brought by the implementation of the SRSJS, and puts forward some reasonable suggestions.

KEY WORDS: SRSJS, comprehensive benefit evaluation, safety benefit, social benefit, economic benefit, questionnaire, multiple linear regression prediction model

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List of Abbreviations

AHP	Analytic hierarchy process method
COLREGS	Convention on the International Regulations for Preventing Collisions at Sea, 1972
IMO	International Maritime Organization
MSA	Maritime Safety Administration
SRSJS	Ships' Routeing Systems in Jiangsu Section of the Yangtze River
SOLAS	International Convention for the Safety of Life at Sea
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
VTS	Vessel Traffic Service

Chapter 1 Introduction

1.1 Background

The Yangtze River shipping has been playing a very important role in China's economic and social development. The Jiangsu section is located in the lower reaches of Yangtze River, which is one of the busiest river segments in the world.

For a long time, the ship's navigation in the Jiangsu section shall comply with the “Rules for Preventing Collision between Vessels on Inland Waters of People's Republic of China”. The principle of navigation is that “downstream vessels should go along the main stream channel, upstream vessels should go along the weak stream channel”, which makes the seagoing vessel competing with the small river boat, interferes with each other. As a result, the navigation environment becomes chaotic, causing difficulties in navigation of the seagoing vessels. Moreover, the night navigation is prohibited.

In 1996, the “Navigation Rule of Lower Reaches of Yangtze River” was implemented in Jiangsu section. This rule had improved the navigation environment to some extent, but because the principle of navigation did not jump out of the habit of “downstream vessels should go along the main stream channel, upstream vessels should go along the weak stream channel”, the navigable environment was still complex, especially the issues like route overlap, unnecessary Ship Crossing Areas (Wu Naiping, 2000).

According to statistics, from 1996 to 2001, only in the crossing areas, there were 133 collisions, resulting in 95 shipwrecks and 103 deaths(Jiangsu MSA, 2013). So we can see that “Navigation rule” is the prominent problem in the Jiangsu section of Yangtze River.

In addition, the number of ships and freight volume have increased year by year in Jiangsu section. However, due to the constraints of many factors, the seagoing vessel can not navigate at night, resulting in the longer operation period and higher operating cost. Shipping companies and ports are increasingly pressing to push forward the reform of ship route and early realization of night navigation.

In order to improve the navigation environment, on July 1, 2003, the regulation of Ships’ Routeing Systems in Jiangsu Section of the Yangtze River (SRSJS) was formally implemented. This is the first time to introduce the Ships’ Routeing System to the inland river in China, and it is a milestone for the inland river shipping in China. After that, the navigation order of the Jiangsu section has been fundamentally improved, and the economic and social development of Jiangsu province has been promoted rapidly. Since 2005, the Yangtze River freight volume has won the world's first inland waterway freight volume for eight consecutive years, and has become a truly "golden waterway".

1.2 The development and research status of Ships’ Routeing System

In order to improve ship safety and navigation efficiency, as early as 1847, the shipping industry began to practice sailing according to scheduled routes.

Up to now, the ships’ routeing system has proved to be an effective method to regulate navigation in congested shipping areas, and reduce the number of accidents. The related provisions can be found in some international conventions.

In UNCLOS(United Nations, 1982), Article 22 states:

> The coastal State may, where necessary having regard to the safety of navigation, require foreign ships exercising the right of innocent passage through its territorial sea to use such sea lanes and traffic separation schemes as it may designate or prescribe for the regulation of the passage of ships.

In SOLAS Chapter V, Regulation 10(IMO, 2017) states:

> Ships' routeing systems contribute to safety of life at sea, safety and efficiency of navigation and/ or protection of the marine environment. Ships' routeing systems are recommended for use by, and may be made mandatory for, all ships, certain categories of ships or ships carrying certain cargoes, when adopted and implemented in accordance with the guidelines and criteria developed by the Organization.

Furthermore, Rule 10 of the COLREGS (IMO, 2017) also stipulates the Traffic Separation Schemes:

> A vessel using a traffic separation scheme shall:
>
> (I) proceed in the appropriate traffic lane in the general direction of traffic flow for that lane;
>
> (II) so far as practicable keep clear of traffic separation line or separation

zone;

(III) normally join or leave a traffic lane at the termination of the lane, but when joining or leaving from either side shall do so at as same an angle to the general direction of traffic flow as practicable.

The current status of the research on the ships' routeing system is as follows:

Wang Ling(2007) conducts a social evaluation of the ships' routeing system in the Anhui section of the Yangtze River by means of questionnaire survey.

Xing Yongheng(2008) uses fuzzy mathematics theory to evaluate the ships' routeing system in Lao Tie Shan waterway.

Yin Xianming(2011) uses AHP method to evaluate the routeing schemes of Rizhao Port waters.

Cui Juan(2012) introduces the time series analysis method into the safety effect evaluation after the implementation of the ships' routeing system, which provides a quantitative method for the maritime management department to evaluate the ships' routeing system.

Hu Zonghua(2012) makes an evaluation of the large ships routeing scheme in the eastern part of Chengshan Jiao through questionnaires.

Fan Zhongzhou(2013) uses AHP, extension theory and fuzzy neural network to evaluate and optimize the ships' routeing system.

Feng Zi Jian(2015) uses AHP to evaluate the implementation of the ships' routing system in the Pearl River estuary waters.

Through analyzing the navigation environment and other factors, Wang Wei(2015) puts forward the navigation safety improvement measures after the implementation of the Chengshan Jiao ships' routing system.

Sun Hao(2016) uses the questionnaire and the mean square deviation method to evaluate the ships' routeing system of Dan Gan waterways.

Li Jiang(2017) makes use of the TOPSIS method (approaching ideal solution ranking method) to select and optimize the alternatives of ships' routing system.

In the foreign researches, taking the Dover Straits as an example, M.J. Barratt(1973) researches the encounter rate of ship traffic flow, mainly based on the recommended route theory and the multi-ships encounter situation.

Taking the England waterway and the Dover Strait as an example, D.R. Johnson (1973) puts forward the prediction method of traffic flow.

B.A.Colley et al.(1984) proposes a collision avoidance method based on computer simulation for ship traffic flow.

Roger Motte(1996) puts forward the relationship between safety navigation and ship accidents and the application of new technologies.

Inoue, K.(2000) proposes a quantitative model to assess the safety of navigation in restricted areas or traffic congested areas, so as to better design the ship's route.

Taking the Dover Strait as an example, Commodore David Squire(2003) puts forward the relations between the navigation rules of the Straits, the types of ships, the nature of the goods, the weather and geographical conditions, the pilotage service, and the safe navigation of the ship.

Wlodzimierz Filipowicz(2004) puts forward some factors that should be taken into consideration in various ports and restricted waters, including the role of supervision and the correct operation of crew.

Kum, S.(2008) puts forward the relationship between the labor intensity of VTS supervisors and ship safety.

Ozgecan S. Uluscu et al.(2009) put forward a mathematical model of process scheduling to improve the efficiency of ship entry and exit the port. At the same time, this mathematical model can also be applied to traffic separation schemes.

Tsou, M. C.and Hsueh, C.K.(2010) propose the path planning of ship based on ant colony algorithm to determine the best route of ships.

Ming-Cheng Tsou et al.(2010) propose a collision avoidance system based on genetic algorithm to improve the navigation safety of ships.

S.J.Bijlsma(2010) proposes the best route for ships according to the direction of flow and velocity.

Seong et al.(2012) put forward the idea that the width of the channel should be determined according to the traffic flow.

Chien-Min Su et al.(2012) propose a new decision-making method for ship collision avoidance. When a ship is at risk of collision, it can analyze the probability of collision and issue an early warning.

Toke Koldborg Jensen, Martin Gamborg Hansen & Tue Lehn-Schioler(2013) put forward the idea of evaluating the efficiency of traffic separation scheme according to traffic flow in busy or restricted waters.

Yip, T. L.(2013) proposes a traffic flow model based on traffic flow theory, and this model has been applied.

Rafal Szlapczynski(2013) proposes the use of evolutionary algorithm to research the optimal trajectory of ships in the traffic separation schemes.

Although there are some researches on ships' routeing system both at home and abroad, the comprehensive benefit evaluation of routeing system is relatively few. So it is necessary to further study the comprehensive benefit evaluation of the routeing system.

1.3 Objectives of research

.1 Through the statistics of relevant data, from safety benefit, social benefit and economic benefit three aspects, this dissertation systematically analyzes the great positive role of the SRSJS in reducing ship accidents, improving navigation order, and promoting the economic and social development in Jiangsu section of the Yangtze river. Furthermore, it provides a reference method for the utility evaluation of ships' routeing system.

.2 This dissertation also analyzes the new changes brought by the implementation of the SRSJS, and puts forward some reasonable suggestions.

1.4 Methodology

.1 Data investigation and collection methods

The relevant technical documents, the national economic and social development report, the statistical yearbook, the newspaper periodicals, the network media and the special investigation report on the implementation of the ships' routeing system in the Jiangsu section of the Yangtze River are collected by the literature method.

.2 Questionnaire investigation

In the form of questionnaires, the crew members, shipping companies and pilots are asked to make comprehensive evaluation and suggestions on the ships' routeing system in the Jiangsu section of the Yangtze River.

.3 Comparison method

By comparing the indexes under "no project" and "have project" (ships' routeing system), the positive effect of the ships' routeing system can be obtained.

.4 Incremental benefit analysis -- prediction method based on mathematical model

In this paper, the incremental benefit analysis method is used to evaluate the economic benefit of the ships' routeing system. Among them, the mathematical prediction model will adopt multiple linear regression equation.

1.5 Structure of dissertation

This dissertation consists of six chapters followed by three appendices.

Chapter two analyzes the main content, innovation point and implementation of the SRSJS.

Chapter three evaluates the safety benefits of the SRSJS from the perspective of navigation safety and navigation efficiency. In addition, the questionnaire is used to collect the feedback of seafarers, pilots and shipping companies on the SRSJS.

Chapter four comprehensively evaluates the social benefits brought by the SRSJS from the aspects of improving port competitiveness, promoting local employment and reducing environmental pollution.

Chapter five calculates the economic benefits of SRSJS by using multiple linear regression prediction model.

Chapter six summarizes the whole paper and puts forward some reasonable suggestions.

Chapter 2 Basic information of SRSJS and its innovations

2.1 Application

The term “navigable waters in Jiangsu section of Yangtze River” means navigable waters promulgated by the administration with the connection line between Cihu river mouth at south bank of Yangtze River (31°46′30″N/118°29′48″E) and Wujiang river mouth at north bank of Yangtze River (31°50′42″N/118°29′24″E) as upper boundary, and the connection line between Liuheiwu (30°30′52″N/121°18′54″E) and Shixin Beacon (31°37′34″N/121°22′30″E) as lower boundary(Ministry of Transport, 2003).

2.2 The main contents of SRSJS

The SRSJS follows the principles of “separating large vessels traffic flow from small vessels traffic flow, avoiding the crossing of traffic routes, navigating on the right side respectively, and liability for fault”.

The relevant provisions (Ministry of Transport, 2003) are as follows:

1 Channel and Routes

Article 5 ：Deep-water channel

Deep-water channel generally arranged in the vicinity of the thalweg is provided mainly for the use of large vessels.

Article 6 ：Traffic lane and separation zone

The upbound traffic lane, downbound traffic lane and separation zone in deep-water channel shall hold respectively two-fifth, two-fifth and one-fifth of the channel width.

Article 7 ：Auxiliary route

Auxiliary route is set up in the waters outside the lateral marks of deep-water channel and provided for the use of small vessels.

2 Navigation Rules

Article 10：Every vessel shall at all times proceed at safe speed in order to avoid any occurrence.

Every vessel, in the case of not endangering the safety of other vessels and facilities, shall proceed at speed of not more than 15 knots and of not less than 4 knots, and while navigating in the traffic lanes below the lower limit buoy of the TaiZhou Highway Bridge water areas, shall proceed at speed of not less than 6 knots in normal conditions.

Article 12 ：Every vessel proceeding within the deep-water channel shall navigate in the prescribed traffic lane and shall as far as practicable keep away from traffic separation zone or separation line.

Article 13：Large vessel and high-speed craft shall navigate within the prescribed traffic lane.

Article 14：Small vessel shall navigate within the prescribed auxiliary route.

In conclusion, as shown in Figure 2.1, the fundamental characters of this system are that: large vessels use deep-water channel, small vessels use auxiliary route which is on the outside of the deep-water channel, and the separation zone is in the middle of the deep-water channel to avoid route overlap. So every ship can keep to the right side according to international practice.

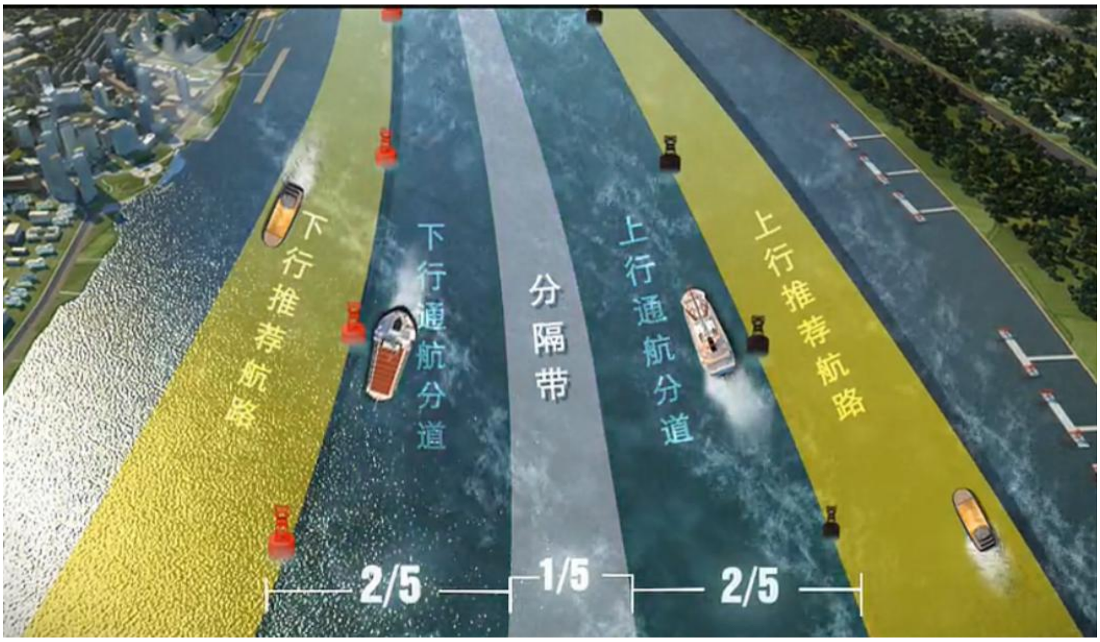

Figure 2.1 - Route Settings of Ships' Routeing System in Jiangsu Section
Source: Ministry of Transport. (2003). *Navigation Rule of Ships' Routeing Systems in Jiangsu Section of the Yangtze River, 2003 edition.* Beijing: Author.

This system reformed the traditional navigation method in Yangtze River ("downstream vessels should go along the main stream channel, upstream vessels should go along the weak stream channel"), standardized the ships navigation order, enhanced the traffic efficiency, improved the navigation safety. The "water highway" has been formed since then.

2.3 The innovation of SRSJS

The SRSJS adopted the principle of "liability for fault" for the first time in navigation regulations.

The relevant provisions (Ministry of Transport, 2003) are as follows:

> Article 26: A small vessel entering deep-water channel in violation of these Regulations and resulting in a collision with any other vessel navigating within deep-water channel, shall be subject to major or full responsibility.
>
> Article 27 ： A vessel, in violation of these Regulations, navigating against the traffic flow in the traffic lane or auxiliary route and resulting in a collision with any other vessel navigating within traffic lane or auxiliary route, shall be subject to major or full responsibility.
>
> Article 28 ： A vessel, in violation of these Regulations, indiscriminately crossing the traffic lane or auxiliary route and resulting in a collision with any other vessel navigating within traffic lane or auxiliary route, shall be subject to major or full responsibility.

The implementation of the fault liability principle is a breakthrough in the legislation of the SRSJS and a historical breakthrough in the history of ships' routeing system. The principle of "liability for fault" urges the crew to abide by the law and further standardize their navigation behaviors, so as to reduce the occurrence of collision accidents.

2.4 Implementation

On July 1, 2003, the Ships' Routeing System in Jiangsu Section of the Yangtze River was formally implemented (Ministry of Transport, 2003).

In March 2004, the Jiangsu MSA held a press conference in nanjing, officially announcing that the Jiangsu section of Yangtze river began to implement night navigation for sea vessels. Since the 1960s, the history of ships unable to sail at night for various objective reasons has come to an end.

Chapter 3 Safety benefit evaluation of SRSJS

3.1 Positive effect of SRSJS on navigation safety of ships

After the implementation of SRSJS, the flow of ships is increasing year by year, but the total number of accidents, the number of wrecks, the number of fatalities, the economic loss and the accident rate are obviously decreased. The safety situation is obviously improved.

Table 3.1 illustrates the statistical summary of 1993-2017 years' ship accidents in Jiangsu section of Yangtze River(Jiangsu MSA, 2017). From these changes, the positive role of SRSJS to the navigation safety of the Jiangsu section of Yangtze River will be analyzed.

Table 3.1 - Statistical summary of 1993-2017 years' ship accidents in Jiangsu section of Yangtze River

Year	Total number of accidents	Collision	Wreck	Fatality	Direct economic loss (10 thousand RMB)	Vessel flow (vessels)	Gross freight volume (ton)
1993	263	-	162	82	2970.30	-	-
1994	301	-	181	101	8345.18	-	-
1995	246	-	151	107	6063.81	-	-
1996	193	-	98	63	3839.79	-	-
1997	192	-	129	106	9745.97	-	-
1998	137	-	97	58	3539.76	-	-
1999	134	-	100	91	7472.79	-	-
2000	113	-	72	62	4268.68	-	-
2001	124	62	91	61	3874.35	351781	178334449
2002	116	66	91	95	5754.32	434280	196241567
2003	65	38	50	74	3296.98	495189	230011764
2004	51	39	47	40	3917.55	625089	369875199
2005	36	35	35	42	9730	674942	425713164
2006	41	30	36	38	9472	718505	469591236
2007	41	31	45	41	10464.1	795991	553424705
2008	42	22	37	53	13801.64	801844	577803688
2009	46	22	34	43	7904.94	807416	671297441
2010	46	26	46	80	5562.55	881755	837894506
2011	30	21	25	26	5650	887705	985137526
2012	28	16	24	42	9675	878678	1061921455
2013	29	20	23	39	4532.16	891657	1156473283
2014	26	17	16	31	1087	903421	1219836751
2015	31	25	21	34	3926.92	918743	1283652486
2016	28	23	19	28	2983	934157	1315267152
2017	29	24	18	35	3579.16	945232	1398570268

Source: Jiangsu MSA (2017). *Jiangsu MSA annual report 2017(internal)*.
Jiangsu: Author.
“-”: No statistics.

3.1.1 Changes in the number of accidents and the rate of accident

3.1.1.1 Changes in the number of accidents

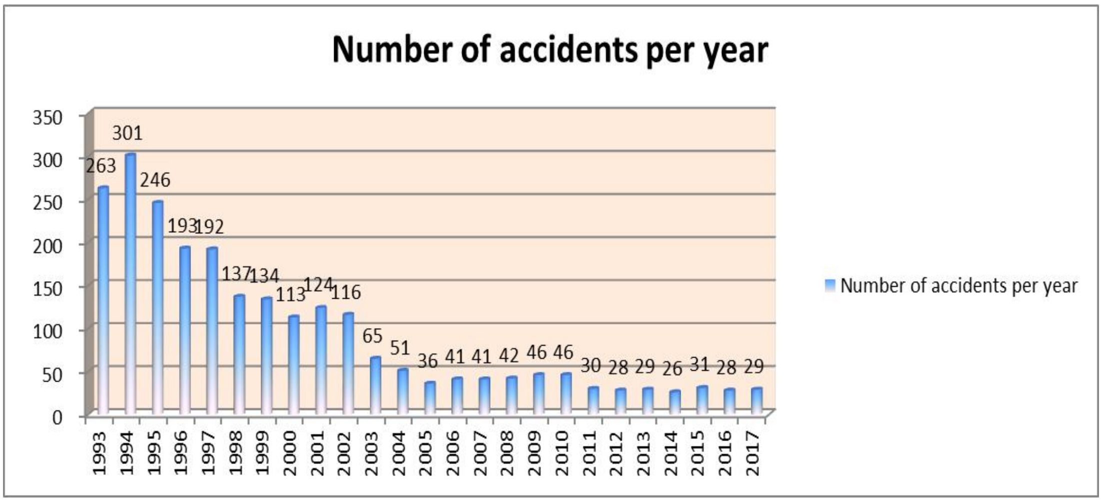

Figure 3.1(a) - Statistical diagram of ship accidents in Jiangsu section of Yangtze River during 1993~2017

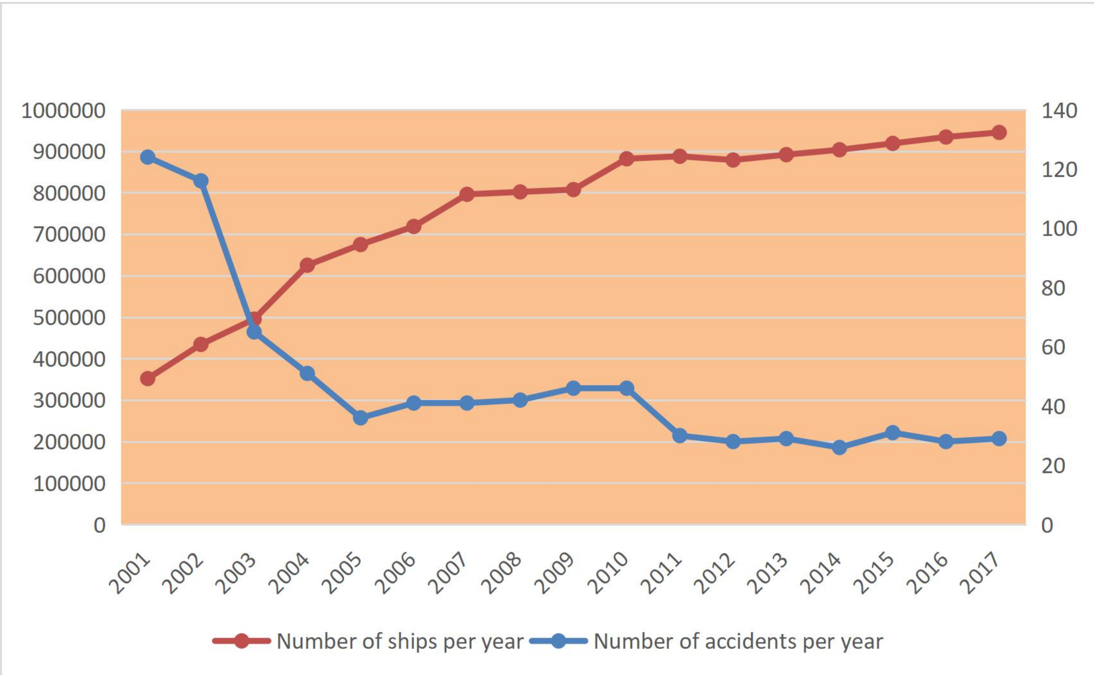

Figure 3.1(b) - Comparison between ship accidents and vessel flow in Jiangsu section of Yangtze River (2001~2017)

Source: Jiangsu MSA (2017). *Jiangsu MSA annual report 2017(internal)*. Jiangsu: Author.

Figure 3.1(a) shows the total number of ship accidents in the Jiangsu section of Yangtze river has decreased significantly after the implementation of SRSJS. In the 10 years (1993-2002), the average number of accidents was 181.9, and the highest was up to 301 (1994). After the implementation of SRSJS (2003-2017), and the average number of accidents was 37.9, the drop was 79.2%, and the lowest was 26 (2014).

As can be seen from figure 3.1(b), there is a sharp contrast between the vessel flow and ship accidents. From 2001 to 2017, the number of ships increased rapidly from 352 thousand per year to 945 thousand per year. By contrast, the number of accidents on water dropped significantly, from 124 in 2001 to 29 in 2017.

From the changes of above data, it can be seen that the implementation of SRSJS has a obvious effect on reducing the ship accident, and the momentum of the water accidents in the Jiangsu section of Yangtze River has been fundamentally restrained.

3.1.1.2 Changes in the rate of accident

Compared with ship accidents indicator, accident rate indicator can objectively and comprehensively reflect the safety level. The ship accident rate can be calculated according to the two reference standards of vessel flow and gross freight volume.

Table 3.2 - Statistics of ship accident rate per unit vessel in Jiangsu section of Yangtze River (2001~2017)

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Vessel flow(thousand vessels)	351.8	434.3	495.2	625.1	674.9	718.5	796.0	801.8	807.4	881.8	887.7	878.7	891.7	903.4	918.7	934.2	945.2
Number of accidents per year	124	116	65	51	36	41	41	41	46	46	30	28	29	26	31	28	29
Accident rate‰	0.352	0.267	0.131	0.082	0.053	0.057	0.052	0.052	0.057	0.052	0.034	0.032	0.033	0.029	0.034	0.030	0.031

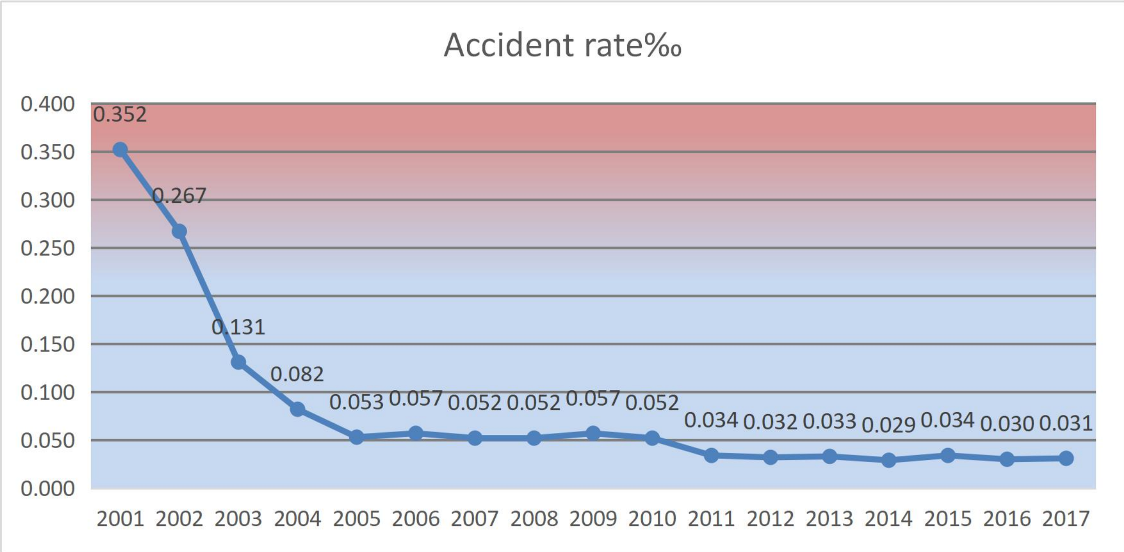

Figure 3.2 - Statistical chart of ship accident rate per unit vessel (2001~2017)

Source: Jiangsu MSA (2017). *Jiangsu MSA annual report 2017(internal)*. Jiangsu: Author.

Table 3.3 - Statistics on ship accident rate per unit freight volume in Jiangsu section of Yangtze River (2001~2017)

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Gross freight volume(million tons)	178	196	230	370	425.7	469.6	553.4	577.8	671.3	837.9	985.1	1061.9	1156.5	1219.8	1283.7	1315.3	1398.6
Number of accidents per year	124	116	65	51	36	41	41	41	46	46	30	28	29	26	31	28	29
Accident rate per ton(10^{-6})	0.70	0.59	0.28	0.14	0.08	0.09	0.07	0.07	0.07	0.05	0.03	0.03	0.03	0.02	0.02	0.02	0.02

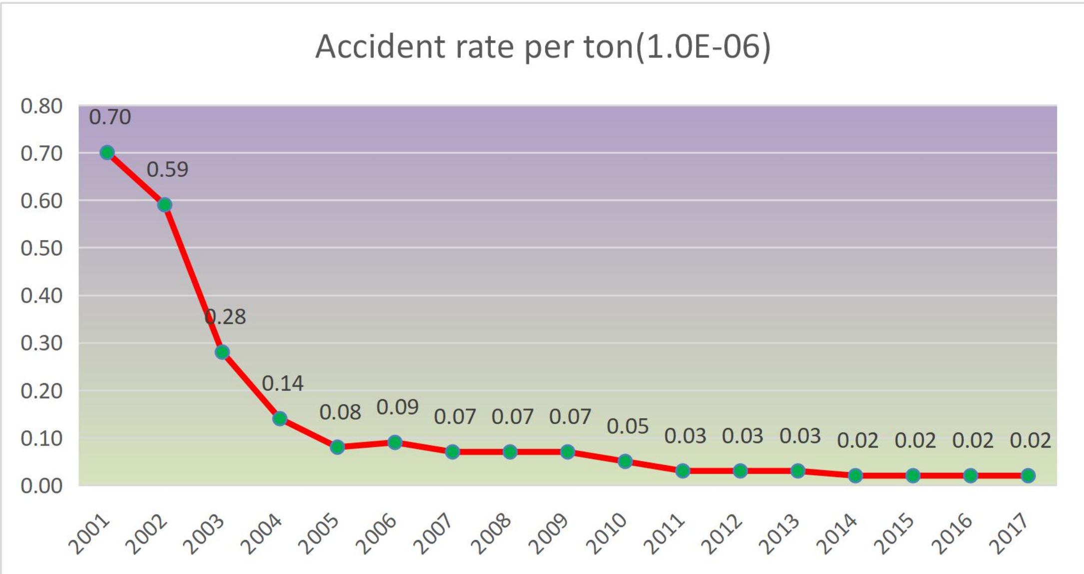

Figure 3.3 - Statistical chart of ship accident rate per unit freight volume (2001~2017)

Source: Jiangsu MSA (2017). *Jiangsu MSA annual report 2017(internal)*. Jiangsu: Author.

Figure 3.2 illustrates that the accident rate per unit vessel in the Jiangsu section of Yangtze River dropped from 0.267‰ in 2002 to 0.031‰ in 2017, a drop of 88%. The accident rate in 2014 is nearly 1/10 of that in 2002, the downward trend is very obvious. The fastest drop in the accident rate is the 2003, 2004 and 2005 three years after the beginning of SRSJS, which shows that the role of the SRSJS has been basically fully played.

Comparing Figure 3.2 and Figure 3.3, we can see that the trend of accident rate per unit freight volume is basically the same as that of accident rate per unit vessel. Specifically, the accident rate of unit freight volume dropped from 0.59 accidents per million tons in 2002 to 0.02 accidents per million tons in 2017, a large drop of 96.6%. Compared with the decrease rate of unit vessel accident rate, the accident rate per unit freight volume decreases more, the effect is more obvious. The accident rate of unit freight volume is closely related to the economic benefits of the shipping companies. Therefore, the implementation of SRSJS brings great benefits to shipping companies.

3.1.1.3 Summary of this section

Analyzing indexes of accident number and accident rate, it can be seen that the water safety situation of the Jiangsu section of Yangtze River has been fundamentally improved after the implementation of SRSJS. Thus, SRSJS is successful in reducing ship accidents and improving the navigation safety.

3.1.2 Changes in accident types and losses

3.1.2.1 Changes in the collision accident

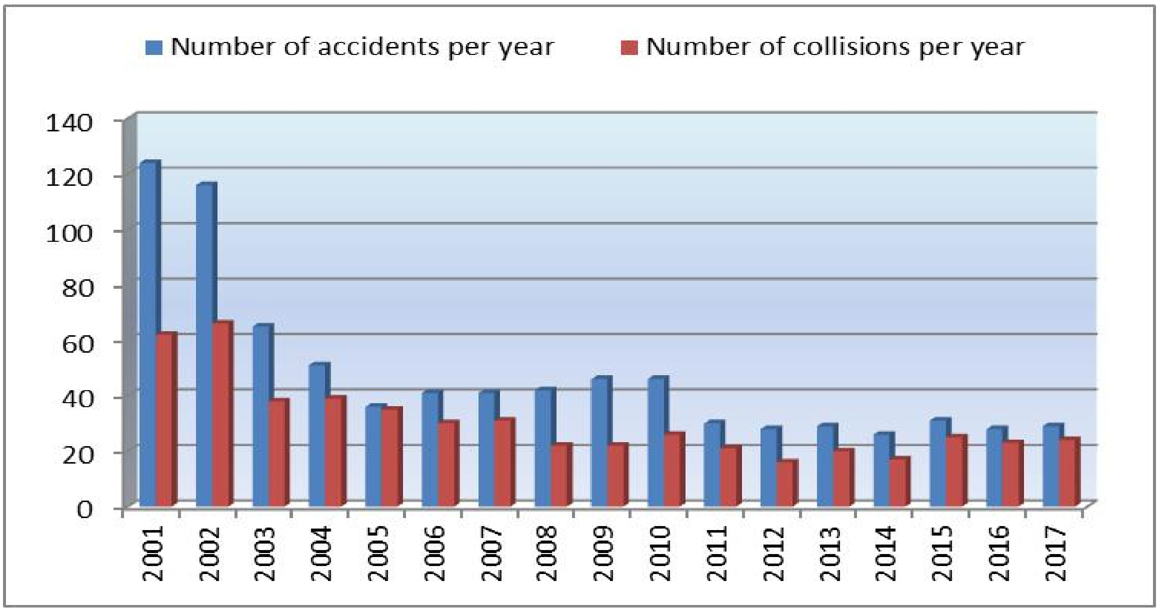

Figure 3.4 - Statistical map of collision accident in Jiangsu waters (2001~2017)
Source: Jiangsu MSA (2017). *Jiangsu MSA annual report 2017(internal)*.
Jiangsu: Author.

From Figure 3.4, it can be seen that after the implementation of the SRSJS in 2003, when the vessel flow increased rapidly, the number of collision accidents generally declined, meanwhile, the total number of accidents also decreased. With the maturity of SRSJS, the overall level of collision accidents is at a relatively low level.

3.1.2.2 Changes in the number of wrecks

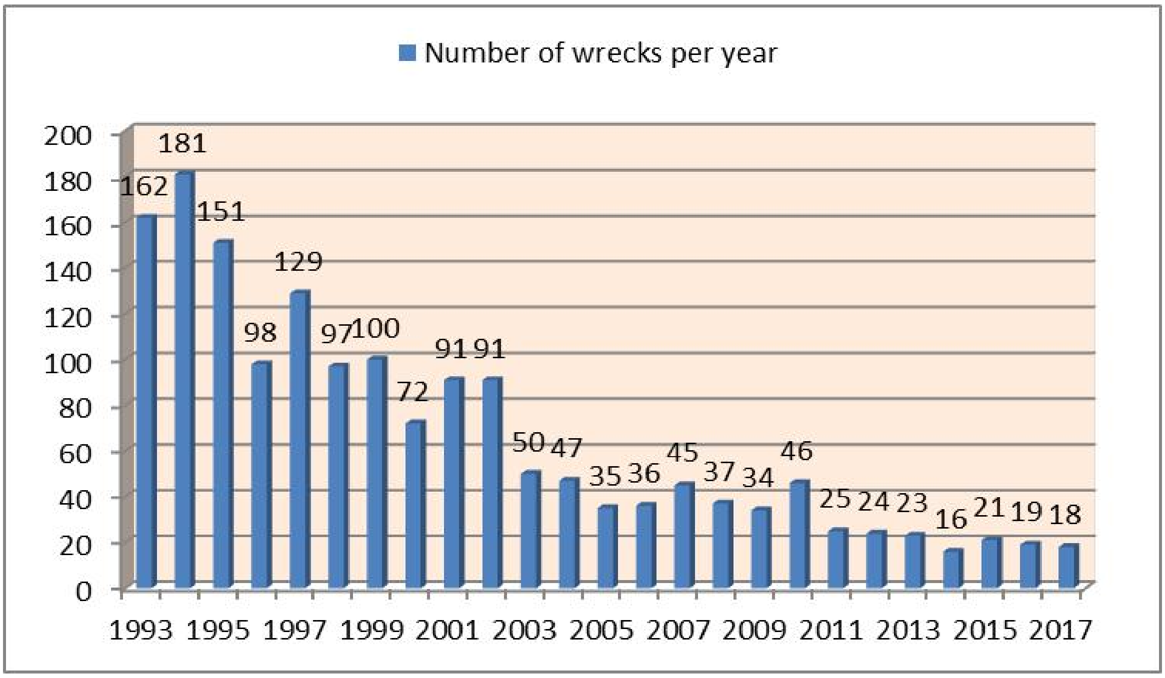

Figure 3.5 - Statistical chart of the number of wrecks in Jiangsu waters (1993~2017)
Source: Jiangsu MSA (2017). *Jiangsu MSA annual report 2017(internal)*.
Jiangsu: Author.

The number of wrecks is an important index reflecting the safety level of a water area. From chart 3.5, we can see that the number of wrecks has been greatly reduced since the implementation of SRSJS. In the first 10 years (1993-2002), the annual average number of wrecks in the waters was 117.2 vessels, and the maximum number of wrecks was 181 vessels (1994). In the period of 2003-2017, the annual average number of wrecks decreased to 31.7 vessels, with a drop of 72.9%.

The significant reduction in the number of wrecks also reflects the obvious effect of SRSJS in reducing the extent of accident losses.

3.1.2.3 Changes in the fatality and mortality rate

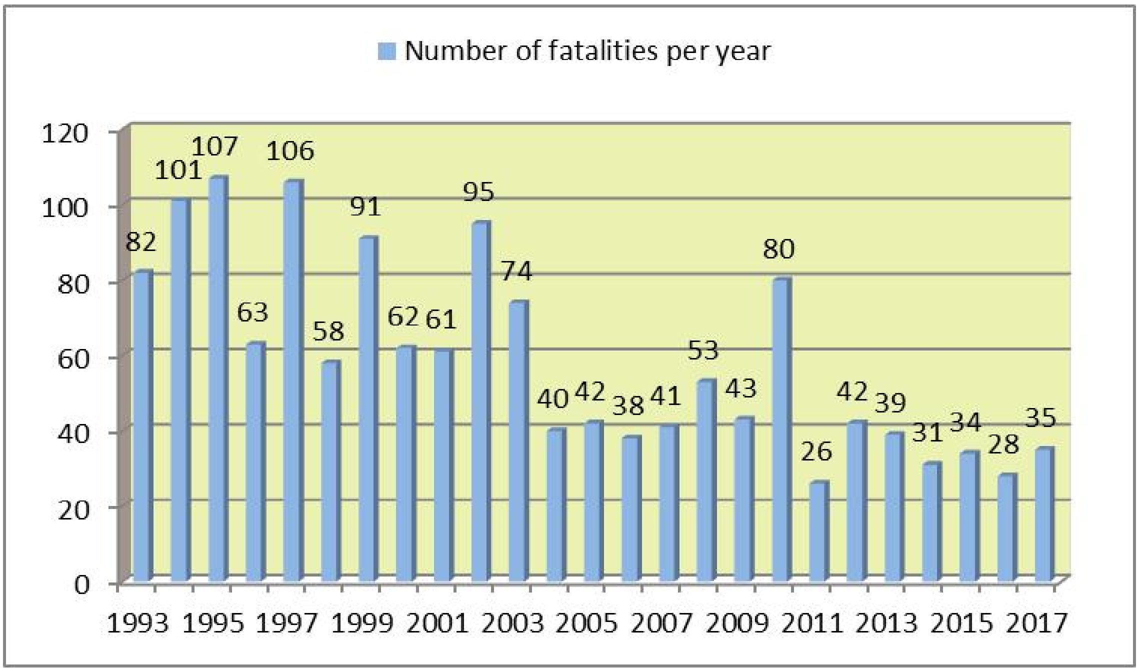

Figure 3.6 - Statistical chart of the number of fatalities in Jiangsu waters (1993~2017)

Source: Jiangsu MSA (2017). *Jiangsu MSA annual report 2017(internal)*. Jiangsu: Author.

Figure 3.6 shows that the number of fatalities in Jiangsu waters has also decreased significantly after the implementation of SRSJS. In the period of 10 years (1993-2002), the average annual number of fatalities was 82.6 persons, after the implementation of SRSJS (2003-2017), the average annual number of fatalities dropped to 43.1 persons, with a decrease of 47.9%. From 2004 to 2017, the number of fatalities is stable at the level of 30-40. But in 2010, the fatalities were 80 persons because of two extraordinarily serious accidents. The fluctuation also reflects the contingency characteristics of accidents.

It is not comprehensive and objective to evaluate the change of water safety level only from the absolute value of fatalities. Mortality rate is another important index. Look at below data.

Table 3.4 - Statistics on mortality rate per million tons in Jiangsu section of Yangtze River (2001~2017)

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Number of fatalities per year	61	95	74	40	42	38	41	53	43	80	26	42	39	31	34	28	35
Gross freight volume(million tons)	178	196	230	370	425.7	469.6	553.4	577.8	671.3	837.9	985.1	1061.9	1156.5	1219.8	1283.7	1315.3	1398.6
Mortality rate per million tons	0.34	0.48	0.32	0.11	0.10	0.08	0.07	0.09	0.06	0.10	0.03	0.04	0.03	0.03	0.03	0.02	0.03

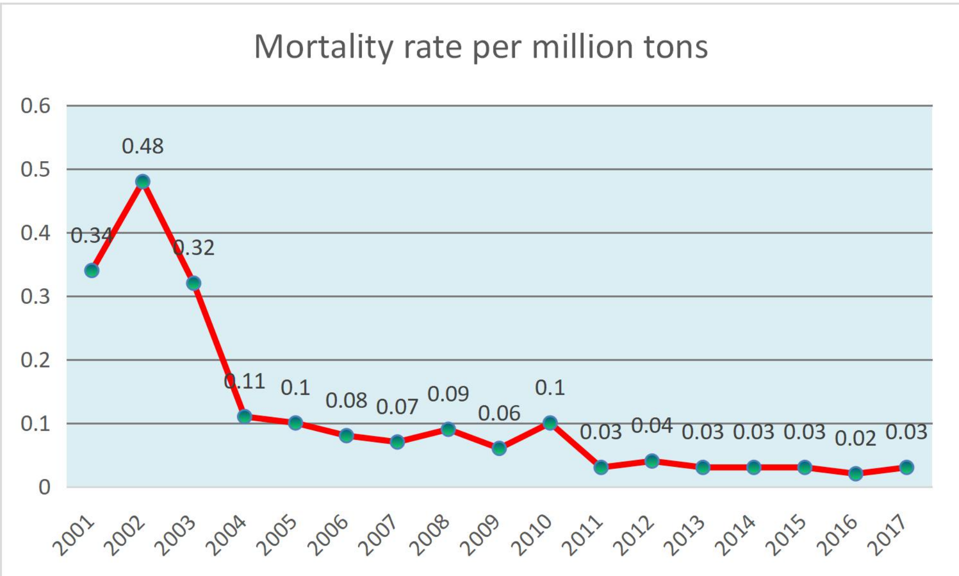

Figure 3.7 - Statistical chart of mortality rate per million tons in Jiangsu waters (2001~2017)

Source: Jiangsu MSA (2017). *Jiangsu MSA annual report 2017(internal)*. Jiangsu: Author.

Figure 3.7 analyzes the trend of mortality rate from 2001 to 2017. It can be seen that after the implementation of SRSJS, the mortality rate per million tons fell from 0.48 in 2002 to average less than 0.10 after 2004, with a decrease of more than 79.2%. The lowest value of mortality rate was 0.02 in 2016.

To sum up, the implementation of SRSJS has improved the navigation environment, while reducing the number of accidents, it also plays an important role in the effective control of the number of fatality caused by accidents.

3.1.2.4 Changes in direct economic losses

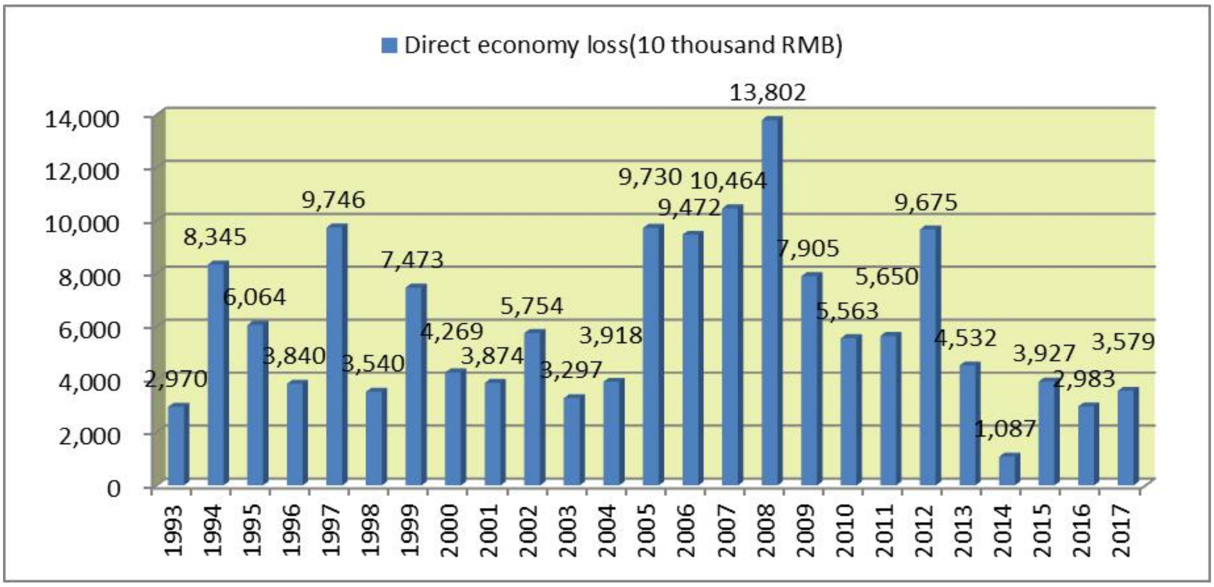

Figure 3.8 - Statistical chart of direct economic loss in Jiangsu waters (1993~2017)
Source: Jiangsu MSA (2017). *Jiangsu MSA annual report 2017(internal)*. Jiangsu: Author.

As can be seen from Figure 3.8, from 2003 to 2008, the direct economic losses caused by accidents are on the rise, which is not consistent with the decreasing trend of the number of accidents. The main reason is that because of the large scale ship, the cost of the ship is greatly increased, so the direct economic loss caused by the same collision will be increased. After 2008, the direct economic losses generally show a downward trend, which is due to the improvement of the safety management level of Jiangsu MSA.

Table 3.5 - Statistics on direct economic loss per unit freight volume in Jiangsu section of Yangtze River (2001~2017)

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Direct economic loss (10 thousand RMB)	3874	5754	3297	3918	9730	9472	10464	13802	7905	5563	5650	9675	4532	1087	3927	2983	3579
Gross freight volume (million tons)	178	196	230	370	425.7	469.6	553.4	577.8	671.3	837.9	985.1	1061.9	1156.5	1219.8	1283.7	1315.3	1398.6
Economy loss per unit (RMB/thousand tons)	217.3	293.2	143.3	105.9	228.6	201.7	189.1	238.9	117.8	66.4	57.4	91.1	39.2	8.9	30.6	22.7	25.6

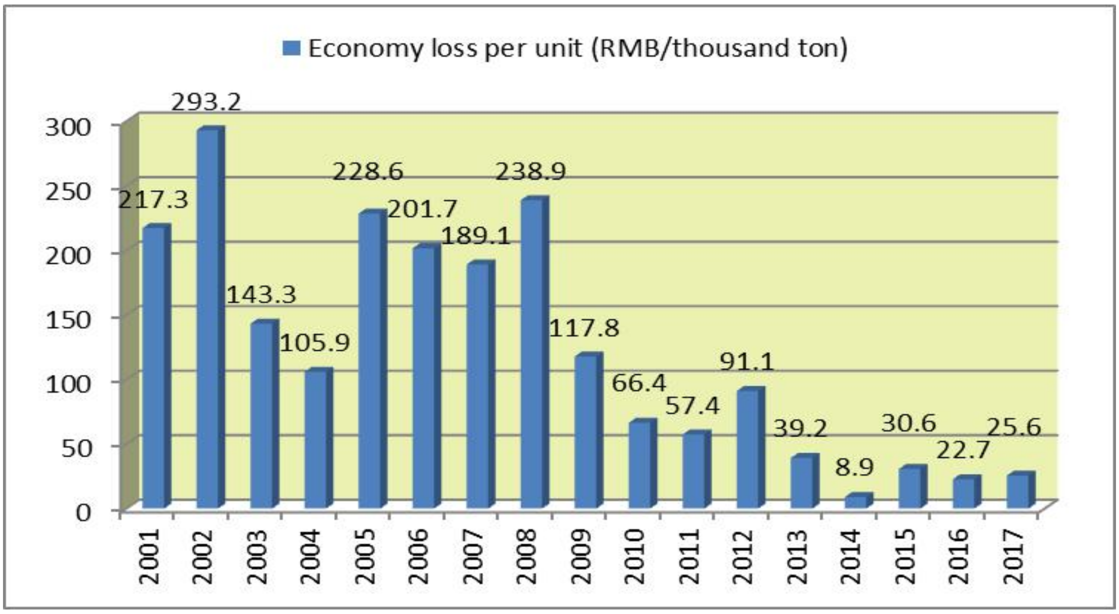

Figure 3.9 - Statistical chart of direct economic loss per unit freight volume in Jiangsu waters (2001~2017)

Source: Jiangsu MSA (2017). *Jiangsu MSA annual report 2017(internal)*. Jiangsu: Author.

Compared with the absolute value of direct economic loss, the relative index (economic loss per unit volume) can objectively reflect the situation after the implementation of SRSJS. In Figure 3.9, we can see that after 2005 the economic loss of unit volume showed a downward trend in general. In 2008, there was a fluctuation, which was also caused by accident contingency. It can be seen that SRSJS plays a positive role in controlling economic losses in the environment of increasing freight volume.

3.1.3 Summary

Through the analysis of the above data, we can find that the total number of accidents, accident rate, the number of wrecks, fatality, the direct economic loss and other indicators all show a downward trend generally. The implementation of the

SRSJS fundamentally improves the navigation safety of the Jiangsu section of Yangtze River.

3.2 Positive effect of SRSJS on navigation efficiency

3.2.1 The number of large vessel is increasing

Due to incomplete data, this paper only finds large ship data from 2001 to 2012. According to the annual report of Jiangsu MSA(2013), since the implementation of SRSJS in 2003, the number of 50000 DWT and above ship has increased from 1402 in 2002 to 11963 in 2012, with an increase of 753.3%. And the number of 100000 DWT and above ship increases faster, from 58 in 2002 to 1021 in 2012, with an increase of 16.6 times. The specific data are shown in Table 3.6 and Figure 3.10.

Table 3.6 - Statistics on large vessel in Jiangsu section of Yangtze River (2001~2012)

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
50000 DWT and above	1029	1402	1606	2239	3180	4216	4959	5428	6709	7706	10256	11963
100000 DWT and above	24	58	89	139	139	221	325	335	616	747	937	1021

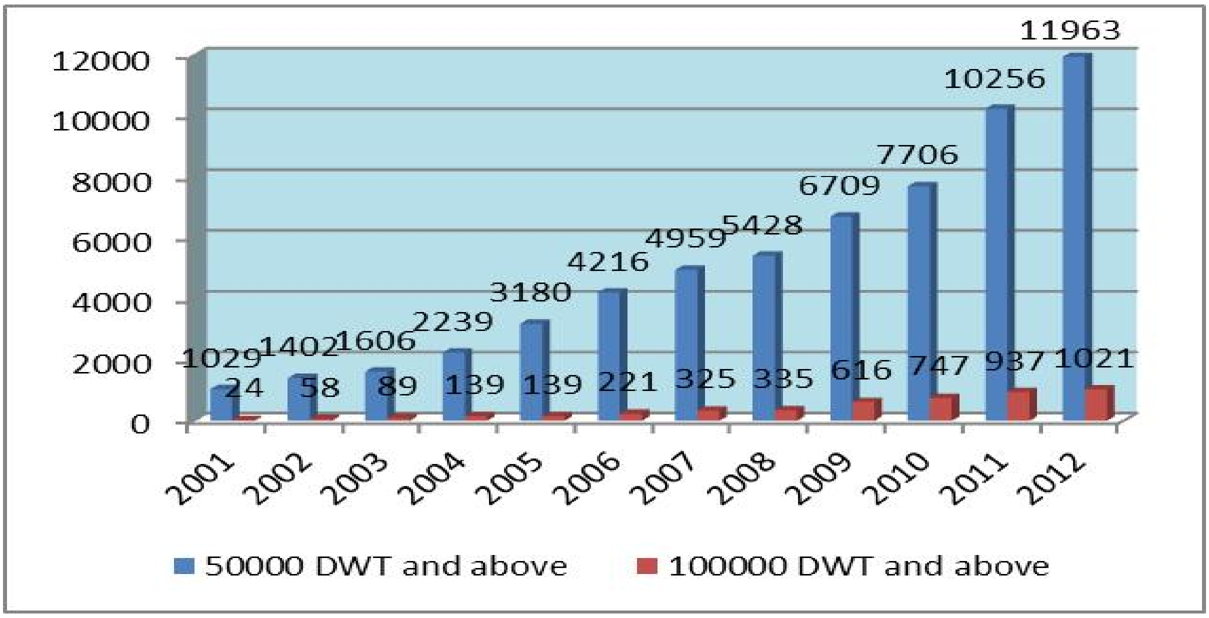

Figure 3.10 - Statistical chart of large vessel in Jiangsu waters (2001~2012)

Source: Jiangsu MSA (2013). *Jiangsu MSA annual report 2013(internal)*.
Jiangsu: Author.

3.2.2 Open the night navigation and improve ship speed-- "quick in and quick out"

Before the implementation of SRSJS, large ship was afraid of the night navigation in the Yangtze River due to safety risks, furthermore,large ship and small ship were sailing in the same channel, so large ship did not dare to navigate quickly. In March 2004, the Jiangsu MSA formally announced that the Jiangsu section of Yangtze River was fully engaged in the safe night navigation, shortening the time of the seagoing vessel in and out of Yangtze River. In 2014, the Jiangsu MSA announced that the minimum speed of navigation ships raised from 4 to 6 knots, again improving the efficiency of ship navigation(Ministry of Transport, 2014).

3.2.3 The freight volume is increasing

Since the implementation of SRSJS in 2003, the gross freight volume of the Jiangsu section of Yangtze River has increased year by year. According to Jiangsu MSA annual report(2013), from 2002 to 2012, the value of gross freight volume increased from 196.2 million tons to 1061.9 million tons, an increase of 441.8%. The freight volume of river ships increased from 89.8 million tons to 484.0 million tons, increased by 439.0%; the freight volume of coastal ships increased from 55.0 million tons to 406.8 million tons, increased by 639.6%; the freight volume of international ships increased from 51.4 million tons to 171.1 million tons, increased by 232.9%. See table 3.7 and figure 3.11 for details.

Table 3.7 - Statistics on freight volume in Jiangsu section of Yangtze River (2001~2012)

Year	Gross freight volume (million tons)	Freight volume of river ships (million tons)	Freight volume of coastal ships (million tons)	Freight volume of international ships (million tons)
2001	178.3	84.8	57.1	36.4
2002	196.2	89.8	55.0	51.4
2003	230.0	114.8	58.7	56.5
2004	369.9	204.1	99.9	65.8
2005	425.7	214.3	128.8	82.6
2006	469.6	207.4	169.3	92.9
2007	553.4	248.6	202.2	102.7
2008	577.8	266.6	219.9	91.3
2009	671.3	289.9	254.4	127.0
2010	837.9	358.6	339.9	139.4
2011	985.1	438.7	393.5	153.0
2012	1061.9	484.0	406.8	171.1

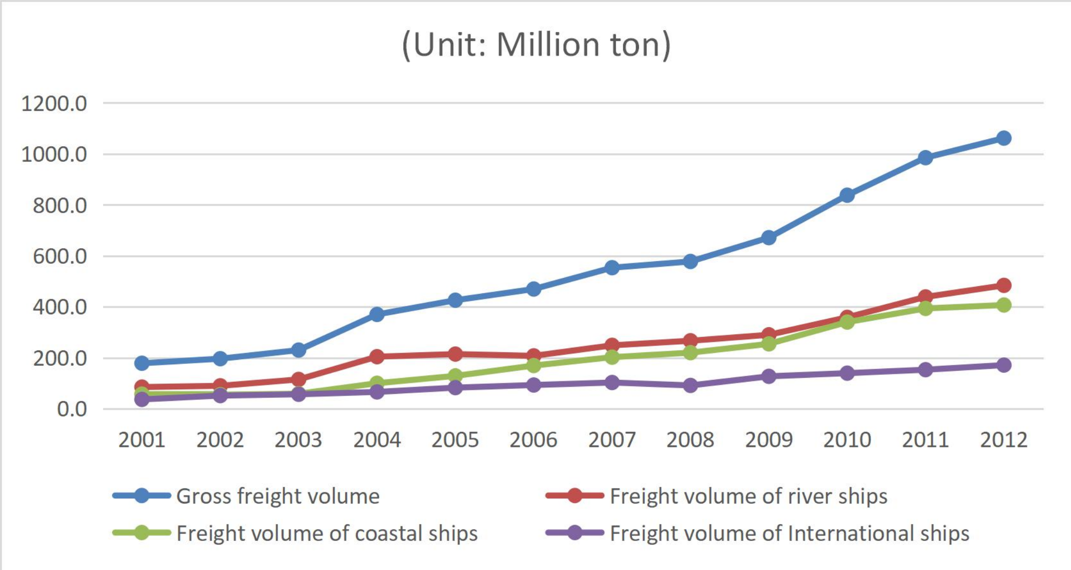

Figure 3.11 - Statistical chart of freight volume in Jiangsu waters (2001~2012)
Source: Jiangsu MSA (2013). *Jiangsu MSA annual report 2013(internal)*. Jiangsu: Author.

3.2.4 Summary

Analyzing the data in this section, we can see that since the implementation of SRSJS, the improvement of navigation order has effectively increased the speed of ships. The flow of ships and freight volume have been greatly improved. Fully opening night navigation has shortened the time of ships entering and leaving the Yangtze River and accelerated the operation period of ships. The efficiency of ship navigation is obviously improved.

3.3 The questionnaire of SRSJS

In order to objectively understand the influence of SRSJS on the improvement of navigation safety, navigation efficiency and MSA service level in the Jiangsu section of the Yangtze River, Jiangsu MSA(2017) designed a questionnaire on the effectiveness of the SRSJS. The questionnaire pattern is shown in Annex 1.

The survey selected 4 direct participants of river shipping, including inland river crew, ocean-going seafarer, pilot and shipping company, and recovered 2583 valid questionnaires, including 1856 inland river crews, 492 ocean-going seafarers, 204 pilots and 31 shipping companies(Jiangsu MSA, 2017). The statistical analysis of the questionnaire is as follows:

3.3.1 Effect of SRSJS on improving ship navigation safety

.1 Improvement effect of SRSJS on ship navigation safety

In the investigation of the improvement effect of SRSJS on ship navigation safety, among the respondents, the proportion of inland river crews, ocean-going seafarers, pilots and shipping companies selecting “high and medium” account for 94.45%, 94.11%, 96.08% and 96.77% of the surveyed people respectively, of which the “high” accounts for 66.33%, 67.89%, 71.08% and 80.65% respectively. See table 3.8 and figure 3.12.

Table 3.8 - Improvement effect of SRSJS on ship navigation safety

Respondent	Options (Effectiveness)	Number of options	Percentage(%)	Cumulative percentage(%)
Inland river crew	high	1231	66.33	66.33
	medium	522	28.13	**94.45**
	null	27	1.45	95.91
	No feedback	76	4.09	100.00
Ocean-going seafarer	high	334	67.89	67.89
	medium	129	26.22	**94.11**
	null	7	1.42	95.53
	No feedback	22	4.47	100.00
pilot	Very high	21	10.29	10.29
	high	52	25.49	35.78
	medium	72	35.29	71.08
	low	51	25.00	**96.08**
	null	4	1.96	98.04
	No feedback	4	1.96	100.00
Shipping company	high	25	80.65	80.65
	medium	5	16.13	**96.77**
	null	0	0.00	96.77
	No feedback	1	3.23	100.00

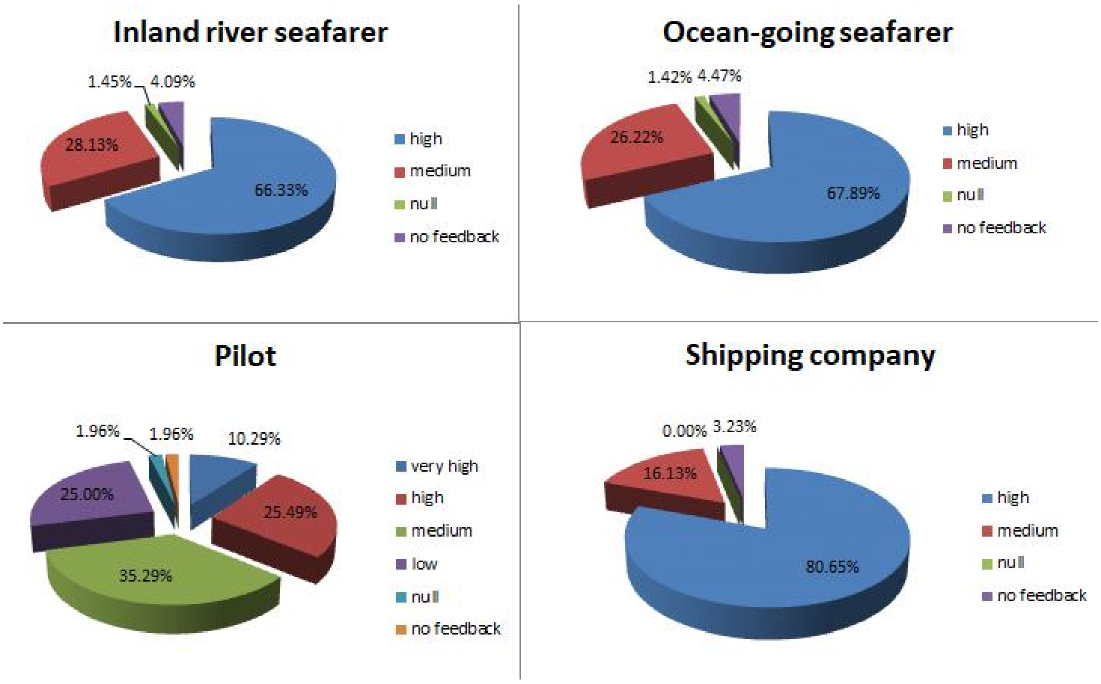

Figure 3.12 - Statistical chart of the improvement effect of SRSJS on ship navigation safety
Source: Jiangsu MSA (2017). *Questionnaire of SRSJS.*
Jiangsu: Author.

From the survey results, it can be seen that whether the seafarer, pilot or ship company, the overwhelming majority of respondents believe that the implementation of SRSJS has an effect on improving the safety of the ship's navigation.

.2 Improvement effect of ships cross meeting situation after implementation of SRSJS

When investigating the improvement effect of ships cross meeting situation after implementation of SRSJS, among the respondents, the proportion of inland river crews, ocean-going seafarers and pilots selecting "medium and above" account for 68.70%, 85.57% and 32.84% of respondents respectively, of which 55.23%, 60.57% and 16.18% of respondents select "high and very high" respectively. See table 3.9 and figure 3.13.

Table 3.9 - Improvement effect of ships cross meeting situation after implementation of SRSJS

Respondent	Options (Effectiveness)	Number of options	Percentage(%)	Cumulative percentage(%)
Inland river crew	Very high	565	30.44	30.44
	high	460	24.78	55.23
	medium	250	13.47	**68.70**
	low	292	15.73	84.43
	null	178	9.59	94.02
	No feedback	111	5.98	100.00
Ocean-going seafarer	Very high	125	25.41	25.41
	high	173	35.16	60.57
	medium	123	25.00	**85.57**
	low	35	7.11	92.68

	null	4	0.81	93.50
	No feedback	32	6.50	100.00
Pilot	Very high	6	2.94	2.94
	high	27	13.24	16.18
	medium	34	16.67	**32.84**
	low	80	39.22	72.06
	null	52	25.49	97.55
	No feedback	5	2.45	100.00

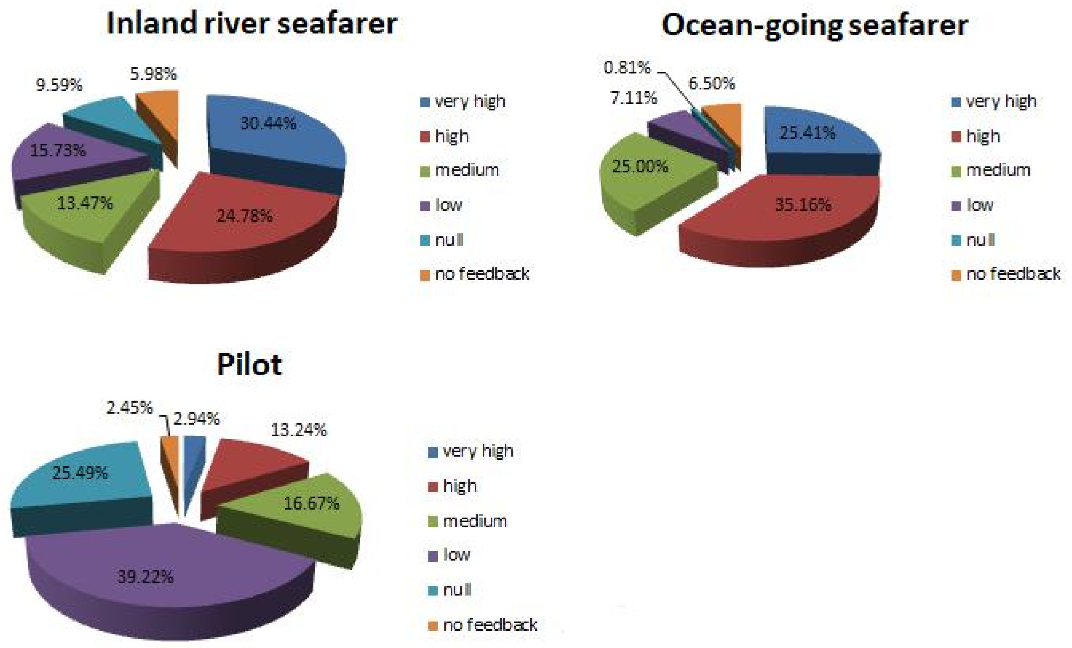

Figure 3.13 - Statistical chart of the improvement effect on ships cross meeting situation after implementation of SRSJS
Source: Jiangsu MSA (2017). *Questionnaire of SRSJS.*
Jiangsu: Author.

According to the survey results, most seafarers believe that the implementation of SRSJS greatly improves the cross meeting situation. Only a small number of pilots think so, because they often cross the fairway when they carry out berthing operation, forming cross meeting situations. On the whole, the cross meeting situation of ships has been improved to a certain extent.

.3 The occurrence of accidents in Jiangsu waters after the implementation of SRSJS

In the question of “Do you have an accident in the waters of Jiangsu after the implementation of SRSJS? ”, the proportion of inland river crews, ocean-going seafarers and pilots selecting “No occurrence” account for 92.62%, 94.11% and 94.12% of the respondents respectively. See table 3.10 and figure 3.14.

Table 3.10 - The occurrence of accidents in Jiangsu waters after the implementation of SRSJS

Respondent	Options (accident)	Number of options	Percentage(%)	Cumulative percentage(%)
Inland river crew	No occurrence	1719	92.62	**92.62**
	Occurrence	73	3.93	96.55
	No feedback	64	3.45	100.00
Ocean-going seafarer	No occurrence	463	94.11	**94.11**
	Occurrence	12	2.44	96.54
	No feedback	17	3.46	100.00
Pilot	No occurrence	192	94.12	**94.12**
	Occurrence	3	1.47	95.59
	No feedback	9	4.41	100.00

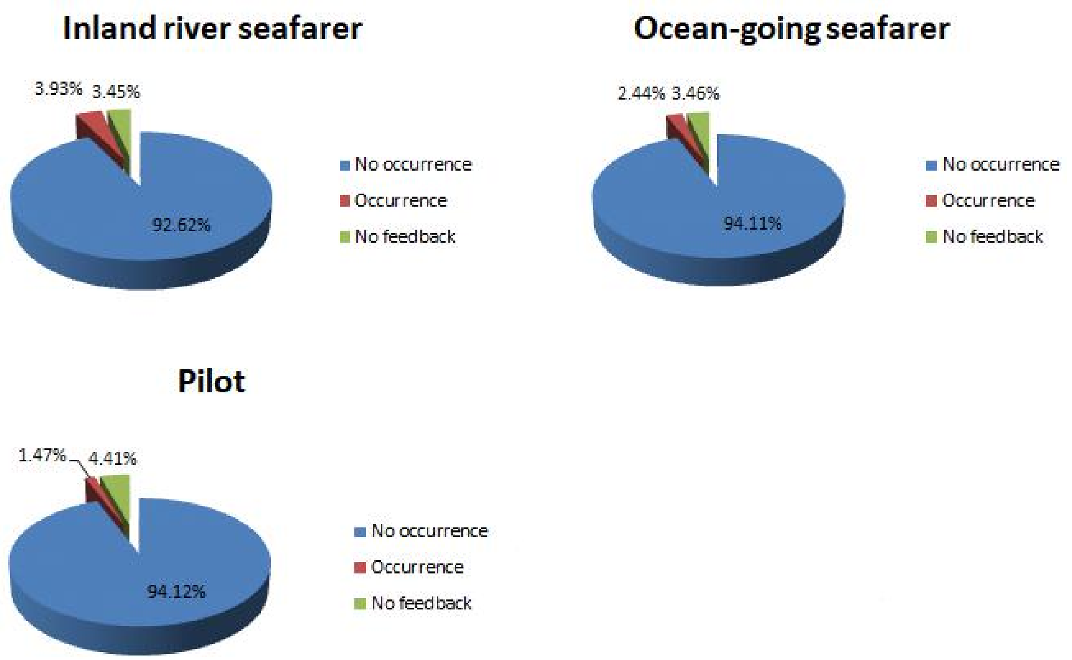

Figure 3.14 - Statistical chart of the occurrence of accidents in Jiangsu waters after the implementation of SRSJS
Source: Jiangsu MSA (2017). *Questionnaire of SRSJS.*
Jiangsu: Author.

From the results of the survey, we can see that after the implementation of SRSJS, the majority of seafarers and pilots do not have a water accident, reflecting the effective improvement of the navigation safety of the Jiangsu section of Yangtze River after the implementation of SRSJS.

.4 The safety degree of the night navigation after the implementation of SRSJS

In the investigation of the safety degree of night navigation after the implementation of SRSJS, the proportion of inland river crews and ocean-going seafarers selecting "high and low" account for 76.24% and 79.27% of the respondents respectively. Among them, the choice of "high" option accounts for 24.19% and 22.56%, respectively. See table 3.11 and figure 3.15.

Table 3.11 - The safety degree of the night navigation after the implementation of SRSJS

Respondent	Options (Degree of safety)	Number of options	Percentage(%)	Cumulative percentage(%)
Inland river crew	high	449	24.19	24.19
	low	966	52.05	**76.24**
	unsafe	309	16.65	92.89
	No feedback	132	7.11	100.00
Ocean-going seafarer	high	111	22.56	22.56
	low	279	56.71	**79.27**
	unsafe	59	11.99	91.26
	No feedback	43	8.74	100.00

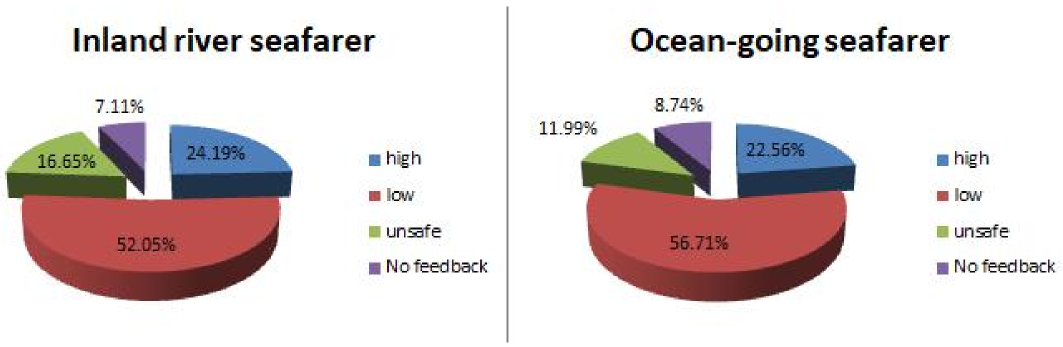

Figure 3.15 - Statistical chart of the safety degree of the night navigation after the implementation of SRSJS
Source: Jiangsu MSA (2017). *Questionnaire of SRSJS.*
Jiangsu: Author.

From the results of the survey, we can see that most of the inland river crews and ocean-going seafarers believe that the implementation of SRSJS can ensure the smooth and safe "night navigation".

To sum up, the implementation of ship routeing system improves navigation safety.

3.3.2 Influence of SRSJS on navigation order and navigation efficiency

.1 Whether the navigation rules are more simple since the implementation of SRSJS

When investigating whether the navigation rules are simpler since the implementation of SRSJS, most of the seafarers have shown that the implementation of SRSJS makes the navigation rules more simple, in which the proportion of inland river crews and ocean-going seafarers selecting "simpler" account for 74.89% and 78.05% of the respondents,respectively. See table 3.12 and figure 3.16 for details.

Table 3.12 - Whether the navigation rules are more simple since the implementation of SRSJS

Respondent	Options	Number of options	Percentage(%)	Cumulative percentage(%)
Inland river crew	Simpler	1390	74.89	74.89
	No change	188	10.13	85.02
	More complex	57	3.07	88.09
	No feedback	221	11.91	100.00
Ocean-going seafarer	Simpler	384	78.05	78.05
	No change	22	4.47	82.52
	More complex	24	4.88	87.40
	No feedback	62	12.60	100.00

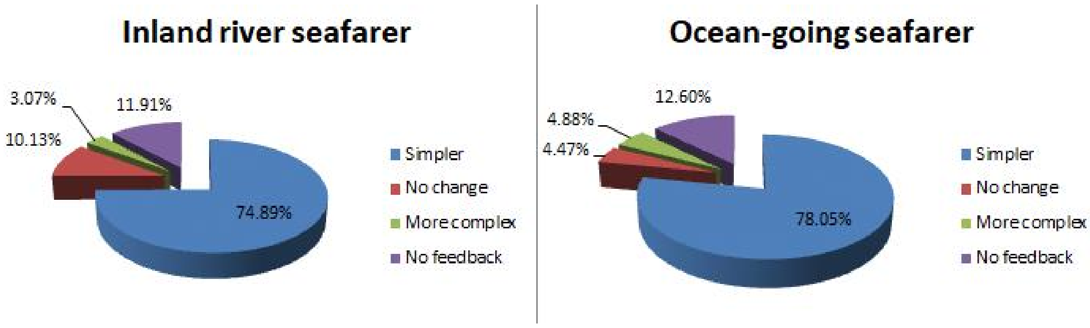

Figure 3.16 - Statistical chart of whether the navigation rules are more simple since the implementation of SRSJS
Source: Jiangsu MSA (2017). *Questionnaire of SRSJS.*
Jiangsu: Author.

From the survey results, we can see that the principle of "navigation on the right side" in SRSJS reduces the crossing of navigation routes and simplifies the rules of navigation.

.2 The improvement of navigation order after the implementation of SRSJS

When investigating the "improvement of navigation order after the implementation of SRSJS", most of the respondents made a positive evaluation. As shown in table 3.13 and figure 3.17, the proportion of inland river crews, ocean-going seafarers and pilots selecting "good and above" account for 91.43%, 86.59% and 77.45% of the surveyed people, respectively. Among them, the seafarers who choose "very good" even reach about half.

Table 3.13 - The improvement of navigation order after the implementation of SRSJS

Respondent	Options (navigation order)	Number of options	Percentage(%)	Cumulative percentage(%)
Inland river crew	Very good	953	51.35	51.35
	good	744	40.09	91.43

	normal	65	3.50	94.94
	poor	5	0.27	95.20
	No feedback	89	4.80	100.00
Ocean-going seafarer	Very good	199	40.45	40.45
	good	227	46.13	86.59
	normal	35	7.11	93.70
	poor	1	0.20	93.90
	No feedback	30	6.10	100.00
Pilot	Very good	34	16.67	16.67
	good	124	60.79	77.45
	normal	40	19.61	97.06
	poor	3	1.47	98.53
	No feedback	3	1.47	100.00

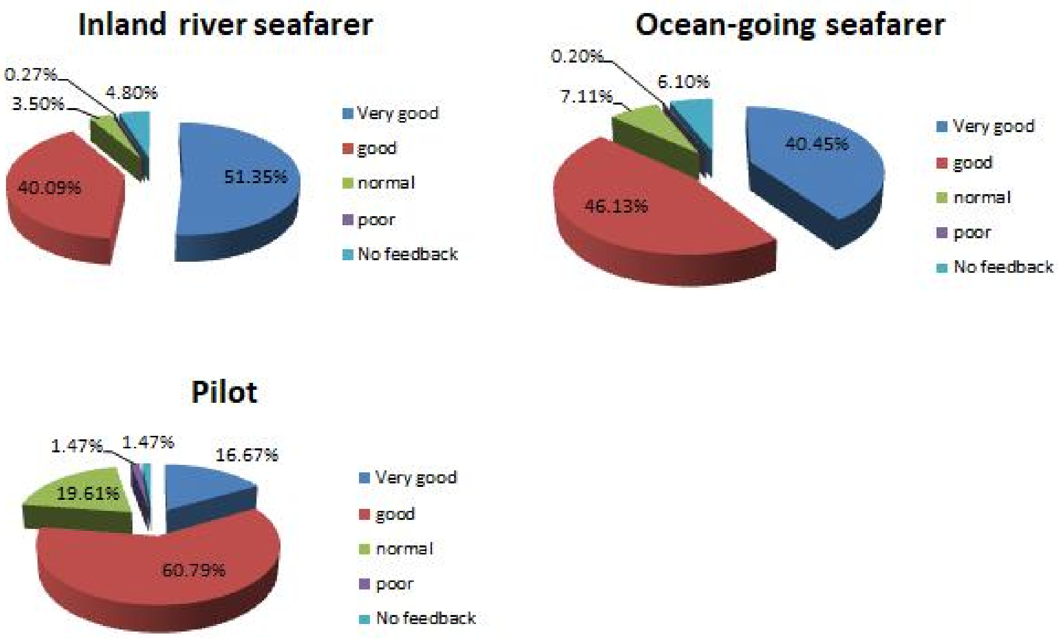

Figure 3.17 - Statistical chart of the improvement of navigation order after implementation of SRSJS

Source: Jiangsu MSA (2017). *Questionnaire of SRSJS.*

Jiangsu: Author.

.3 Changes in ship speed after implementation of SRSJS

In the investigation of "whether the ship speed is improved after the implementation of SRSJS", the proportion of inland river crews, ocean-going seafarers and pilots selecting “slightly and above” account for 86.64%, 89.23%, and 73.53% of the respondents, respectively. It is worth mentioning that 40.45% of ocean-going seafarers think the ship speed increases greatly or even more, as shown in table 3.14 and figure 3.18.

Table 3.14 - Whether the ship speed is improved after the implementation of SRSJS

Respondent	Options (Degree of rise)	Number of options	Percentage(%)	Cumulative percentage(%)
Inland river crew	significantly	278	14.98	14.98
	greatly	293	15.79	30.77
	slightly	1037	55.87	86.64
	No change	89	4.80	91.43
	No feedback	159	8.57	100.00
Ocean-going seafarer	significantly	98	19.92	19.92
	greatly	101	20.53	40.45
	slightly	240	48.78	89.23
	no	23	4.67	93.90
	No feedback	30	6.10	100.00
Pilot	significantly	14	6.86	6.86
	greatly	16	7.84	14.71
	slightly	120	58.82	73.53
	no	51	25.00	98.53
	No feedback	3	1.47	100.00

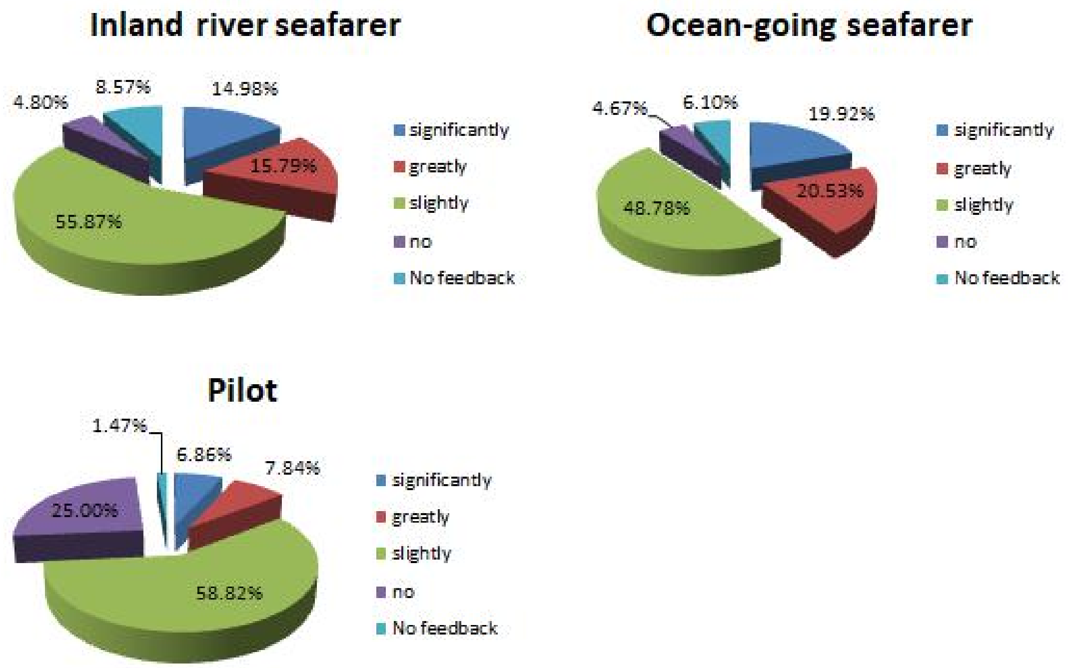

Figure 3.18 - Statistical chart of whether the ship speed is improved after the implementation of SRSJS
Source: Jiangsu MSA (2017). *Questionnaire of SRSJS.* Jiangsu: Author.

From the survey results, we can see that since the implementation of the SRSJS, the speed of ship navigation has been improved to a certain extent.

.4 The effect of SRSJS on improving navigation efficiency

In the investigation of "the effect of SRSJS on improving the navigation efficiency of ships", among the investigators, the inland river crews and ocean-going seafarers selecting “medium and above” account for the vast majority, reaching 95.42% and 95.93% respectively. As shown in table 3.15 and figure 3.19.

Table 3.15 - The effect of SRSJS on improving navigation efficiency

Respondent	Options (effectiveness)	Number of options	Percentage(%)	Cumulative percentage(%)
Inland river crew	high	1230	66.27	66.27
	medium	541	29.15	95.42
	null	20	1.08	96.50
	No feedback	65	3.50	100.00
Ocean-going seafarer	high	349	70.93	70.93
	medium	123	25.00	95.93
	null	1	0.20	96.14
	No feedback	19	3.86	100.00

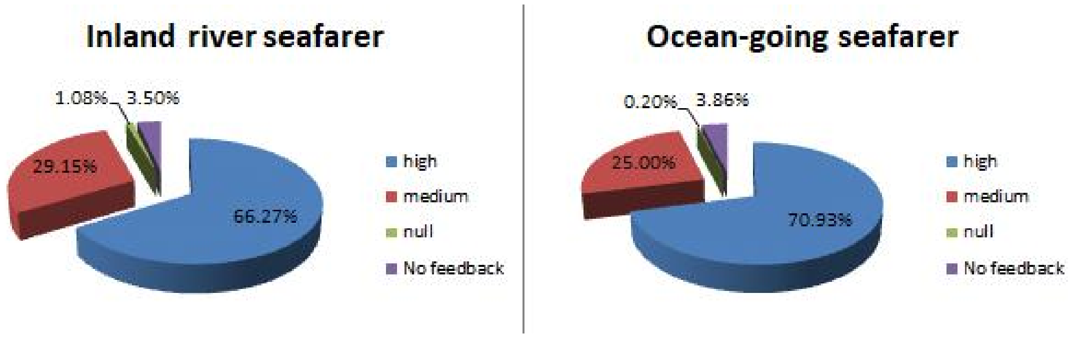

Figure 3.19 - Statistical chart of the effect of SRSJS on improving navigation efficiency
Source: Jiangsu MSA (2017). *Questionnaire of SRSJS.*
Jiangsu: Author.

From the survey results, we can see that the implementation of SRSJS has improved the navigation efficiency of the Jiangsu section of the Yangtze River.

3.3.3 Improvement of VTS management level after implementation of SRSJS

In the investigation of "the improvement VTS management level after the implementation of SRSJS", among the respondents, the proportion of inland river crews and ocean-going seafarers selecting "medium promotion and above" account for 89.87% and 86.99% of the respondents, of which "no promotion" accounts for 1.45% and 1.22% respectively. See table 3.16 and figure 3.20.

Table 3.16 - Improvement of VTS management level after implementation of SRSJS

Respondent	Options (Degree of promotion)	Number of options	Percentage(%)	Cumulative percentage(%)
Inland river crew	Very high	457	24.62	24.62
	high	577	31.09	55.71
	medium	418	22.52	78.23
	low	216	11.64	**89.87**
	null	27	1.45	91.33
	No feedback	161	8.67	100.00
Ocean-going seafarer	Very high	221	44.92	44.92
	high	107	21.75	66.67
	medium	78	15.85	82.52
	low	22	4.47	**86.99**
	null	6	1.22	88.21
	No feedback	58	11.79	100.00

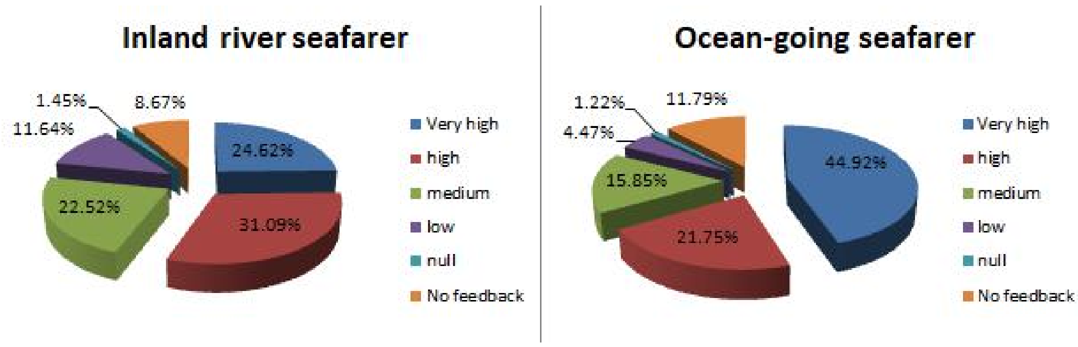

Figure 3.20 - Statistical chart of the improvement of VTS management level after implementation of SRSJS

Source: Jiangsu MSA (2017). *Questionnaire of SRSJS.*

Jiangsu: Author.

From the survey results, we can see that the implementation of SRSJS has led Jiangsu MSA to greatly promote technical equipment construction and professional personnel training, so the management level of VTS rises.

3.3.4 Summary of survey questionnaire

According to the statistics and analysis of the questionnaire, the direct feedback from inland river crews, ocean-going seafarers, pilots and shipping companies can be found that the implementation of SRSJS has improved the safety level of navigation, the efficiency of navigation, and the management level of VTS in the Jiangsu section of Yangtze River. The results of the questionnaire are consistent with the conclusions above.

Chapter 4 Social benefit evaluation of SRSJS

When the SRSJS brings direct safety benefits, it also brings huge social benefits. At present, there is no uniform standard social benefit assessment index system. In view of this, this chapter will combine qualitative analysis with quantitative analysis. Owing to the limit of data, the following content will focus on the most direct benefit area(Jiangsu Province) as a representative to analyze.

4.1 Enhance the port competitiveness of the Jiangsu section of Yangtze River

4.1.1 Promoting the transformation and upgrading of the port

Since the implementation of SRSJS, the cargo throughput and container throughput of Jiangsu port has maintained a rapid growth trend. In order to play the hub role of the port in the comprehensive transport system, the transformation and upgrading of the port is imperative.

The development of the world port is divided into four stages: the first generation port is the traditional loading dock, the second generation port has port logistics, the third generation ports have the developed logistics industry, and the fourth generation ports realize the global resource allocation(Chen Gang, 2017). Most ports in Jiangsu province are still in the second generation, and the essential difference between the second and third generation ports lies in the degree of development of the logistics industry.

At present, with the help of the improvement of navigation environment brought by SRSJS, the port of Jiangsu is no longer simply pursuing the growth of throughput. It will focus on the development of the third generation ports of modern logistics and economy, and becomes a resource allocation hub of international commodities, capital, information and technology.

4.1.2 Improving the competitiveness of Jiangsu Port

Since the implementation of SRSJS, Jiangsu Port has been developing rapidly. According to statistics of the 10th anniversary research report of ships' routeing system in Jiangsu section of the Yangtze river(Marine Science Institute of Chinese Ministry of Transport, 2013) (see table 4.1), the throughput of Jiangsu Port in 2002 is only 456 million tons, of which the throughput of foreign trade goods is 53 million tons and the container throughput is 1.44 million TEU. By 2011, the throughput of Jiangsu Port has reached 1.63 billion tons, of which foreign trade cargo throughput is 190 million tons, and container throughput is near 9.30 million TEU. In the ten years, the implementation of SRSJS has greatly improved the cargo throughput. Meanwhile, the 10000 DWT berths in Jiangsu Port increase from 124 in 2002 to 337 in 2011. The construction of the port infrastructure promotes the development of Jiangsu Port, and encourage the shipping companies to carry out large container ships in Jiangsu waters, thus further reducing the cost of logistics and enhancing the competitiveness of Jiangsu Port.

Table 4.1 - Comparison of throughput and berths before and after the SRSJS

Year	Throughput of Jiangsu Port (million tons)	Throughput of foreign trade goods (million tons)	Container throughput (million TEU)	10000 DWT Berth
2002	456	53	1.44	124
2011	1630	190	9.29	337

Source: Marine Science Institute of Chinese Ministry of Transport.(2013). *The 10th anniversary research report of ships' routeing system in jiangsu section of the Yangtze river*(pp. 19-20). Yangtze river economic belt construction annual conference, Beijing, China.

4.2 Promoting employment

The implementation of SRSJS has contributed to the economic development of Jiangsu Province, providing more employment opportunities and jobs, and promoting the flow of labor in Jiangsu Province. According to the Jiangsu Statistical Yearbook(2012), the increase in the number of employment in 2003-2011 years is larger than that of the previous ten years. The economic pull of the SRSJS has played a certain role in this period. Look at Figure 4.1.

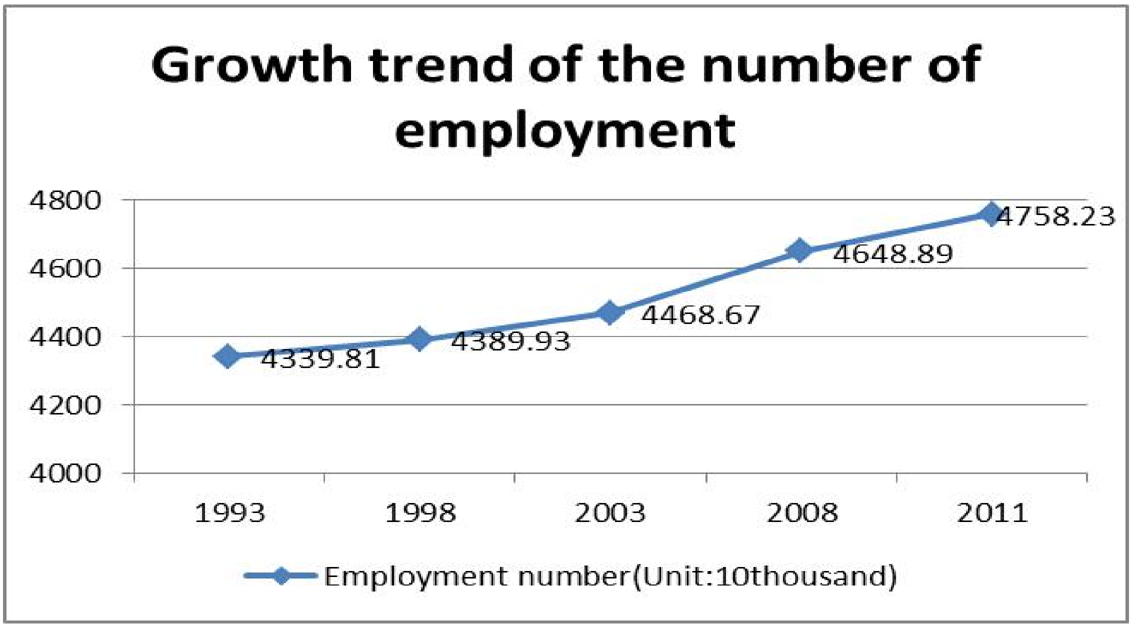

Figure 4.1 - Growth trend of the number of employment in Jiangsu Province
Source: China Statistics Press.(2012). *Jiangsu Statistical Yearbook of 2012*(pp. 58-59). Beijing: Author.

4.3 Reducing environmental pollution

With the development of Jiangsu's economy, the flow of ships has increased year by year, and the freight volume and dangerous goods has also increased yearly. Therefore, the probability of ship pollution accidents in Jiangsu section is increasing.

However, the implementation of SRSJS not only reduces the number of ship accidents, but also effectively reduces the occurrence of water pollution events. According to Jiangsu MSA annual report (2013), in 2001 and 2002, the actual oil spill were 2.51 and 39.41 tons respectively, while the traffic flow were 351781 and 434280 respectively. It means 5.33 oil spill per 100000 traffic flow on average. Assuming that potential oil spill rate is proportional to the ship traffic flow if ships' routeing system was not implemented. Then the benefit of reduced probability of oil spill can be estimated as shown in Table 4.2.

Table 4.2 - Quantity of reduced oil spill after the implementation of Ships' Routeing System in Jiangsu Section

Year	**2001**	**2002**	**Average between 2001 and 2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Potential oil spill (ton)	-	-	**20.96**	26.41	33.34	35.99	38.32	42.45	42.76	43.06	47.02	47.34	46.86
Actual oil spill (ton)	2.51	39.41	**20.96**	0.21	29.91	0.01	0.082	0.45	2.02	0	$9*10^{-4}$	0	0.1
Reduced oil spill (ton)	-	-	0	26.20	3.42	35.98	38.24	42.00	40.74	43.06	47.02	47.34	46.76

Source: Jiangsu MSA (2013). *Jiangsu MSA annual report 2013(internal)*. Jiangsu: Author.

It can be calculated that ten years since the implementation of SRSJS, a total of 370 tons of oil spill has been reduced. Therefore, the implementation of the ships' routeing system has brought us the obvious environmental benefits.

4.4 Summary

In this chapter, from three aspects of improving the competitiveness of Jiangsu port, promoting employment and reducing environmental pollution, the social benefit of the SRSJS has been evaluated. It can be seen that the implementation of this system plays a positive role in the port construction and social development of Jiangsu province.

Chapter 5 Economic benefit evaluation of SRSJS

5.1 Scope of evaluation

The economic benefit contribution of the SRSJS to jiangsu province includes direct economic contribution and indirect economic contribution, in which the quantitative calculation of indirect economic contribution is difficult. This chapter mainly focuses on the analysis of the direct economic benefit brought by the routing system to the development of ports and shipping companies, and concretely uses the throughput index to calculate.

5.2 Method of calculation

At present, Analytic hierarchy process (AHP) method and model prediction method are frequently used in the field of benefit evaluation. Fan Zhongzhou, Wu Zhaolin & Zhang Chuang (2014) analyzed the application of AHP method in the evaluation of ships' routeing system. Furthermore, Liu Jia, Liu Chenglin & Wang Yanjie(2014) applied the model prediction method to the economic evaluation of ships' routeing system.

In this chapter, the multiple linear regression prediction model is adopted. By comparing the difference between the forecast value and the actual value of the throughput, the added throughput value brought by SRSJS will be obtained. Due to limited data, only the data before 2012 are evaluated.

5.3 Economic benefit analysis

The multiple linear regression method assumes that the subjects studied are subject to multiple factors(X_1 , X_2 ,… X_k). Assuming that the relationship between the various factors is linear, and the multiple linear regression model is established as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k$$

Y : Explained variable;

$X_j\left(j = 1, 2, \cdots, k\right)$: Explaining variables;

$\beta_j\left(j = 0, 1, 2, \cdots, k\right)$: Unknown parameter.

For the N sets of predicted values Y_i , X_{1i} , X_{2i} ,… $X_{ki}\left(i = 1, 2, \cdots, n\right)$, the form of equations is as follows:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} \left(i = 1, 2, \cdots, n\right)$$

After determining variables and data, linear regression analysis can be used to obtain multiple linear regression prediction model.

According to the research by Fei Da & Shan Hengnian(2011), there are three main factors that affect the growth of throughput: the development of macro economy, the port capacity and the improvement of port facilities. Here, we use the GDP in Jiangsu Province to represent the macro economic development, the length of berths represents the port capacity, and the fixed assets investment of the port facilities represents the improvement of port facilities.

Using multiple linear regression method, the throughput prediction model is constructed as follows:

$$G = C_1 + C_2 D + C_3 F + C_4 B + \mu$$

G: Throughput;

D: GDP (Jiangsu Province);

F: Length of berths;

B: Fixed assets investment of the port facilities;

$C_{i\ (i=1,2,3,4)}$: Regression constant;

μ: Stochastic disturbance.

In order to ensure the accuracy of the prediction of multiple regression method, it is necessary to use the historical data of years before the ships' routeing system as the basis. There are 8 ports in the Jiangsu section of Yangtze River at present. Because of the incomplete historical data in some ports, the historical data of Nanjing, Zhenjiang, Jiangyin and Nantong ports are selected by sampling, then calculating the contribution of ships' routeing system to the throughput of these 4 ports. The statistical data (1993-2012) are shown in table 5.1 (China Transportation Press, 2012; National bureau of statistics of the people's republic of China, 2012; Ministry of Transport of the people's republic of China, 2012). And then according to the throughput of these 4 ports, the total contribution of the ships' routeing system to Jiangsu ports throughput can be calculated.

Table 5.1 - Statistics on throughput and related variables of 4 ports in Jiangsu section of Yangtze River

Year	Throughput (million tons)	GDP (billion RMB)	Length of berths (meter)	Fixed assets investment of the port facility (million RMB)
1993	79.33	299.8	26059	4473.94
1994	79.39	405.7	25025	8395.16
1995	86.19	518.5	25604	10403.02
1996	90.35	600.4	25272	12487.73
1997	95.35	668.0	22571	12742.41
1998	94.45	719.9	23550	15789.02

1999	104.97	769.7	24077	18498.33
2000	122.46	858.2	23184	21143.63
2001	125.41	951.1	22512	22698.29
2002	138.41	1060.6	22877	24742.13
2003	168.26	1244.2	33983	29122.95
2004	243.29	1500.3	61790	44553.44
2005	291.38	1830.5	71529	48619.21
2006	325.34	2164.5	82055	42835.40
2007	382.40	2601.8	85427	43772.61
2008	417.84	3098.1	95097	44697.69
2009	446.03	3445.7	116199	51407.14
2010	529.45	4142.5	121110	62016.57
2011	594.04	4911.0	127148	65838.50
2012	610.56	4860.4	133186	69660.43

Source: China Transportation Press.(2012). *Year Book of China Transportation & Communications 2012*(pp. 67-70). Beijing: Author.
National bureau of statistics of the people's republic of China. (2012). *China statistical Yearbook 2012*(pp. 134-152). Beijing: Author.
Ministry of Transport of the people's republic of China. (2012). *Compilation of national transportation statistics*(pp. 76-83). Beijing: Author.

Because the SRSJS was implemented in 2003, it is considered that the ships' routeing system plays a role since 2003. According to table 5.1, based on the data of 1993-2002 years, we can calculate the regression parameters and get the following regression equation:

$$G= 2854.21 +0.4095\times D +0.1026\times F +0.0013\times B$$

After solving the multiple linear regression equation, the correlation coefficient R is needed to check it (The correlation coefficient R is used to describe the amount of the linear relationship between x and y). The formula is as follows:

$$R^2 = \sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y}) / \sum_{i=1}^{N}(x_i - \bar{x})^2 (y_i - \bar{y})^2$$

The range of the value of R is between [0,1]. The larger the R, the greater the change caused by the independent variable, that is, the better the linear relationship between x and y is. The smaller the R, the worse the linear relationship between x and y is. When R=1, x and y have the best linear relationship, and they are highly correlated; when R=0, x and y are irrelevant; in most cases, 0<R<1.

After calculation, the R^2 of the throughput prediction regression equation is as high as 0.9602. It means that 96% of the port throughput can be explained by the variables(GDP, the fixed assets investment of the port facilities, the length of berths). It shows that the multiple regression equation is well fitted and the prediction method is credible. Using this model to calculate port throughput in 1993~2012, the deviation from actual port throughput is shown in table 5.2.

Table 5.2 - The deviation between the actual throughput and the predicted value of the model

Year	Actual Value of Port Throughput (million tons)	Predictive Value of Port Throughput (million tons)	Deviation (million tons)	Deviation Degree(%)
1993	79.33	73.64	5.69	7.17
1994	79.39	82.24	-2.85	-3.59
1995	86.19	90.19	-4.00	-4.64
1996	90.35	96.03	-5.68	-6.29
1997	95.35	96.37	-1.02	-1.07
1998	94.45	103.64	-9.19	-9.73
1999	104.97	109.90	-4.93	-4.70
2000	122.46	116.20	6.26	5.11
2001	125.41	121.43	3.98	3.17
2002	138.41	129.07	9.34	6.75
2003	168.26	153.93	14.33	8.51
2004	243.29	213.92	29.37	12.07
2005	291.38	242.96	48.42	16.62
2006	325.34	259.59	65.75	20.21

2007	382.40	282.23	100.17	26.19
2008	417.84	313.74	104.10	24.91
2009	446.03	358.74	87.29	19.57
2010	529.45	406.73	122.72	23.18
2011	594.04	449.60	144.44	24.32
2012	610.56	458.91	151.65	24.84

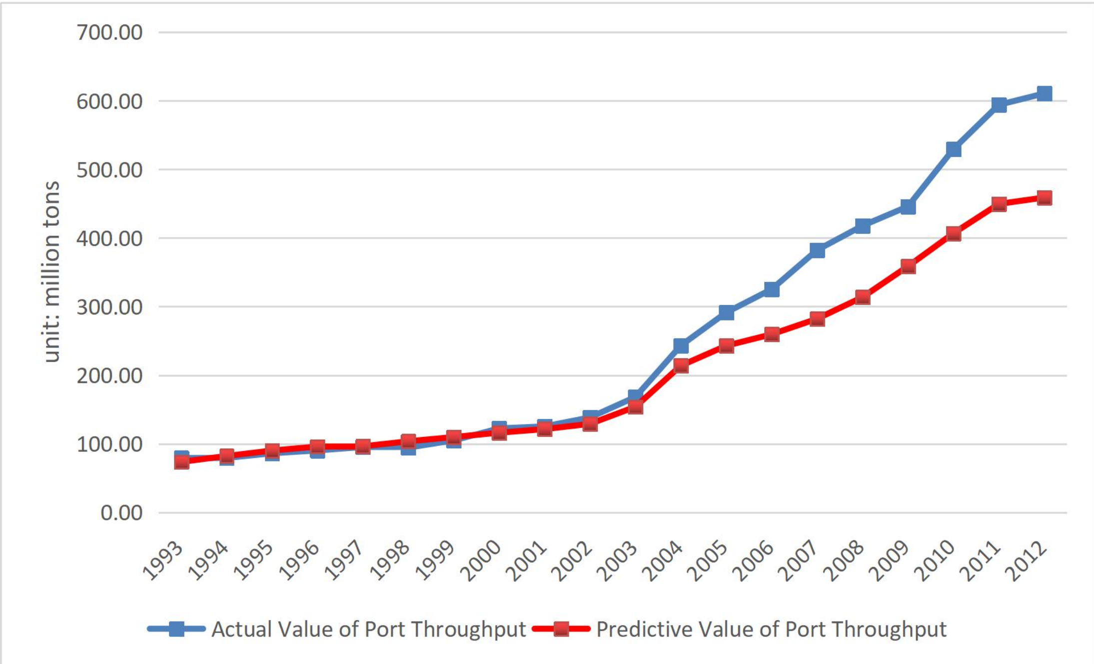

Figure 5.1 - The deviation between the actual throughput and the predictive value of the model

According to Table 5.2 and Figure 5.1, the port throughput predicted by the multiple linear regression model is well fitted to the actual port throughput data before 2002, while there is a certain deviation in 2003~2012 years. So the cumulative deviation value of the 10 years is the throughput increment brought by the SRSJS to 4 ports, and the statistics are 866 million tons. According to the annual report of the Jiangsu MSA (2012), the data of each port in the Jiangsu section of Yangtze River in 2009~2011 years are relatively complete. Using this three years data to calculate, the average throughput of the four ports is estimated to be about 52.25% of the entire

Jiangsu section of Yangtze River. Therefore, it can be reckon that the throughput increment of the Jiangsu province is about 1.657 billion tons in the ten years brought by the ships' routeing system.

Furthermore, according to the research report - Economic and social benefits of the 12.5-meter deep water channel at the mouth of the Yangtze river, made by the Fiscal Science Research Institute of Ministry of Finance (2012), the direct economic benefit of throughput per ton is 10.41 yuan(RMB). Based on this, it can be calculated that the ships' routeing system has brought economic benefits to Jiangsu province for 17.249 billion yuan(RMB) in ten years.

5.4 Summary

Through the calculation of the throughput index, it can be seen that the ships' routing system of Jiangsu section plays a significant role in the development of Jiangsu port economy.

Chapter 6 Summary and suggestions

The Ships' Routeing Systems in Jiangsu section of the Yangtze river is the first ships' routeing system for the inland river in China. It is the first time that the navigation rules of china's inland river are in line with the international practice. This system fundamentally solves the contradiction between the traditional backward navigation rules of the Yangtze river and the development of modern shipping. Since the implementation of this system, the navigation order in the Jiangsu section has been fundamentally improved. At the same time, the ships' routeing system brings huge safety, social and economic benefits.

In terms of safety benefits, statistics show that the total number of accidents, the number of wrecks, fatality, the economic loss of accidents, the accident rate and other indicators have all dropped significantly in the jiangsu section of the Yangtze river. In contrast, the ship's flow and freight volume have been greatly improved. The implementation of ships' routeing system has fundamentally improved the navigation environment and reduced the occurrence of accidents.

In terms of social benefits, the implementation of the ships' routeing system has improved the competitiveness of Jiangsu port, promoted local employment and reduced environmental pollution. This system plays a positive role in the port construction and social development of Jiangsu province.

In terms of economic benefits, the throughput increment of Jiangsu port in the ten years since the implementation of ships' routeing system reaches 1.657 billion tons, generating economic benefits of 17.249 billion yuan(RMB). The SRSJS contributes greatly to the economic development of Jiangsu province.

In recent years, with the development of the Yangtze River shipping economy, the port size, vessel traffic and ship size are changing in the Jiangsu section of the Yangtze River. In order to adapt to the new navigation environment, it is necessary to systematically upgrade and improve the SRSJS, especially the classification standards of large and small vessel. When setting up the new classification standard, Jiangsu MSA should take into account the current factors such as the number of ships, the types of ships and the width of the channel, so as to make full use of the existing channel resources.

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Appendix: A

Questionnaire of the Ships' Routeing Systems in Jiangsu Section of the Yangtze River(Shipping company)

.1 Basic information:

1) Occupation: _______________

2) Working life:

□5~10 years □10~15 years □15~20 years □20~30 years □30 years and above

.2 What types of ships do you have in your company:

□Bulk cargo □General cargo □Container □Passenger □Dangerous cargo □Oil tanker □LNG / LPG

.3 What is the number of ships in your company:________________

.4 What is the annual freight volume of your company?

Year	Freight volume(ton)	Year	Freight volume(ton)
2003		2011	
2004		2012	
2005		2013	
2006		2014	
2007		2015	
2008		2016	
2009		2017	
2010			

.5 Is it necessary to implement the SRSJS?

□ It is very necessary

□ It is necessary

□ It is unnecessary

.6 Are your company's ships equipped with the "Ships' Routeing Systems in Jiangsu Section of the Yangtze river" brochure?

□ Yes □ No

.7 Does the crew of your company know the principle of “separating large vessels traffic flow from small vessels traffic flow” in the SRSJS?

□ Yes □ No

.8 Does the crew of your company know the principle of “navigating on the right side” in the SRSJS?

□ Yes □ No

.9 Does the crew of your company know the principle of “ liability for fault” in the SRSJS?

□ Yes □ No

.10 The improvement effect of SRSJS on ship navigation safety:

Effectiveness: □ high □ medium □ null

.11 The improvement of ship traffic order after the implementation of SRSJS:

□ very good □ good □ normal □ poor

.12 Does the Yangtze River night navigation improve the operation efficiency of shipping companies?

□ A great improvement（50%~100%）

□ A certain degree of improvement（30~50%）

□ A small improvement（8~30%）

□ Basically no change（0~8%）

.13 Please evaluate the existing anchorage resources:

□ enough to use □ shortage □ very shortage

.14 Please evaluate the service of the Jiangsu Maritime Administration:

□ very good □ good □ general □ bad

.15 In order to further improve the navigation environment, what are your suggestions for the SRSJS?

____

Appendix: B

Questionnaire of the Ships' Routeing Systems in Jiangsu Section of the Yangtze River (Pilot)

.1 Pilot grade
□ first-class pilot □ second-class pilot □ third-class pilot

.2 Age: _______________
□ 20~30 years old □ 30~40 years old □ 40~50 years old
□ 50~60 years old □ 60 years old and above

.3 Working life:
□5~10 years □10~15 years □15~20 years □20~30 years □30 years and above

.4 Improvement effect of SRSJS on ship navigation safety:
Effectiveness: □ high □ medium □ null

.5 Improvement effect of ships cross meeting situation after implementation of SRSJS:
Effectiveness: □ very high □ high □ medium low □ null

.6 Do you have an accident in the waters of Jiangsu after the implementation of SRSJS?
□Yes □No

.7 The safety degree of the night navigation after the implementation of SRSJS:
Degree of safety: □ high □ low □ unsafe

.8 Whether the navigation rules are more simple since the implementation of SRSJS?
□ Simpler □ No change □ More complex

.9 The improvement of navigation order after the implementation of SRSJS:
□ very good □ good □ normal □ poor

.10 Whether the ship speed is improved after the implementation of SRSJS:

Degree of rise : □ significantly □ greatly □ slightly □ no change

.11 The effect of SRSJS on improving navigation efficiency:
Effectiveness: □ high □ medium □ null

.12 Improvement of VTS management level after implementation of SRSJS:
The degree of promotion: □ very high □ high □ medium □ low □ null

.13 Please evaluate the existing anchorage resources:
□ enough to use □ shortage □ very shortage

.14 Please evaluate the service of the Jiangsu Maritime Administration:
□ very good □ good □ general □ bad

.15 In order to further improve the navigation environment, what are your suggestions for the SRSJS?

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Appendix: C

Questionnaire of the Ships' Routeing Systems in Jiangsu Section of the Yangtze River (crew)

.1 Basic information:
1) □ Inland river crew □ Sea-going seafarer
2) □ Captain □ Chief officer □ Second officer □ Third officer

.2 Age:
□ 20~30 years old □ 30~40 years old □ 40~50 years old
□50~60 years old □60 years old and above

.3 Working life:
□5~10 years □10~15 years □15~20 years □20~30 years □30 years and above

.4 Improvement effect of SRSJS on ship navigation safety:
Effectiveness: □ high □ medium □ null

.5 Improvement effect of ships cross meeting situation after implementation of SRSJS:
Effectiveness: □ very high □ high □ medium low □ null

.6 Do you have an accident in the waters of Jiangsu after the implementation of SRSJS?
□Yes □No

.7 The safety degree of the night navigation after the implementation of SRSJS:
Degree of safety: □ high □ low □ unsafe

.8 Whether the navigation rules are more simple since the implementation of SRSJS?
□Simpler □ No change □ more complex

.9 The improvement of navigation order after the implementation of SRSJS:
□ very good □ good □ normal □ poor

.10 Whether the ship speed is improved after the implementation of SRSJS:
Degree of rise : □ significantly □ greatly □ slightly □ no change

.11 The effect of SRSJS on improving navigation efficiency:
Effectiveness: □ high □ medium □ null

.12 Improvement of VTS management level after implementation of SRSJS:
The degree of promotion: □ very high □ high □ medium □ low □ null

.13 Please evaluate the existing anchorage resources:
□ enough to use □ shortage □ very shortage

.14 Please evaluate the service of the Jiangsu Maritime Administration:
□ very good □ good □ general □ bad

.15 In order to further improve the navigation environment, what are your suggestions for the SRSJS?

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